PROCEEDINGS ON ACM/CSI/IEEECS RESEARCH & INDUSTRY SYMPOSIUM

IOTCLOUD'21

IN HONOUR OF

SHRI. F.C. KOHLI

FATHER OF INDIAN SOFTWARE INDUSTRY

ORGANIZERS

SHAJULIN BENEDICT
H.R.MOHAN

Symposium Title:

ACM/CSI/IEEECS Research & Industry Symposium on

IoT Cloud For Societal Applications (IoTCloud'21)

(In honour of Shri. F.C. Kohli, Father of Indian Software Industry)

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Aim and Scope:

The symposium on IoT Cloud for Societal Applications aims at bringing online together specialists and researchers who propose innovations in the field of the recent trends of technologies such as IoT, Cloud, Edge, Fog, Blockchain, AI and so forth. The symposium will include invited lectures and research paper presentation from industries and academia covering the recent trends.

Keynote Speakers:

Mr. Sunderasa Subramanian,

Director - NextGen QA Services (Americas), Infosys Limited, Atlanta Metropolitan Area, USA. , Mr. Sundaresa has 20 years of Industry Experience in Embedded Systems Development and Testing, Automotive OEM Validation and is currently Director of Sales - Quality Assurance at Infosys Limited. Sundar is based out of USA in his current role and focuses on Digital Transformation, Cloud Modernization, Big Data and IOT specific Quality Assurance solutions to his customers. He is a certified Cloud Practitioner across 2 Hyperscalers and has authored whitepapers for National/International conferences on various aspects of Quality Assurance.

Dr. Debanand Singdeo,

Engineer - Mathworks India Pvt. Ltd, India. , Debanand Singdeo works as part of Education Team at MathWorks India Private Limited. In this role, he collaborates with researchers with the aim of accelerating the pace of innovation in science and engineering. Also, he works closely with academic institutions for effective utilization of MathWorks resources in education. He has a Bachelor's degree in physics from Visva Bharati, Santiniketan, followed by MSc-PhD degree from the Department of Energy Science and Engineering, IIT Bombay. His prior research experience is in the area of modelling and simulation of renewable energy systems. In previous roles, he has worked as a postdoctoral fellow in the Department of Energy Technology, Aalborg University, Denmark.

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Mr. H.R. Mohan, Chair, ACM Chennai

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Foreword from Organizer…

ACM / CSI / IEEE CS Research & Industry Symposium on IoT Cloud For Societal Applications (IoTCloud'21)

Greetings!!!

In IoTCloud'21, we attracted 56 submissions from several states of India; we shortlisted 38 articles based on the future scope and relevance to the symposium. Out of these, 36 papers were presented in the symposium and 3 prizes were distributed to the winners. Two keynote talks were organized for motivating the authors of the symposium by offering the cutting-edge discussion about IoT.

The symposium had remained as a forum for boosting research in the direction of "Innovative Trends in Internet of Things". It brainstormed several new ideas which would be banked for future innovations relating to the identified field of research such as IoT, Cloud, AI, and so forth. I anticipate with wishes a bright future for the IoTCloud'21 participants through this event!

Dr. SHAJULIN BENEDICT

Foreword from IEEECS/ACM/CSI…

ACM / CSI / IEEE CS Research & Industry Symposium on IoT Cloud For Societal Applications (IoTCloud'21)

(In honour of Shri. F.C. Kohli, Father of Indian Software Industry)

Jointly organised by ACM Chennai, IEEE CS Madras & CSI Chennai in Association with AIC IIIT Kottayam & IIIT Kottayam on 3rd May 2021

The Information Technology Services and Software Industry in India was in its infancy during the 1960s. Computing activities were confined to few universities and research centres and to a small set of companies till then. It took the vision and competence of an intellectual giant called Shri F.C. Kohli to nurture and guide TCS, the newly setup computing arm of the Tata Group, to be a global leader in three decades.

He was a disciplinarian, patriot, visionary, and a scholar. He chose to recruit the nation's best minds from top universities, mentor them and challenge them to walk on unchartered territories.

He sought friendship and collaboration from leading academic institutions to build research competence within the firm. It led to the establishment of TRDDC in 1981 and 19 more TCS innovation labs in India and abroad over the next three decades. He was an active member in professional bodies such as IEEE, ACM and CSI and encouraged staff to organize and participate in every activity that would nurture a research and knowledge sharing mindset

In the process, he played a seminal role in placing India on the global map of service providers and rightfully earned the moniker," The Father of the I.T. Industry in India". He remained active in service of the nation and the profession till he passed away in Nov 2020, at the age of 96.

There are many of us who owe our growth in person and in profession to him. It dawned on us that supporting the causes he advocated could be the best way to pay our tribute to this visionary and pioneer. One of his lifelong passions has been to bring the industry and academia together to advance the research competence in TCS and in the country. He worked with focus and commitment with many top-notch educational institutions to foster applied research. He knew that the developments would continue for decades and India must remain involved in cutting edge work, be it in traditional Software engineering or in state-of-the-art Analytics, AI, Speech recognition, Indian language processing etc.

Many of us at the Chennai chapters of CSI, ACM and IEEE CS have been the beneficiaries of his vision and wisdom over many decades. We have interacted with him and his team and have built our careers through his mentorship. This industry and research symposia series is borne out of our desire to honour him by keeping his mission in focus and in running mode.

Messrs. H.R. Mohan, Chair, ACM Chennai, P.V. Subramanian, Chair, CSI Chennai, P. Sakthivel, Chair, IEEE CS Madras and I deliberated in early January to evolve this proposition of sponsoring a series of symposia in Shri FCK's honour. The events would continue to build bridges between practitioners and researchers and advance technology applications in multiple areas. Eminent speakers would be invited to share their knowledge with young researchers and the latter would get an opportunity to present their work to get a feedback.

We deliberated as a team and decided on the four themes of
Data Sciences & Analytics, Intelligent & Smart Systems, Cloud Computing, IoT, CPS, and Information & Cyber Security

"Practice what you preach" is an adage. We decided to seek collaboration with reputed institutions to organize these events. We found the first of such partners in AIC IIITK who shared our vision to

leverage technology for societal missions. We are thankful to the institute and Dr. Shajulin Benedict to have joined hands to organize the conference on IoT, Cloud, AI, and Applications. We also thank Fortess , a body of professionals who have been mentored by Shri FCK for its support.

With this event, we have placed the first stones to build this bridge between academia and industry and contributed to the cause of building our country's skills in advanced technologies by challenging best minds on high quality research. We trust the symposium provides young scholars the means to connect with other scholars, explore deeper into research areas of interest, and remain committed and motivated to serving the cause of scientific enquiry.

Dr. Parasuram Balasubramanian
Member, Advisory Committee

Articles of Proceedings of IoTCloud’21

PID101 Title: Remote Monitoring And Data Analysis For Textile Machinery Authors: K.B.Nihilesh, R Kowshikh, Anasuya K V	PID102 Title: Framework for Roadside Litter Identification and Face Recognition using Convolutional Neural Networks Authors: Abiga Sansuri M, Anasuya K V, Nivethitha M, Gutta Abhinav Krishna Sai
PID107 Title: IoT based Smart Parking System using Cloud database Authors: Nivetha S R	PID104 Title: Design and Implementation of Custom Built Quarantine Service Mobile Robot Using Deep Learning and ROS Authors: Sanjuna Mariam Mathews, Sreeja S
PID108 Title: IoT Based Remote ECG Monitoring System Authors: Sneha S, Shwetha Srikanth, Vibish Kashyap B, Vishnu K Krishnan, R Hemalatha, S Radha	PID105 Title: Design and Development of Stylometric based Fake News Detection on Social Media using Natural Language Processing and Machine Learning Authors: Swetha Thashini S, Kavitha Devi M K, Nivetha S, Meenakshi Aiswarya N
PID113 Title: A review of IoT systems and machine learning techniques in crop yield prediction Authors: Nitin Zachariah, Chaitra Ankesh, Aliva Mohanty R, Bhuvaneswari R D, Preethi Sheba Hepsiba	PID111 Title: Smart Mobility Model for Driver Assistance in Semi-Autonomous Vehicles Authors: Kezia M, Anasuya K V, Bharath M

PID115 Title: Consumer and Industrial IoT: A systematic review Authors: Lokitha T, Mirthula R, Suvetha P, Sasikala S	PID118 Title: Application of Deep learning for Solid waste trash classification using Deep CNN Authors: Karthikeyan S, Sivakumar M, Jeysiva A P, Maheshkumar C
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PID123 Title: Serverless Functions for IoT Applications - An Analysis Authors: Varun Bhaaskar, Tania Simon, Shreshta Shajimon, Joms Antony	PID126 Title: Electricity Theft Detection using Deep Learning and IoT Authors: Abin M K, Aiswarya Suresh, Athira C, Avin Joseph, Aswathy Wilson
PID119 Title: 3DP-FAS: An Intelligent Quality Assurance System for 3D Printer Authors: Basil C Sunny, Shajulin Benedict, Keerthana B	PID142 Title: Internet of Things: A Review on Machine Learning based Intrusion Detection System Authors: Priyanka Gupta, Lokesh Yadav, Deepak Singh Tomar
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PID128 Title: Development of Fish Feeder Bot for Aquaculture Authors: Sakthivel P, Selvamuthukumaran D, Sudhakar S, Jhanvi K R, Brindha S	PID120 Title: RF Module Based Automated Toll collection System Authors: Somalatha T, Anasuya K V, Salai Prajeetha R, Jaishree J
PID130 Title: IoT security - A Brief Review Authors: Moni Sree S, Nithyaa shri R B, Pavithra R, Sasikala S	PID122 Title: A novel temporal-spatial interpolation method for spatio-temporal air quality forecasting Authors: K.Krishna Rani Samal, Korra Sathaya Babu, Santos Kumar Das
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PID135 Title: Blue Ocean IoT Cloud based Early Warning System Authors: Dineshkumar Singh, Subhadravarma Pusapati, Karthik Srinivasan, Vaibhav Lonkar, SrinivasanPappula, Veerendra Veer Singh	PID136 Title: An Android based Application for Computation Offloading in Mobile Cloud Computing Authors: Mohit Bansal, Arman Jaiswal, Mohd. Asif Ansari, Dinesh Kumar
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PID141 Subject: IoT fueled AI system for Food Wastage Reduction and Efficient Redistribution of Excess Food Authors: Akhil V B, Raghu C V	PID138 Title: Sound Sensor to Control Traffic System for Emergency Vehicles Authors: P Kavipriya, S Kavin Sagar, D Komalavalli
PID156 Title: IoT Based Smart Medicine Reminder Kit Authors: Keerthi Sreenivas Konjety, V. Panchami, Vangapandu Sandeep, Sai Manoj Konidana'	PID144 Title: Number Plate Recognition Using CNN For Identification Of Theft In Toll Collection System Authors: Baavessh M, Vijaya Nagarajan, Giridharan Murali, Gunasekaran Gnanasekaran
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AWARDEES:

PRIZE	Prize Money	Paper ID
I	10000	PID104
II	7500	PID119
III	5000	PID122

REMOTE Monitoring and Data Analysis for Textile Machinery

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***Abstract*— Internet of Things - The common vision in smart systems, having sensors coupled with information and communication technologies. Intelligent monitoring and management of devices are achieved via sharing of data through networked embedded devices. The paper aims at designing a response-based machine monitoring system, by observing the vital parameters of the machine and by leveraging the Thing Speak platform. The machine parameters like the vibration and oil level and the environmental observances like the humidity and temperature are measured to enable the cooling/heating of devices or for long-term statistics. The statistics are stored on the cloud to get accessed by the needy applications and supplementary procedures. The uploaded data is shown on the webpage as graphs for easy interpretation. In addition to all this, the paper aims to provide a solution to the frequent occurrence of thread breaks in spinning machines by using image processing done using a camera and a simple mechanism to actuate the camera from one position to another position.**

Keywords- IoT, Cloud storage, Machine monitoring, Thread break, Webpage, Image processing

I. Introduction

Inadequate maintenance and poor monitoring of machines decay its efficiency. An efficient insight into the various parameters of the machine improves the quality of the final product. This demands the collection of key parameters such as temperature, humidity, oil level, and vibration, etc., and further analyzing the data for predictive maintenance as shown in [1], [2], and [3]. Hence a generic product – A machine monitoring system that can be used for analyzing the vital parameters in any type of machine is designed. As the study of parameters varies from machine to machine, the application focus is constrained towards the thread breakage monitoring in spinning machines. This functionality can be applied to any of the textile machinery, where the thread is processed and their breakage is a frequent occurrence. The product supports the interfacing of multiple sensors.

A spinning machine that has thousands of spindles on each side, with a thin strand of thread transferred from one spindle to the other at high speed is considered. Here, the thread breakage is inevitable. As a common scenario, the machine operators called Siders are to splice the thread with greater difficulty and the process is time-consuming. This leads to the decay in production efficiency. The current solution of employing the Electronic Yarn Clearer (EYC) and Splicer equipment add cost to the machine. Recent research to detect the thread breaks in yarn is shown by [6], [7] and [8]. All these systems use laser and optoelectronic technologies. However, the proposed product detects the thread breaks at a much lower cost with improved accuracy by applying the image processing techniques. This data is also uploaded to the cloud for further processing. The results of this processing are used for the predictive maintenance of the machine. This data can be further analyzed by machine learning models to predict optimum working conditions of the machine.

II. Proposed Work

In the proposed model, the machine parameters such as core temperature, humidity, rpm of the gears, oil level, current flow in the wires, vibration data of the machine structure, etc. are periodically monitored using industry-grade sensors as clearly depicted in [3], [5], [7] and [8]. The sensor signals are processed by the Central Processing Unit (CPU) – Raspberry Pi 4 microcontroller. Note that any microcontroller with sufficient processing power can be used to process the data. The microcontroller used will also control the response systems such as the air conditioning unit, heater unit, and automatic oil refilling mechanism, etc. using electromagnetic switches. Threshold values, which are the maximum and the minimum values of a particular parameter, are programmed into the microcontroller. Whenever the corresponding sensor reads values below the threshold, the appropriate response system is activated until the values are stable inside the threshold condition. As an example, the temperature of the environment around a spinning machine must be X° C. Whenever, the sensor reads a value greater than X° C, the air conditioning system will be triggered by the microcontroller to stabilize the temperature value within X° C. This functionality is similar to the system shown by [4]. Additionally, all the data collected from the machine is logged periodically into the Thing Speak database through the Internet. The data is fetched from the database and plotted in the form of graphs. These graphs are imported in the form of API to a custom-built website. This is the end interface available to the machine owner for remote monitoring of the machine. This data can be further analyzed using machine learning and artificial intelligence tools to perform predictive maintenance of the machine.

For the thread break detection, we consider the same spinning machine. The normal / break condition of the thread is captured as an image with a camera that moves from one end of the machine to another end by using a screw rod rotating on a fixed axis. The stepper motor controls the movement of the rod and hence the camera. The stepper motor in turn is directly controlled by the microcontroller. This enables precise movement of the camera. The threads moving from top to bottom in a spinning machine are shown in Fig. 1.

Fig. 1. Threads in a spinning machine.

The captured image is sent to the microcontroller where image processing algorithms are applied to identify the break-in threads. If a thread break is detected in any image, the microcontroller alerts the machine worker to repair the thread breakage. This system thus speeds up the detection process to ramp up production efficiency. This data is also uploaded in the Thing Speak Cloud. This is similar to the system shown in [2], [3], [4], and [5]. This data is used to find the frequency of the thread breaks on a particular spindle and to calculate the production efficiency. Fig. 2 depicts the hardware model of the proposed system.

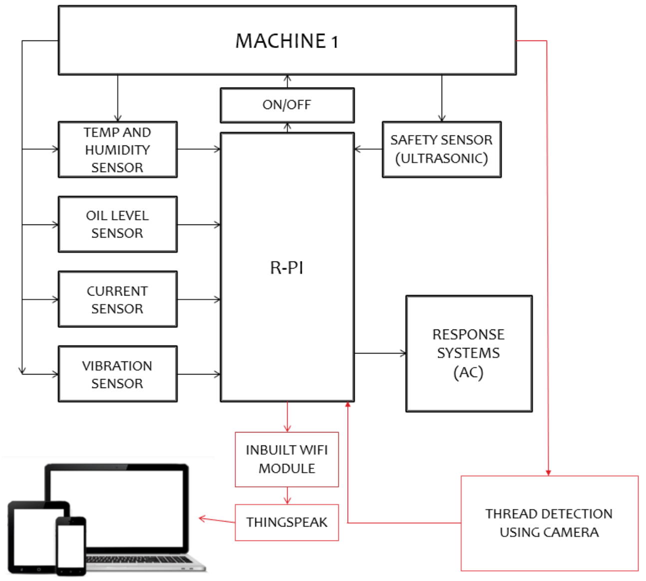

Fig. 2. Proposed hardware model.

A. *Thread breakage detection mechanism for spinning machine*

The camera employed to capture the images covers five spindles or threads per frame. The camera moves in the horizontal axis on the screw rod from one end to another end of the machine, capturing images on the way. Thus, the camera moves in such a way that five different threads can be captured in each frame. It moves from one end to the other in this manner and captures the images on both the trips, from start to end and from end to start of the machine. Fig. 3 depicts the detection mechanism.

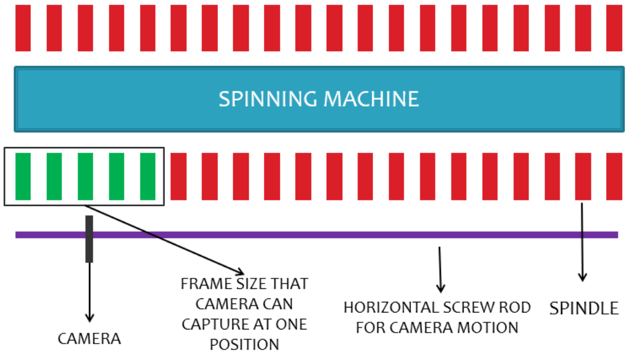

Fig. 3. Thread detection mechanism.

The microcontroller employs the image subtraction algorithm with a reference image, on the captured images to detect the thread break. The reason for employing the simple but powerful image subtraction algorithm is that the lighting, the shadow on every point of the machine will be the same and will not vary according to time or weather. When the thread breakage is detected in the image, the sector where the image is captured will be highlighted on an LCD screen. This eases the identification of the thread-cut zone/sector. Each thread break with the spindle number is uploaded to the cloud. The complete process of machine parameter monitoring and the thread breakage detection mechanism are illustrated in Fig. 4.

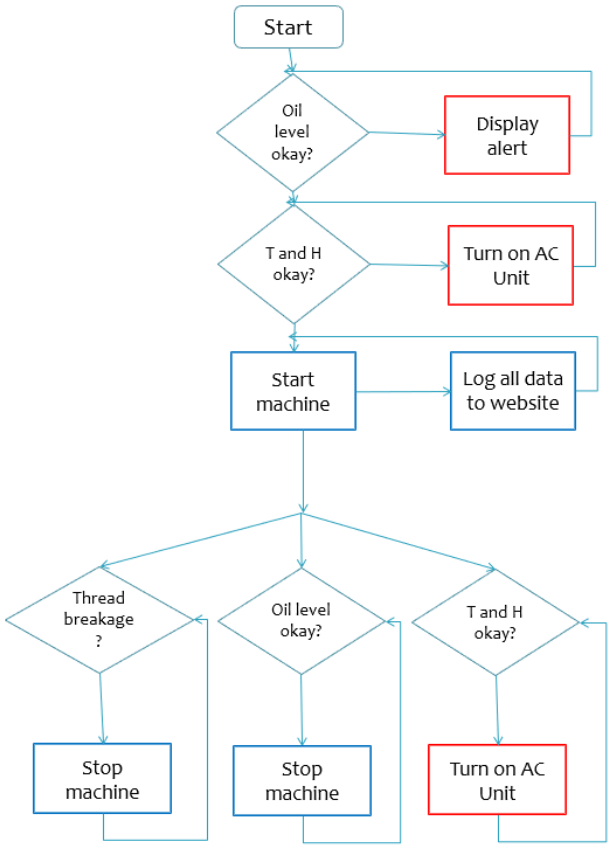

Fig. 4. Flowchart of the software model.

III. IMPLEMENTATION

The prototype implements the hardware interface in Raspberry Pi 4 microcontroller, programmed using Python. Alternatively, any PC connected to the Internet through a WIFI can also be used. The system receives inputs from the temperature and humidity sensors, the vibration sensor, the oil level sensor (ultrasonic), the RPM sensor (infrared), the current sensor, and from a camera (raspberry pi camera) and additionally, a safety sensor (ultrasonic) to stop the machine in case of emergencies. The machine is allowed to start upon the satisfaction of two conditions:

- Under normal temperature and humidity values.
- The oil level should be above the minimum required value.

All the sensors are hardwired to the microcontroller. Industry grade sensors can be used to increase the efficiency of data sampling. Any number of sensors of the same or different types can be connected at various parts of the machine for maintaining optimum conditions. Further threshold values for individual sensors can be specified. As an example, the length of a spinning machine is very high such that the atmospheric temperature and humidity cannot be kept in check by using a single sensor. Thus, multiple temperature and humidity sensors are connected at various parts of the machine and they are all regulated by their respective threshold values.

The microcontroller collects the data from the sensors and uploads the same every 30 seconds to the Thing Speak cloud. Table 1 shows the assumed value of parameters for the sensors for testing the prototype.

TABLE I. PARAMETER VALUE CONSIDERED IN PROTOTYPE

Parameter	Value
Temperature	30º C
Humidity	50%
Oil level	10 cm from the bottom of the tank
Vibration	20 kHz
Current	100mA
Safety sensor (Ultrasonic)	10 cm

For the thread detection part, the spinning machine is taken as a reference and the mechanism for moving the camera is constructed. Fig.5 shows the screw rod mechanism. The camera is mounted at the top of the screw rod mechanism such that each frame of the camera contains exactly five threads. The camera is made to actuate linearly by rotating the screw rod. The rotation is taken care of by the stepper motor which is controlled by the microcontroller. The camera moves from one end of the rod to the other, thereby moving from one end of the machine to the other end. The camera captures images with exactly five threads in one frame which is processed by the image difference algorithm and the output is displayed on the LCD screen. The thread break status is indicated on the screen. Thus, the break is attended to immediately by the siders. This process saves time and is highly accurate since the lighting of the environment never changes.

Fig. 5. Screw rod mechanism

The relative efficiency of the machine is calculated based on the time taken to convert the given raw material into the finished product in a machine regulated by the proposed system ($t_{regulated}$) compared to the time taken to convert the given raw material into the finished product in a machine not regulated by the proposed system ($t_{unregulated}$).

$$\eta = \frac{t_{regulated}}{t_{unregulated}} \times 100$$

Finally, all the data uploaded to the cloud is visible to the machine owner. For ease of use, a custom-built website is developed which shows the real-time value of all the sensors thereby indicating the status of the machine. The data is fetched from the cloud and is shown as graphs on the website. Also, remote access to the machine is given to the machine owner who can directly switch on and off the machine using the buttons available on the website. Control to other response systems is also given on the website such as the air conditioning unit etc. As further response systems are added to the machine, the control for the same can be included in the website also. Furthermore, all the data collected is stored along with the timestamp for further analysis using MATLAB or using any machine learning or artificial intelligence models.

IV. EXPERIMENTAL EVALUATION

The prototype is tested using the LR G5/1 Ring Frame spinning machine. The raspberry pi microcontroller is isolated at a safe position from the machine. The sensors such as the temperature and the humidity sensor, the vibration sensor, the current sensor, etc. are placed at various strategic parts of the machine and connected to the microcontroller. All the sensor values are monitored through the terminal of the microcontroller as well as in the custom-built website. An LCD screen is mounted in front of the machine to display the status of the thread break in any spindle of the machine.

The thread break detection system is constructed using the screw rod mechanism and the camera is mounted on the top of the plate attached to the screw rod. Initial calibration of the system is required as well as the threshold values for all the parameters have to be manually entered initially. All the threshold values will be automatically updated by the microcontroller after it receives the result of the analysis carried out MATLAB scripts in the cloud. These threshold values change according to the production efficiency calculated. This is done in order to maintain the production efficiency at an optimum value. Note that the automatic update of the threshold value starts only when there is enough data in the cloud that can be analyzed. Naturally, the update will start only after the machine has been operated for a few days and there are at least 4 sets of data each giving one production efficiency. The efficiency for the first one is calculated by using the efficiency of a machine that is not using the proposed system. The subsequent production efficiencies are calculated based on the previous production efficiencies in to push the machine towards optimum production.

Fig. 6 shows the control panel for the machine and the response systems in the custom-built website. The values of the buttons that are ON or OFF are communicated to the machine using the Internet. Note that the system should be connected to a WiFi network with internet access for data update to the cloud. However, the system can also work in standalone mode without data update to the cloud in cases of Internet failure. All the programs used in the system are threaded to increase the degree of multiprogramming as well as provide independence to every other program running in the background.

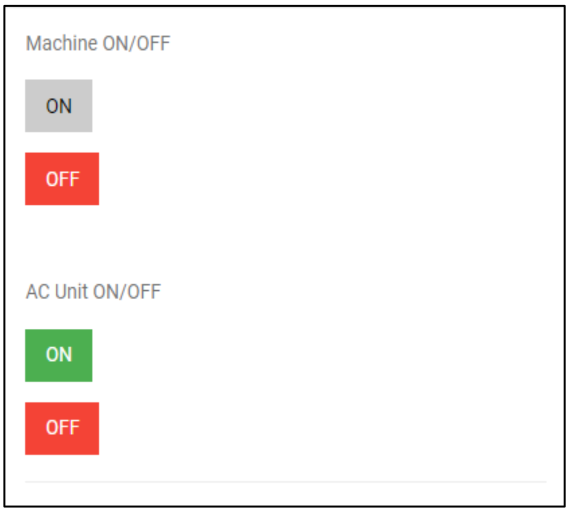

Fig. 6. The machine control panel in the custom-built website

Fig. 7 shows the output data graphs at the custom-built website. These graphs are imported as API (Application Program Interface) from the Thing Speak cloud. All these graphs are real-time based meaning that they are updated every time a new data record has been updated in the cloud database. The sample design of the custom-built website incorporates a left sidebar having START / STOP buttons for machine control and response system (AC) control for manual operation. The graphs are displayed in the center. Individual graphs for each parameter are plotted to give better readability and provide efficient monitoring of the machine. Since the website is linked directly to the cloud and not to the localhost, that is the microcontroller itself, the website can be accessed through any system from anywhere in the world. Several accounts with privileges have been created to gain access to the website. Only the accounts with administrator access will be capable of controlling the machine remotely while the others will allow only to see the real-time parameters of the machine and learn about the production efficiency and other results of data analysis.

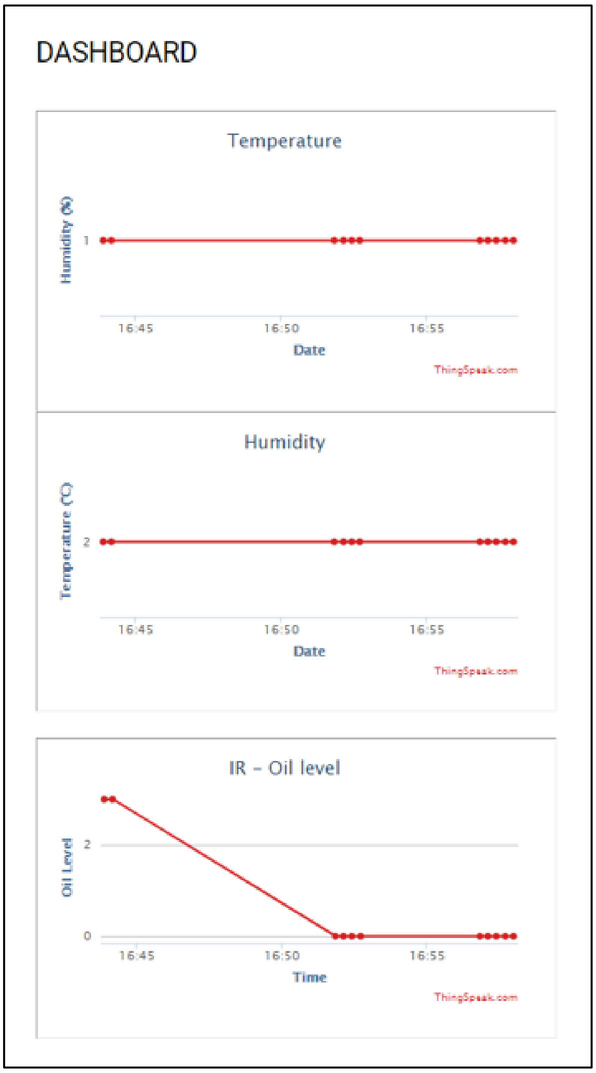

Fig. 7. Custom built website with data graphs

Graphs can be analyzed further using MATLAB tools. Alerts are displayed on the website and the LCD screen simultaneously, for any deviation in parameters, demanding actions from the response systems. The sample alert messages obtained from the test results are depicted in Fig. 7.

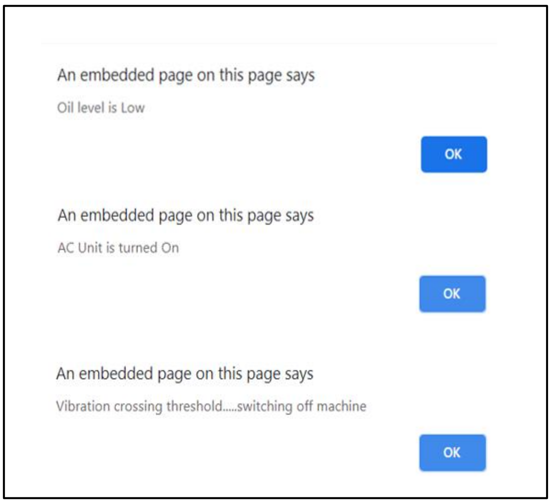

Fig. 8. Alerts in website

The prototype is tested using the ring frame machine. The various sensors are placed in strategic portions of the machine. The temperature and humidity sensor is placed near the spindles where the thread is transferred from top to bottom. The oil level sensor is placed in the oil tank under the machine. The vibration sensor is placed on the panel enclosing the motors and the gear assembly. The current sensor is wired serially to the DC lines feeding the motors. For the prototype, only the line going to one of the motors is tested. The safety sensor (ultrasonic sensor) is placed on one of the panels of the machine. The brain of the prototype, the raspberry pi 4 was placed along with the safety sensor on the machine panel. The raspberry pi is provided with a WiFi network with Internet access for uploading the data. The thread break detection system is set up, as previously explained, with the help of a screw rod controlled by a stepper motor. Data is continuously sampled from the sensors and is analyzed using the python program to find new threshold values to find the optimum machine parameter values for efficient production. Thus, comparing with machines without this monitoring system, the prototype increases the production efficiency of the machine by 5%. This value can be further increased by using industry-grade sensors with a higher sampling rate, increasing the number of sensors used, using multicore processors for computation, and improving the algorithm used to calculate the threshold values. Usage of machine learning models can significantly ramp up the threshold calculation once a sufficient dataset has been collected. In addition to this, the thread break detection time was cut down to seconds compared with the manual checking which takes up to minutes depending on the workers' efficiency.

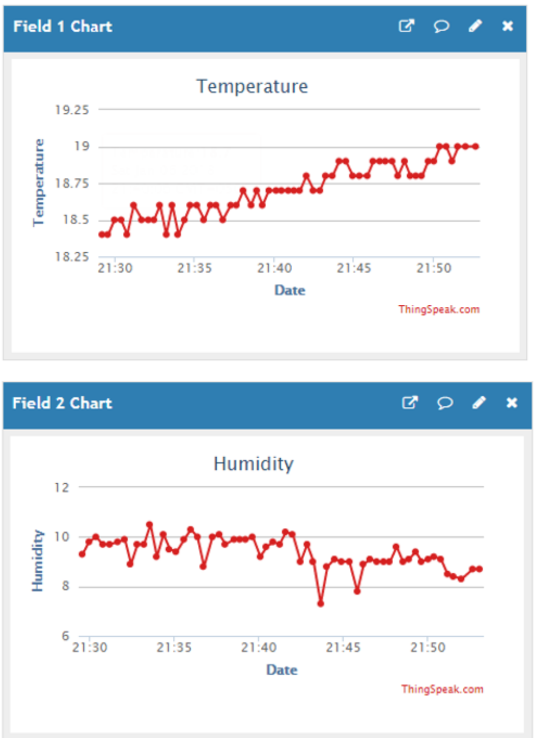

Fig. 9. Temperature and Humidity data received from the ring frame

V. Conclusion

A response-based remote monitoring system to monitor and auto-control machines is implemented with a specific application for thread-break analysis of spinning machines. This product improves the production efficiency of the machine by monitoring its vital parameters, comparing with the benchmark statistics, and taking appropriate response actions. The periodic monitoring of key parameters indicates the sickness possibilities at early stages and hence the actions to avoid a total shutdown of the machine. Moreover, it is a cost affordable system. The system design can be further enhanced by using machine learning / artificial intelligence techniques.

Acknowledgment

We thank Nyloplastics, Coimbatore for allowing us to test the prototype on their machine "LR G5/1 Ring Frame spinning machine".

References

[1] H. Carvalho, A. Rocha, J. L. Monteiro and L. F. Silva, "Parameter monitoring and control in industrial sewing machines - an integrated approach," 2008 IEEE International Conference on Industrial Technology, Chengdu, 2008, pp. 1-6, doi: 10.1109/ICIT.2008.4608388.

[2] K. Gayathri, "Implementation of Environment Parameters Monitoring in a Manufacturing Industry using IOT," 2019 5th International Conference on Advanced Computing & Communication Systems (ICACCS), Coimbatore, India, 2019, pp. 858-862, doi: 10.1109/ICACCS.2019.8728365.

[3] Priyanka, E.B. and Chenniappan, Maheswari & Thangavel, S.. (2018), "IoT based field parameters monitoring and control in press shop assembly,". Internet of Things. 3-4. 1-11. 10.1016/j.iot.2018.09.004.

[4] Dutta, Atrayee and Dubey, Aditya and Barman, Snehakshi and Borah, Rupsikha, IoT Based Industrial Equipment Controlling and Parameter Monitoring System (2018). International Journal of Computational Intelligence & IoT, Vol. 1, No. 1, 2018.

[5] Telagam, Nagarjuna & Kandasamy, Nehru & Nanjundan, Menakadevi & TS, Arulanandth. (2017). Smart Sensor Network based Industrial Parameters Monitoring in IOT Environment using Virtual Instrumentation Server. International Journal of Online Engineering (iJOE). 13. 111. 10.3991/ijoe.v13i11.7630.

[6] LAPPAGE J. End breaks in the spinning and weaving of wearable singles yarns: part 2: end breaks in weaving [J]. Textile Research Journal, 2005, 75(6): 512-517.

[7] ELDAR M. Line-laser-based yarn shadow sensing break sensor [J]. Optics & Lasers in Engineering, 2011, 49(3): 313-317.

[8] SONG Xiaoliang, LIU Jianli, Xuyang, et al. On-line detecting system based on optoelectronic technology for ring spun-yarn breakage [J]. Journal of Textile Research, 2014, 35 (8): 94-98.

AN IoT-based Smart Parking System using Cloud database

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Abstract—In recent times, the concepts of smart cities had attained a greater reputation. The internet of things plays a significant role in connecting various physical devices and automating them to make human life much easier. By using different software, we can connect objects and transfer information. Continuous efforts are being taken in the particular field to improve the efficiency and assurance of urban foundations. Nowadays government has made it a priority to make cities smart across the country. Various things make a city smart, one such main thing is a smart parking system. Parking is almost a need in every metro city. In this system, the user can keep tracking the availability of parking slots from the cloud server. Here the registered users don't want to waste their effort and time on seeking the availability of a parking spot in the specified parking area. The parking detail is sent to the user via SMS. Thus, the wastage of time for the particular registered user in search of free space is minimized.

Keywords—RFID Card, Arduino, Reader Module, GSM Module, IR Sensor, IoT, cloud database

I. Introduction

The internet of things states the internet of sensible physical objects -"things"- that is been embedded with software, sensors, or other technologies and their main motive is for connecting and exchanging information with other systems and devices over the internet without involving human interactions [14, 16]. Cloud computing is nothing but the mediator between things and applications. It is directly related to IoT. To interact with the actual world entities clouds can extend their capability by holding the IoT system.

A main feature of IoT is a large amount of data resources can be accessed. The factors that justify both IoT and cloud include scalability, interoperability, power consumption, availability, and capability of storing. In this system, automatic retrieval, image analysis, vehicle measurements, etc. are maintained by IoT [15]. The particular devices could be traced, managed, and monitored using accessible computing with the help of the internet [1]. The aim of creating a smart city is becoming achievable with the evolution of the internet of things. According to the current valuation, the vehicle's population is steadily increasing and estimated to reach 1.6 billion within 15 years [7].

Here is a solution for the problem that is been rose. Thus, this system acts as a key solution to lessen the wastage of fuel, to lower air pollution and it also helps in traffic congestion [4]. In this system, the user can interact with the cloud database as well as the parking lot and get notified about the parking space availability [2].

II. Related works

An algorithm is used to improve the efficiency of a Cloud based smart parking system. It is used to find the parking space with the lowest cost [9]. Here the registered user can access the cloud server and know about the details of the parking slot. It considers the number of an available parking slots and the distance of the particular slot from the user. An application is installed on the mobile to know about the information. With this system, waiting time can be reduced. This paper does not include the characteristics of the security. [10]To find the slot to park the registered user's vehicle, a smart mobile application with a wireless sensor node is used. This technology improves efficiency and accuracy. Here the ID and ticket key are given only to retrieve the vehicle. In this technique, an RFID card is given to the user and the user's privacy is not protected. [8]This system proposed a way for the parking area to identify the car which is already parked in the parking slot. The main aim of this system is to be user-friendly and inexpensive. It helps to sustain the data of about 90% accuracy.[6]A real-time smart parking system is implemented with the help of IoT to provide data about the nearest free space availability. To improve security, a vehicle number plate is detected. Through mobile payment, the registered user can pay for the parking space. Here the users receive the relevant details about the free space through a message. It also detects the license plate text. Here the ultrasonic sensor is used to reduce the cost for a user. Various researches are done to illustrate the best model but still, there are not enough studies describing how to design an IoT-based smart parking system for common people. Therefore, this issue needed further investigation. This paper overcomes various disadvantages that arise in the above research papers and gives the best model for smart parking systems using cloud databases.

III. SYSTEM ARCHITECTURE

This system consists of three main categories. The first category includes a parking lot which consists of an Arduino device and IR Sensor. This device is very much helpful for the user to interact with the parking slot available in that area [3]. The next category includes the cloud-based web services that act as a negotiator between a parking lot and a registered user. The cloud services are administrated by the executive and then it is permitted for the registered user to view and check for the availability of parking slot [6]. The last category includes the user side. Based on the availability, the user receives the message through the GSM module [3].

The hardware component consists of an RFID card, GSM module, and IR sensor. Once the registered user enters the parking lot, his RFID card is scanned and the user gets details about the position of the parking slot. IR sensor sends the signal according to the existence of vehicles. The software component includes cloud server which connects to the Wi-Fi module that acts as an arbitrator between the modules. Once the IR Sensor identifies the existence of a vehicle in the particular slot, the position of the cloud will be refreshed from 0 to 1 and vice versa. Here figure 1 represents the system architecture of IoT based smart parking system using cloud database

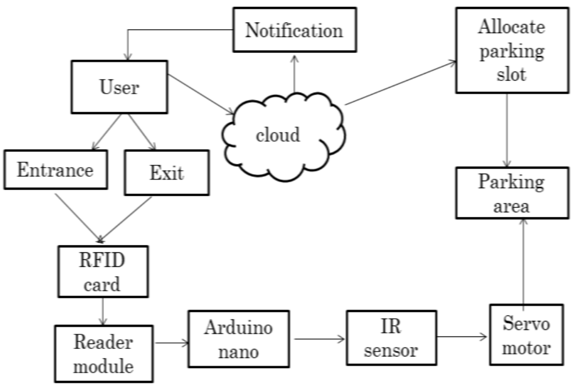

Fig.1. System architecture

IV. IMPLEMENTATION

In the above section, we have discussed the system architecture. Here we are going to discuss the block diagram and implementation of an IoT-based smart parking system using a cloud database. Once the registered user enters the parking area, his RFID card is scanned through the reader module. RFID card acts as a credit card or identification badge that contains information about an object [18].

Fig.2. RFID Card

At the same time, the data from the RFID card gets transferred to the Arduino Nano in the form of radio waves. This tag is used for tracking when it is attached to the devices. The Arduino Nano is the one in which the memory operation of digital and analog pins is done. Arduino Nano sends the signal to the IR sensor. An infrared sensor is an electronic device that emits infrared light to sense some aspects of the surroundings like detecting the existence of objects. If the sensor does not recognize any infrared light reflected it means the particular slot does not have any vehicle in it. If the sensor detects the light, then the object is present in the particular area. Then the user receives a message about the availability of free space through the mobile communication network of the GSM module. GSM module is a circuit that acts as a communication setup between mobile phones and microcontrollers. The message is conveyed in the form of voice messages, MMS, and SMS. High data transmission is permitted by GPRS extension in GSM [17]. Then the barrier gate is opened or closed with the help of a servo motor according to the availability of free space. Servo motor is a type of rotator device that permits the control of linear and angular motion. Electrical signals are transferred to the servo motor to produce motion. Now the vehicle is successfully parked in the parking lot. Here the WIFI module helps the system by storing all the information in the cloud. Using TCP/IP protocol it sends the data of the embedded system to the communication network [20]. The WIFI module acts as a negotiator between the cloud server and the devices. It has a 32-bit controller that contains 16 gpio with 80kb user data. The cloud is refreshed every 2 minutes.

V. FLOW CHART

Here figure 3 represents the flow chart from which the registered user enters the parking area till he successfully park the vehicle in the particular parking slot and figure 4 represents the real time view of the parking area.

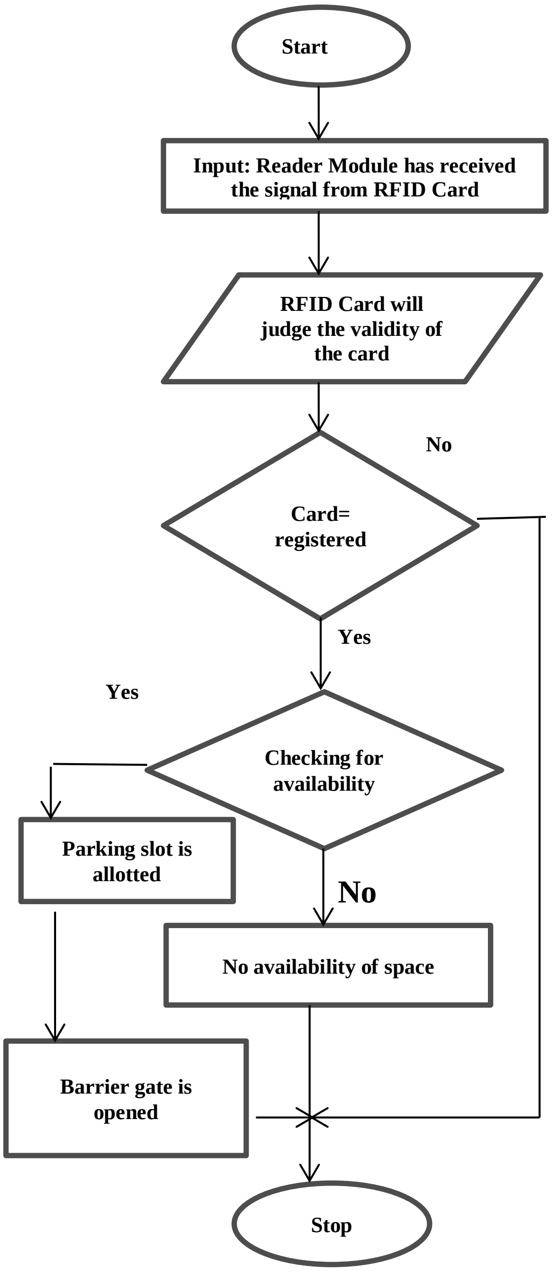

Fig.3. Flow chart

Fig.4. Real view of the parking area

VI. CHALLENGES

- To make the smart parking system to be available, we must improve the existing infrastructure.
- IoT devices consume more power. So the maintenance cost will be high [12].
- If the particular free parking slot has any other object other than the vehicle, the sensors may detect and think that the particular slot is not free [13].
- The installed apparatus is very expensive and can be stolen.

VII. FUTURE SCOPE

The future scope of IoT-based smart parking systems is expecting the arrival of multilayer parking, automated billing system, etc. The project can also be enhanced for tracking the vehicle speed on the roads, to differentiate the vehicles of VIP's and staff.

VIII. CONCLUSION

It is a dream for several countries to implement the concept of smart cities. The ultimate aim is to enrich the standard of living. The improvement of cloud technologies and the internet of things had given hope for better possibilities in that field. The system that we propose brings forth real-time data regarding the availability of free space in the parking lot. The importance of IoT-based smart parking systems using cloud databases is progressively increasing day by day. The concept of IoT based smart parking system has been implemented using a cloud server and different sensors available. In this system, the registered user can view the real outlook of the parking lot of any registered buildings like shopping malls, hospitals, sports stadiums, and many more public parking lots. It is a well-organized system of car parking that forbids traffic obstruction [5, 9], lowers air pollution, increases safety [19], improves user experience [11], etc.

REFERENCES

[1] Abhirup Khanna, R. A. (2016). IoT based Smart Parking System. International Conference on Internet of Things and Applications (IOTA) (p. 5). Pune: IEEE, DOI: 10.1109/IOTA.2016.7562735.

[2] Elakya, R. (2019). Smart-Parking System using IoT. Issue-1, Vol:9, ISSN: 2249-8958, IJEAT.

[3] Hafeez Sidd, S. (2019). A Review on Smart IoT based Parking System. IRJET, Research gate..

[4] Khaoula Hassoune, W. D. (2016). Smart parking Systems:A Survey . IEEE , 6.

[5] Wael Alsafery, B. A. (2018). Smart Car Parking System Solution for The Internet of Things in Smart Cities, IEEE, 5.

[6] Rachapol Lookmuang, K. N. (2018). Smart Parking Using IoT Technology. 5th ICBIR, IEEE, 6.

[7] Mohit Patil, R. S. (2014). Smart Parking System Based On Reservation. ISSN: 2347-3878, Issue 6, International Journal of Scientific Engineering and Research (IJSER), 5.

[8] Vishwanath Y, A. D. (2016). Survey paper on Smart Parking System based on Internet of Things. International Journal of Recent Trends In

Engineering & Research. ISSN: 2455-1457, Issue -3 ,Volume 02 (IJRTER) , 5.

[9] Deng, D. (2015). A Cloud based Smart Parking System Based on Internet of things Technologies. IEEE, 11.

[10] O. Orrie, B.S. (2015). A Wireless Smart Parking System. IECON (p.5).Yokohama: IEEE.

[11] Ahteshamul huq osma ni, A. G. (2016). Research paper on Smart City Parking System. Volume -2, Issue-3, ISSN(O)-2395-4396, IJARIIE , 3.

[12] Asghar Ali Shah, G. M. (2019). Video Stitching with Localized 360o Model for Intelligent Car Parking Monitoring and Assistance System. Volume-19, IJCSNS International Journal of Computer Science and Network Security, 6.

[13] Bachhav, J. D. (2017). Smart car parking system, Volume-9, Issue-9, ISSN: 2278-0181, International Research Journal of Engineering and Technology (IRJET), 3.

[14] R, M. B. (2015). Automatic Smart Parking System using Internet of Things (IOT), Volume-5, Issue -12, International Journal of Scientific and Research Publications , 4.

[15] Sadhukhan, P. (2017). An IoT-based E-Parking System for Smart Cities. Research gate, 6.

[16] Syed Zainuddin. (2019). Smart Parking System using IoT, e-ISSN: 2395-0056, p-ISSN: 2395-0072, Vol-06, Issue: 03, IRJET, 2019.

[17] T.Bhanusri, K.R. (2016). Advanced Car Parking System with GSM Supported Slot Messenger, IOSR Journal of Electronics and Communications Engineering, e-ISSN: 2278-2834, p-ISSN: 2278-8735, Vol-10, Issue 1, pp 14-18.

[18] J. Cynthia, C.B (2018). IOT based Smart Parking Management System, International Journal of Recent Technology and Engineering (IJRRTE), ISSN: 2277-3878, Vol-7, Issue-4S.

[19] Supriya Shindel (2017), IOT Based Parking System Using Google, I-SMAC, pp-634-636.

[20] Kalekar Nikita, U, (2019), Smart Paking System using IoT Technology, IJSTMR, ISSN: 2456-0006, Vol-4, Issue-4.

IOT BASED REMOTE ECG MONITORING SYSTEM

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Abstract - This paper is aimed to present a system that aids in monitoring a patient"s heart health condition through the Internet of Things (IoT) technology. The proposed system screens the patient"s heart health condition by extracting ECG signals using an ECG sensor. The acquired data is transmitted to the ThingSpeak database by ESP8266. A server periodically extracts data from the database and classifies it using a CNN model, as a situation of emergency or not. The results of the classification are sent back to ThingSpeak. Based on the results, a notification is sent to the doctor and the patient"s relatives with the help of IFTTT App in case of any emergency.

Keywords - Healthcare, Continuous Heart Health Monitoring, Internet of Things, ESP8266, ThingSpeak.

I. Introduction

Internet of Things (IoT) is extensively used across various spaces and has gained immense attraction for its ability to transfer data over a network without requiring human-to-human or human-to-computer interaction and all the communication happening through the internet. A large portion of IoT devices is created for consumer use, ranging from wearable technologies to smart homes. Internet of Things (IoT) has been increasingly applied to interconnect the available medical resources and provide reliable, efficient and smart healthcare service to the elderly and patients with chronic illnesses. The application of IoT in Healthcare diminishes the challenges faced by doctors and patients by providing round the clock, remote monitoring. IoT has also allowed patients to effectively engage with their health care providers and has also increased satisfaction as interactions with doctors have become more efficient and easier. Additionally, remote monitoring of a patient's health helps in reducing the length of hospital stay and prevents readmissions. IoT also has a significant impact on reducing healthcare costs and enhancing treatment outcomes.

Traditional healthcare systems lack the ability to constantly monitor the patient's health. This leads to the untimely detection of several heart conditions. This is tackled by using IoT. ECG AD8232 sensor connected to the patient"s body collects data and the storing of the patient"s details in the Thingspeak database is mediated through the ESP8266 [1]. This makes it an efficient system with less complexity. With the help of a CNN model, the received ECG signal is classified into different classes of arrhythmia. A notification feature is in place to alleviate the problem of helplessness during an emergency, making it a reliable and cost-effective product for patients. The proposed paper presents a dependable solution for continuous monitoring of heart health by doctors, for patients using an IoT based remote ECG monitoring system.

The rest of the paper is organized as follows. In Section II, related work is discussed. Section III provides the proposed system. Section IV deals with the implementation and results. Finally, Section V concludes the paper.

II . Literature Survey

In [2], Zhe Yang et al. proposed an IoT-based method for monitoring ECG. Using a wearable device, ECG data are gathered and with the help of Wi-Fi, it is transmitted directly to the IoT cloud. For providing visual and timely ECG data to users, HTTP and MQTT protocols are employed.

In [3], Uttam Deshpande et al. proposed a Cypress Wireless Internet Connectivity for Embedded Devices (WICED) Internet of Things (IoT) platform-based ECG monitoring system. A wearable monitoring device collects the data from the user and is updated to an IoT cloud by means of Wifi. Data communication and device management by IoT is done with protocols such as CoAP/HTTP, MQTT, TLS/TCP, DTLS/UDP, and OMA LW M2M.

In [4], Pamveer Singh et al. proposed an ECG monitoring system for a distant patient. In the proposed system an ECG sensor collects the Biosignals from the patient, which undergoes processing using development boards, and is sent to a distant IBM owned cloud, Bluemix for further analysis by a doctor or authorized personnel. The Bluemix cloud uses the MQTT protocol.

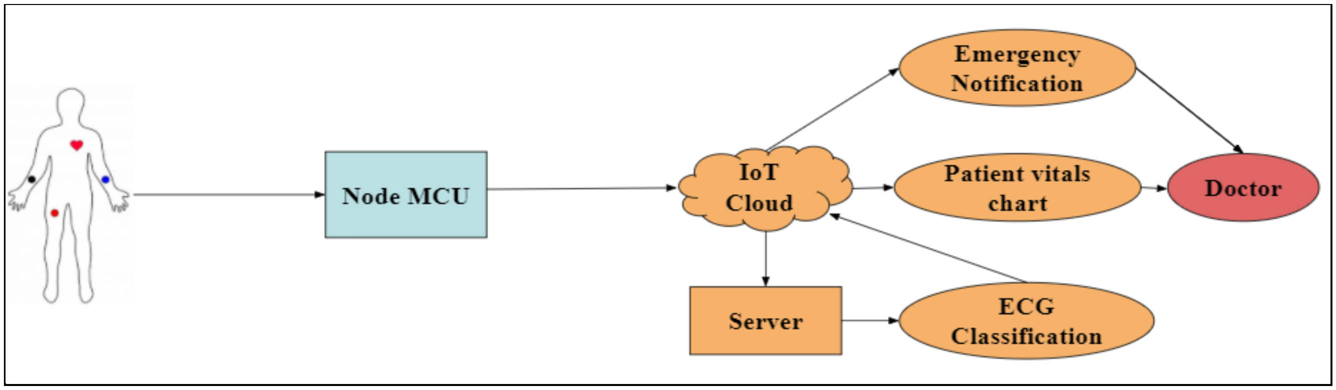

Fig 1: Block Diagram of the Proposed System

In [5], Mohammad Kachuee et al. proposed a deep convolutional neural network that is trained to detect arrhythmia in a given ECG signal. Furthermore, using the learned representation of arrhythmia, myocardial infarction classification is also performed. The proposed methods were evaluated on PhysionNet"s MIT-BIH and PTB Diagnostics datasets.

In [6], Mehak Chhabra et al. proposed an IoT based ECG monitoring system for calculating the value of a patient"s heart rate in beats per minute (bpm) and sending it to a cloud-based database. The critical parameters sent by the system can be analysed by the doctor and the real-time parameters of patients who are not admitted to the hospital can be monitored.

In [7], Auday A.H Mohamad et al. proposed a system in which a Node-MCU transmits the gathered ECG signals to the ThingSpeak platform. On the ThingSpeak-MATLAB cloud, PCA is employed which compares the received ECG signal with the various ECG signals stored in the Thingspeak channel databases. Based on this comparison, the system now classifies the signal into three groups namely, Arrhythmia-MLII, Atrial Fibrillation, and Normal-Sinus.

III. PROPOSED SYSTEM

The proposed system can be represented by the block diagram as in Fig 1. The three lead ECG pins are placed at three different locations on the patient"s body. The AD8232 ECG sensor amplifies the signal and converts the physical quantity into electrical quantity. The NodeMCU receives these signals and processes it before sending it to the cloud. The ThingSpeak platform is the chosen IoT cloud application for this purpose. Authorised personnel can view the patient"s data on the ThingSpeak channel [8]. A server is used to periodically extract the data from the ThingSpeak database and perform arrhythmia classification with the help of a CNN model. The output of the classification is sent back to the IoT cloud. Using React on Thingspeak, a request is sent to the WebSocket in case of an emergency. Then a notification is sent to the authorised personnel using the IFTTT App(If this then that) [9].

A. DESIGN METHODOLOGY

The design procedure associated with the proposed IoT system for ECG monitoring is elaborated in this section. The purpose of this system is to collect ECG signals using a single end node that sends data to the cloud.

1) PROCESS SPECIFICATION

Fig 2 shows the process diagram for the ECG monitoring system. When the ECG signal detected from the patient is classified as abnormal by the CNN model the system sends an emergency notification.

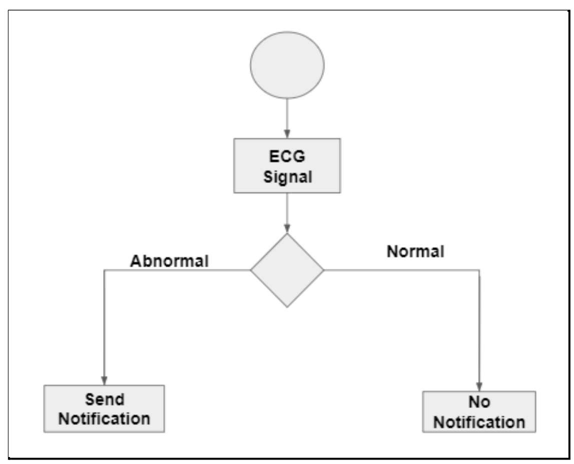

Fig 2: Process Specification for ECG Monitoring System

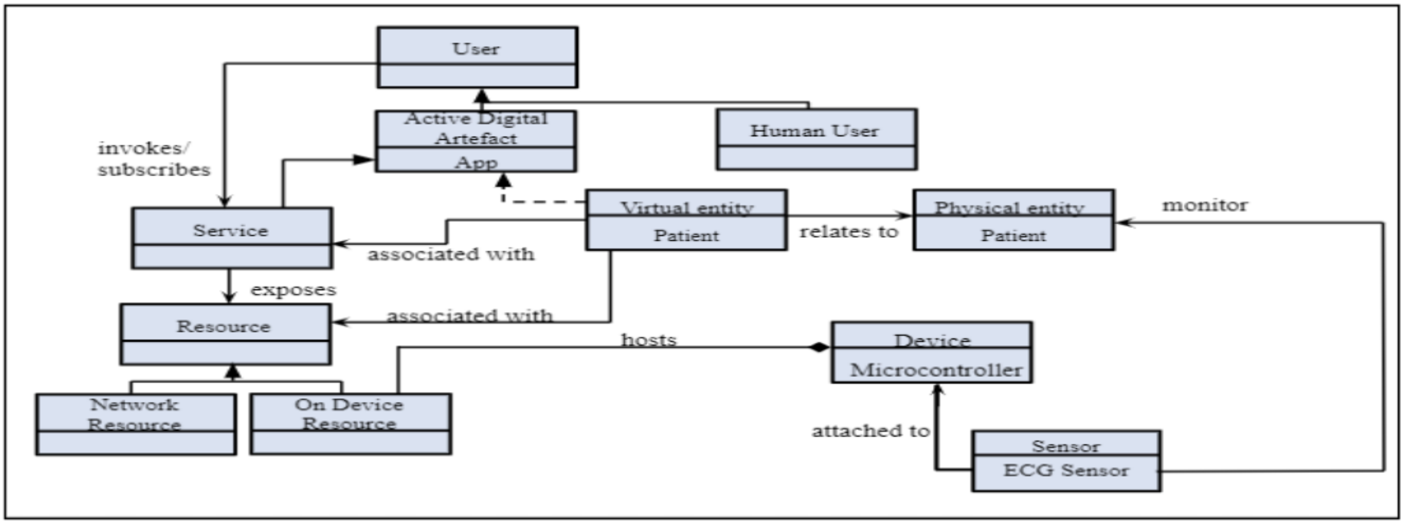

Fig 3: Domain Model

2) DOMAIN MODEL

Figure 3 represents the domain model of the monitoring system. In this domain model, the physical entity is the patient who is monitored. There is a virtual entity for the patient. Devices include an ECG sensor and ESP8266. Resources are software components that can either be on-device or network-resources. The service includes the provision to send emergency notification to the doctor.

3)INFORMATION MODEL

Figure 4 represents the information model of the ECG monitoring system. For the given system there is one virtual entity for the patient with the attribute ECG signal.

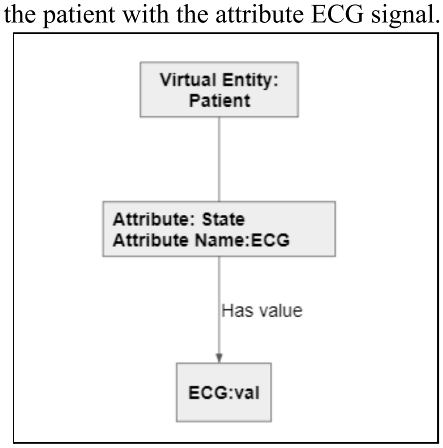

Fig 4: Information Model

4) IoT LEVEL SPECIFICATION

Figure 5 represents the deployment level of the ECG monitoring system which is Level 3. It has a single node and the data is stored and analysed in the cloud and the application is cloud-based as shown below. The node in the proposed system is the ECG sensor which is used to obtain ECG signal from the patient. The ESP82666 then transmits the data to the ThingSpeak Cloud through which the doctor can access details about the patient"s heart health condition at any time by using a computer or smartphone [10]. A server periodically pulls data from the cloud and classifies the signal as normal or abnormal with the help of a CNN model. In case the output of the classification is an abnormal signal, then an emergency notification is sent to the doctor via IFTTT App.

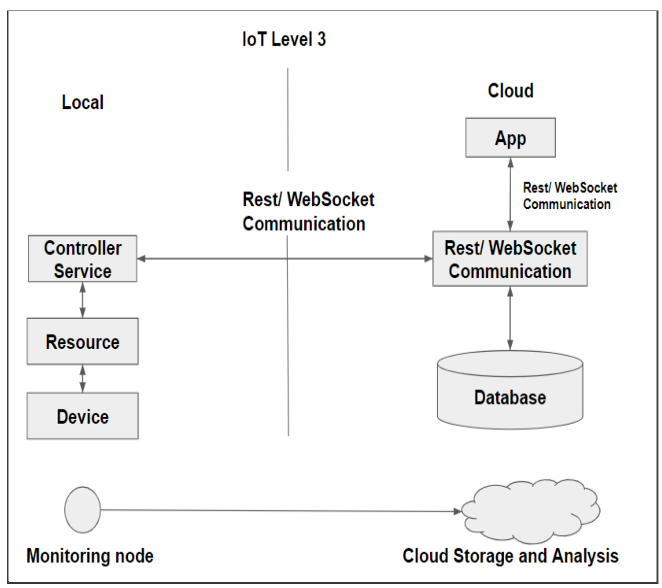

Fig 5: IoT level-3

5) APPLICATION DEVELOPMENT

Figure 6 represents the screenshot of the mobile application. The application sends a notification in case of an emergency as classified by the CNN Model.

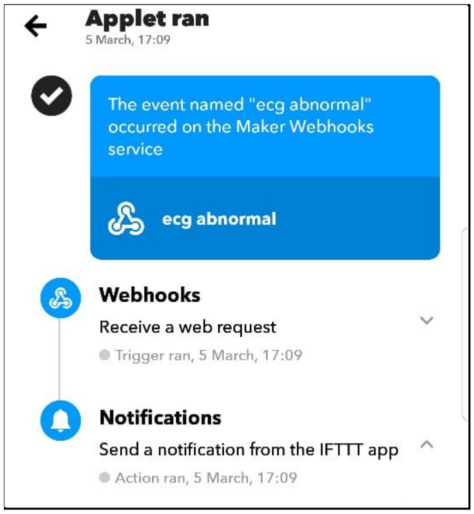

Fig 6: Application screenshot

B. ECG CLASSIFICATION

The ECG signals are classified into 5 classes of Arrhythmia as given in Table 1 by training a convolutional neural network on the MIT-BIH Database [18]. It consists of 48 half-hour excerpts of two-channel ambulatory ECG recordings, taken from 47 subjects studied by the BIH Arrhythmia Laboratory between 1975 and 1979. The recordings were digitized at 360 samples per second per channel with 11-bit resolution over a 10 mV range.

Table 1: ECG Classification

CLASS 0	NORMAL
CLASS 1	ATRIAL PREMATURE
CLASS 2	PREMATURE VENTRICULAR CONTRACTION
CLASS 3	FUSION OF VENTRICULAR AND NORMAL
CLASS 4	FUSION OF PACED AND NORMAL

Class 0 is considered normal and classes 1 through 4 are considered abnormal. The architecture for the proposed system has been illustrated in Figure 7. Every convolution layer consists of 32 kernels each of size 5 and applies 1-D convolution. The max pool layers used have a stride of 2 and a size of 5.

The neural network used for classification has 2 fully connected layers with 32 neurons preceded by 5 residual blocks, each of which contains 2 ReLU non-linear layers, 2 convolutional layers, 1 residual skip connection, and a pooling layer. A softmax layer is then used to predict the output classification probability. Therefore, the proposed deep neural network has 13 weight layers. Cross-entropy loss is used as the loss function and the Adam Optimizer is used to optimize the model.

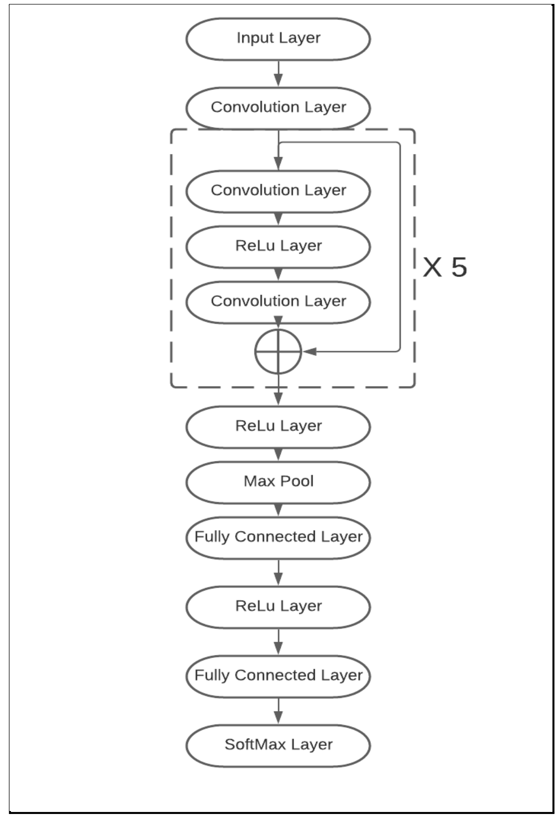

Fig 7: Network Architecture

IV PERFORMANCE EVALUATION OF THE PROPOSED SYSTEM

The performance of the classification model can be comprehended through the confusion matrix and the classification report as shown in Figure 8 and Figure 9 respectively.

```
[[18059    26    25     2     6]
 [  128   422     6     0     0]
 [   35     1  1392    16     4]
 [   40     0    15   107     0]
 [   15     0     1     0  1592]]
```

Fig 8: Confusion Matrix

	precision	recall	f1-score	support
Normal	0.99	1.00	0.99	18118
Artial Premature	0.94	0.75	0.84	556
Premature ventricular contraction	0.98	0.95	0.96	1448
Fusion of ventricular and normal	0.84	0.75	0.79	162
Fusion of paced and normal	1.00	0.99	0.99	1608
accuracy			0.99	21892
macro avg	0.95	0.89	0.91	21892
weighted avg	0.99	0.99	0.99	21892

Fig 9: Classification report

Table 2 compares the accuracy of the proposed model with the existing literature.

Table 2: Comparison

Paper	Methodology	Accuracy
This Paper	Deep CNN	99.00%
Li et al	DWT + Random Forest	94.60%
Song et al	SVM	94.22%
Acharya et al	Augmentation + CNN	93.50%
Kachuee et al	Deep Residual CNN	93.40%
Ye et al	SVM	92.17%
Yu et al	PNN	88.87%
Park et al	Hierarchical SVM	85.00%
de Chazal et al	LD	83.00%

CNN: Convolutional Neural Network; DWT: Discrete Wavelet Transform; SVM: Support Vector Machine; PNN: Probabilistic Neural Network; LD: Linear Discriminant

From Table 2 it is evident that the proposed model has the highest accuracy followed by the models proposed by Li et al [11], Kachuee et al [5], Song et al [12], Acharya et al [13], Ye et al [14], Yu et al [15], Park et al [16] and de Chazal et al [17]. The proposed model has a 5.99% increase in accuracy compared to Li et al [11].

V SYSTEM IMPLEMENTATION

The project implementation setup is shown in Figure.10. The AD8232 sensor measures the ECG (Electrocardiogram) signal of a patient by placing electrodes on the right arm, left arm and right leg of the patient. The data is then uploaded to the Thingspeak IoT cloud via the ESP8266. Figure. 11 shows the ECG graph as viewed on ThingSpeak by the doctor [18]. The continuously monitored data is saved on the cloud and is accessible to the doctor in charge.

The data is periodically pulled by a server where a CNN model classification of ECG signals takes place. A mobile notification indicating the condition of the patient is sent to a predefined individual who can be a nurse, doctor or relative using the IFTTT App in case of emergencies, as shown in Figure 12.

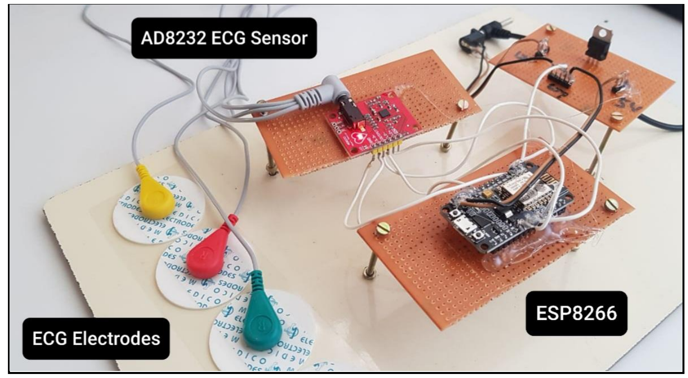

Fig 10: Hardware setup of the Project

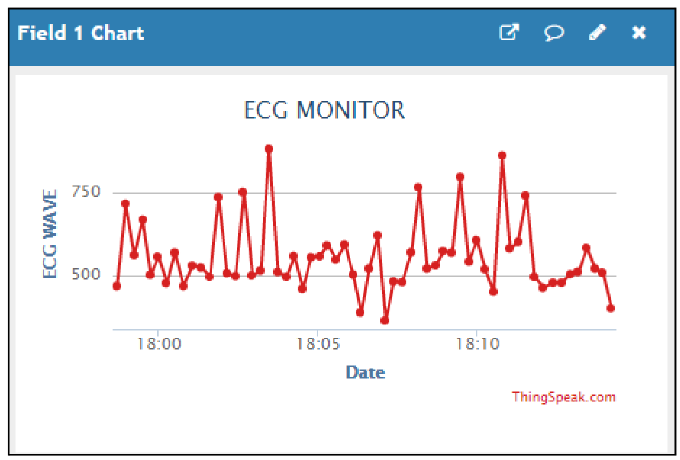

Fig 11: ECG graph as viewed on ThingSpeak

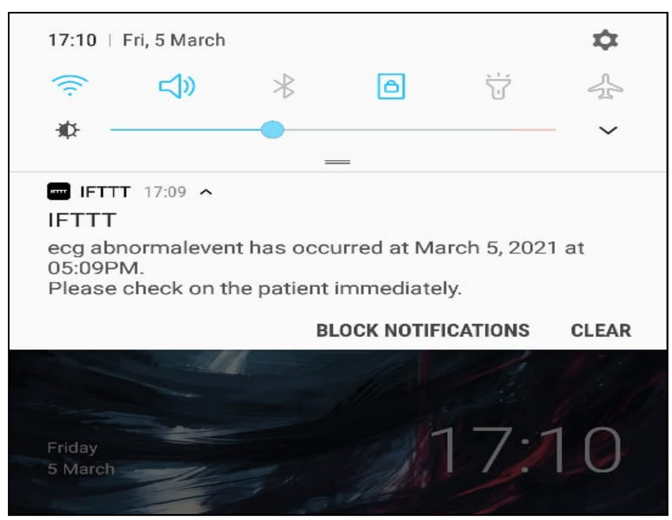

Fig 12: IFTTT Notification on a mobile device

VI. CONCLUSION AND FUTURE WORK

IoT is transforming healthcare by redefining the space of devices and human interaction in providing healthcare solutions. The timely detection of heart diseases is crucial in providing the appropriate treatment. The proposed system enables effective remote health care services to patients which helps doctors to provide immediate and suitable treatment. The proposed arrhythmia classifier has an improved classification accuracy of 5.99% in comparison to the existing literature. This system enables remote ECG monitoring and early detection of heart diseases.

However, this system can be improved by using a more accurate ECG sensor. Video calling and distress button provisions can also be a future scope of this paper.

VII. REFERENCES

[1]. V. Patil, S. S. Thakur and V. Kshirsagar, "Health Monitoring System Using Internet of Things," *2018 Second International Conference on Intelligent Computing and Control Systems (ICICCS)*, 2018, pp. 1523-1525

[2]. Yang Z, Zhou Q, Lei L, Zheng K, Xiang W. An IoT-cloud Based Wearable ECG Monitoring System for Smart Healthcare. J Med Syst. 2016 Dec;40(12):286.

[3]. Uttam U. Deshpande, Milan A. Kulkarni, "IoT based Real Time ECG Monitoring System using Cypress WICED"- International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, 2017, vol 6, issue 2, pp.710-720.

[4]. Parmveer Singh, Ashish Jasuja, "IoT based low-cost distant patient ECG monitoring system"- 2017 International Conference on Computing, Communication and Automation (ICCCA), Greater Noida, 2017 pp.1330-1334.

[5]. M. Kachuee, S. Fazeli and M. Sarrafzadeh, "ECG Heartbeat Classification: A Deep Transferable Representation," *2018 IEEE International Conference on Healthcare Informatics (ICHI)*, 2018, pp. 443-444.

[6]. Mehak Chhabra, Manik Kalsi, "Real Time ECG Monitoring system based on Internet of Things (IoT),"International Journal of Scientific and Research Publications, 2017, vol 7, issue 8, pp. 547-550.

[7]. Auday A.H Mohamad, Noor Kareem Jumaa, Sameer Hameed Majeed,"Thingspeak Cloud Computing Platform Based ECG Diagnose System,"International Journal of Computing and Digital Systems,2019.

[8]. S. P. Kumar, V. R. R. Samson, U. B. Sai, P. L. S. D. M. Rao and K. K. Eswar,"Smart health monitoring system of patient through IoT," International Conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud) (I-SMAC), Palladam, 2017, pp. 551-556.

[9]. Vasan, CR & Charan, Guru & Babu, Chenchu, "An IoT based SMART patient health monitoring system," Indonesian Journal of Electrical Engineering and Computer Science,2020,vol 18,pp. 1657-1164.

[10]. A. Maity and I. S. Misra, "Prototype Design of An IoT Enabled Cost-Efficient Portable Heart-Health Data Acquisition System," IEEE Kolkata Conference (CALCON), Kolkata, India, 2020, pp. 137-141.

[11]. T. Li and M. Zhou, "Ecg classification using wavelet packet entropy and random forests," Entropy, vol. 18, no. 8, p. 285

[12]. Song, M.H.,Lee, J. , Cho, S.P.,Lee, K.J., Yoo, S.K. , "Support vector machine-based arrhythmia classification using reduced features," Int.J.Control. Autom. Syst. 2005,vol 3, pp. 571–579.

[13]. U. R. Acharya, H. Fujita, S. L. Oh, Y. Hagiwara, J. H. Tan, and M. Adam, "Application of deep convolutional neural network for automated detection of myocardial infarction using ecg signals," Information Sciences, 2017, vol. 415, pp. 190–198.

[14]. Ye, C.; Coimbra, M.T.; Kumar, B., "Arrhythmia detection and classification using morphological and dynamic features of ECG signals,"Annual International Conference of the IEEE Engineering in Medicine and Biology Society, Buenos Aires, Argentina, 2010; pp. 1918–1921.

[15]. Yu, S.N.; Chen, Y.H., "Electrocardiogram beat classification based on wavelet transformation and probabilistic neural network,'' Pattern Recognit. Lett. ,2007, vol 28, pp. 1142–1150.

[16]. K. S. Park *et al*., "Hierarchical support vector machine based heartbeat classification using higher order statistics and hermite basis function," 2008 Computers in Cardiology, Bologna, Italy, 2008, pp. 229-232

[17]. Philip de Chazal, M. O"Dwyer and R. B. Reilly, "Automatic classification of heartbeats using ECG morphology and heartbeat interval features," IEEE Transactions on Biomedical Engineering, 2004, vol. 51, no. 7, pp. 1196-1206.

[18]. Goldberger AL, Amaral LA, Glass L, Hausdorff JM, Ivanov PC, Mark RG, Mietus JE, Moody GB, Peng CK, Stanley HE. PhysioBank, PhysioToolkit, and PhysioNet: components of a new research resource for complex physiologic signals. Circulation. 2000 Jun 13;101(23):E215-20. doi: 10.1161/01.cir.101.23.e215

[19]. www.thingspeak.com

A Review of IoT Systems and Machine Learning Techniques in Crop Yield Prediction

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Abstract— The agricultural sector across the world has always faced challenges in ensuring adequate production amidst changing seasons, weather conditions, arable land, and unpredictable natural disasters. Internet of Things (IoT) and data analytics play an important role in monitoring various parameters affecting the crop yield and using state-of-the-art machine learning techniques to predict the yield based on dependent variables. The IoT systems related to agriculture and the most commonly used components of the system are presented. The trends of various machine learning techniques and the emphasis on certain dependent parameters are identified. The only way forward is to ensure that an affordable and robust solution for crop yield prediction is reaching the farmers at all levels in the agricultural sector.

Keywords— IoT analytics, IoT system, Machine Learning, Multi-Layer Perception, Random Forest

I. INTRODUCTION

In India, there are more than a hundred crops planted around the whole country. As reported by Kapil [17], agricultural share in GDP hit 20% after 17 years in 2020-2021. India's rice production is at a record 102.36 million tons in the Kharif season of 2020-2021 [18]. However, there exists a high risk of vulnerability as reported by [19] on the yield because of climactic factors. Another major problem is pointed out by Puja Mondal [20] because of small and fragmented land holding due to the inheritance laws of our nation.

Even though IoT Analytics and Decision Support Systems (DSS) have greatly improved the prediction of crop yield, the research challenges remain. The benefits of IoT systems in agriculture are manifold.

The contributions of this review work are as follows:

- Examine existing IoT systems for crop yield prediction
- Determine dependent parameters that affect crop yield prediction from literature.
- Identify techniques that provide the best results for crop yield prediction.

In the following section, a review of IoT systems and data analytics for agriculture is examined.

II. IOT SYSTEMS FOR CROP YIELD PREDICTION

A typical IoT system for agriculture requires sensors for sensing various parameters affecting crop yield, a microcontroller to control the actions of the sensors, a cloud to store the data, and a data analytics system to process the information and predict or offer decision support.

Sushanth et al [21] proposed an IoT system using Arduino Uno R3 microcontroller board with LM35 temperature sensor and also sensors for humidity and moisture. The IoT gateway then transmits the data to the cloud for processing. Prathiba et al [22] use CC3200, a single chip with an integrated microcontroller, network processor, and Wi-Fi with temperature sensor TMP007 and humidity sensor, HCD1010 to set up a system for monitoring farmland.

Lee et al [23] use an IoT gateway with temperature, humidity, soil electrical conductivity (EC), and pH sensors attached. Their system runs an analytics decision support at the back end to help to make decisions and they report an increase in the yield of apple and tomato yield.

Garcia et al [24] report that

- YL69 is the most popular sensor to monitor soil moisture.
  - Its output voltage goes from 3.3V to 5V.
  - Outputs 0-300 for dry soil and 300-700 for humid soil.
- LDR is the most used luminosity sensor
- DHT11 is the most popular sensor for humidity and temperature.
  - DHT11 has a range of measuring 20% to 95% humidity and a temperature of 0°C to 50°C
- Arduino Uno is the most popular node in IoT systems for agriculture.
- WiFi is the most utilized communication system
- ESP82666 is the most utilized communication module
- The database and cloud are mostly varied but MySQL and ThingSpeak are most popular.

The various components highlighted by Garcia et al [24] are shown in Table I.

III. MACHINE LEARNING TECHNIQUES

Machine learning techniques use the dependent variables that affect crop yield. Using various clustering approaches or models, a prediction model can predict the crop yield with a certain accuracy. The various techniques used include Linear Regression, Logistic regression, Random Forest and decision tree, K Nearest Neighbour (KNN), Artificial Neural Network

(ANN), and Multilayer Perceptron (MLP) neural network. Autoregression models are also used. The following discussion reports the effectiveness of various clustering and learning models.

TABLE I. COMPONENTS OF THE PHYSICAL AN IOT SYSTEM

Type of Sensor	***Working Voltage***	***Specifications***
Soil Moisture Sensor YL69 	3.3V-5V	Analog and digital output
Luminosity Sensor LDR 	The maximum voltage at 0 lux: 200V	Peak wavelength: 600nm
Humidity and Temperature Sensor DHT11 	3.3V-5V	Temperature: 0°C to 50°C Humidity: 20% to 95%
Microcontroller Arduino Uno 		14 digital I/O pins 6 analog inputs, 16MHz quartz crystal USB connection power jack ICSP header reset button
Communication Module ESP82666 		Micro USB for power, programming, and debugging 15-pin header

Neural Network-based techniques

Kadir et al [1] predict wheat yield prediction using Multi-Layer Perceptron (MLP) backpropagation based-feedforward artificial neural networks (ANN). Many parameters such as temperature, frost, and rain are passed through neurons. The model predicts with an accuracy of 98%. Gandhi et al [2] use precipitation, minimum temperature, maximum temperature, area, production, and yield for the Kharif season (June to November) for rice production in various districts in Maharashtra. A Multilayer Perceptron Neural Network (MLP) performs with an accuracy of 97.5%. Another work by Gandhi et al [3] report that when MLP was compared with another classifier, Sequential Minimal Optimization (SMO), it performed much better. Ahamad et al [8] have considered rainfall, temperature, and soil attributes such as pH, salinity, and area of production to predict rice yield in Bangladesh. They have used Linear Regression, KNN, and Neural networks. No one method produces the best results for all crops. ANN performs better for some crops that have more missing values. Linear regression performs better for most crops. They also report that their training set was small.

Islam et al [6] used soil type, type of land, fertilizer, rainfall, temperature, and humidity information about various agriculture zones in Bangladesh to predict the crop yield. They concluded that deep neural network performs better than logistic regression and SVM and Random Forest with an accuracy of over 94% for all the crops considered.

Random Forest and Decision Tree

Champaneri et al [15] use a Random Forest classifier on crop yield prediction based on temperature, rainfall, and area. They report a prediction accuracy of over 75%. Kumar et al [10] use parameters such as pH, temperature, humidity, rainfall, and crop name to predict crop yield using Random Forest, and Decision Tree. Their results help farmers decide on which crops would give the greatest yield and hence the highest profit. Jeong et al [14] use Random Forest and Multiple Linear Regression (MLR) on global wheat grain yield and, US maize grain yield, North-eastern Seaboard region potato and maize yield. RF gave a better prediction than MLR in all instances. Kumar et al [10] use parameters such as pH, temperature, humidity, rainfall, and crop name to predict crop yield using Random Forest, and Decision Tree. Their results help farmers decide on which crops would give the greatest yield and hence the highest profit.

K-Means clustering techniques

Awan et al [4] use Weighted Kernel K-Means with Spatial Constraints (SWK-Means) for predicting oil-palm yield by analyzing rainfall values. The model can also be used for other parameters such as precipitation, temperature, pressure in different areas, and their effect on oil palm production. Ananthara et al [16] use region, pH, sunlight, soil type and use a beehive clustering algorithm to predict crop yield. The proposed algorithm overcomes shortcomings of K-Means clustering and performs with an accuracy of over 84% for all years for paddy and sugarcane yield.

Autoregression Models

Bang et al [5] use three methods, Auto Regressive Moving Average (ARMA), Seasonal Auto-Regressive Integrated Moving Average (SARIMA), and ARMA with exogenous variables (ARMAX). They take the temperature and rainfall data, use it to predict the temperature and rainfall of the Kharif and Rabi season and in turn use the crop yield dataset to predict the crop yield. They report that temperature is predicted accurately by the SARIMA model.

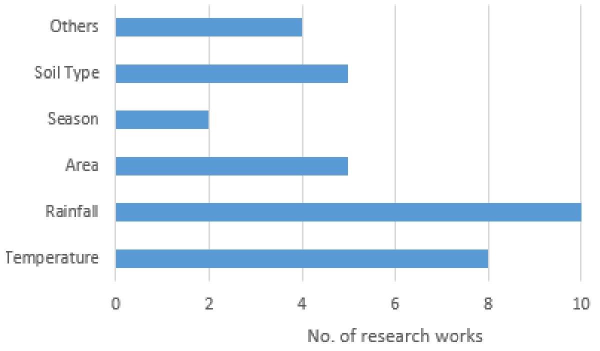
Tools used

Bhosale et al [7] use data visualization tool, Tableau. Paul et al [9] use RapidMiner 5.3 to run KNN and Naïve Bayes classifiers on a soil dataset that was taken from Madya Pradesh. Gandhi et al [11] used Netbeans IDE and Microsoft access database for developing a Decision Support System(DSS).

Fig. 1. Type of parameters used in various research works

IV. DISCUSSION

From the survey done, research done on data set from various parts of India [2,3,5,15,16], Bangladesh [6,8], Malaysia [1,4],



U.S. [14], and worldwide data [14] is considered. Some data sets were collected from labs in specific areas such as Madhya Pradesh [11], Allahabad [5] whereas others are those provided by government organizations [6,14].

TABLE II. COMPARISON OF VARIOUS PARAMETERS

Author	*Temperature*	*Rainfall*	*Area*	*Season*	*Soil Type*	*Others*
Kadir et al[1]		✓				
Gandhi et al [2]	✓	✓	✓	✓		
Gandhi et al [3]	✓	✓	✓	✓		
Awan et al [4]	✓	✓				pressure
Bang et al [5]	✓	✓				
Islam et al [6]	✓	✓			✓	humidity, fertilizer, type of land
Bhosale et al [7]		✓	✓		✓	
Ahamad et al [8]			✓			salinity
Paul et al [9]					✓	
Kumar et al [10]	✓	✓				
Jeong et al [14]	✓	✓			✓	Radiation
Champaneri et al [15]			✓			
Ananthara et al [16]	✓	✓			✓	

The crop yield prediction of major interest is rice [2,3,6,8,16] and wheat [1,5,6,14] and instance of sugarcane [7,16], jute [6], oil palm [4], potato [6,14] and maize [14].

The parameters that affect crop yield that is used for prediction are predominantly temperature and rainfall [1-6,10,16] as can be seen in Table II and also Figure. 1. In India, the Kharif and Rabi seasons are of particular interest due to the rice yield predictions in those seasons [2,3].

The soil type is used by some researchers to predict yield. Ananthara et al [16] classify it as black soil, clay soil, and alluvial soil. Paul et al [9] examine the nutrients and micronutrients of the soil such as organic carbon, nitrogen, potassium, sulfur, zinc, and iron. In certain regions, the land type is of importance such as in [6] where land is classified as highlands, medium highland, medium low land, low land, very low land, and miscellaneous land. Jeong et al [14] use additional parameters such as seasonal radiation, irrigation, clay content, and others to predict. Pressure and other climactic factors are used by [4] and classified.

The popular classifiers (Table III) are Naïve Bayes and KNN [7-9] are used to classify a set of climatic and agronomic parameters to predict yield or the best crop to grow in such circumstances to get maximum profit. LR or RF [8,10,14,15] to obtain a good prediction of a particular crop type given a set of dependent variables. ANN gives the best prediction with 98% prediction accuracy for the wheat [1]. The visual representation of the summary of various classifiers is summarized in Figure 2.

TABLE III. COMPARISON OF VARIOUS TECHNIQUES

Author	*Naïve Bayes*	*KNN*	*ANN*	*LR/RF*	*SVM*	*Others*
Kadir et al[1]			✓			
Gandhi et al [2]			✓			
Gandhi et al [3]			✓		✓	SMO
Awan et al [4]						SWK-Means
Bang et al [5]						ARMA, SARIMA, ARMAX
Islam et al [6]					✓	Logistic Regression
Bhosale et al [7]	✓	✓				
Ahamad et al [8]		✓	✓	✓		
Paul et al [9]	✓	✓				
Kumar et al [10]				✓		Decision Tree
Jeong et al [14]				✓		MLR
Champaneri et al [15]				✓		
Ananthara et al [16]						Bee Hive Clustering Algorithm

V. RESEARCH CHALLENGES AND RESEARCH DIRECTIONS

IoT Systems and ML techniques for DSS in crop yield have a tremendous positive impact in the agriculture sector. Elijah et al [24] indicate the impact of IoT systems on operational efficiency wherein the data can be put to use to optimize and plan out agricultural interventions. Although the benefits are manifold, research challenges remain. The following are some research challenges and possible future research directions stemming from the review of IoT systems and ML techniques.

Scientists struggle to channel the research findings and convey them in a timely, relevant, and user-friendly manner to the stakeholders. Some research has reached the farmers in the form of a mobile app [11,13,26,27]. Developing **user-friendly apps** and the maintenance thereof still poses a formidable challenge.

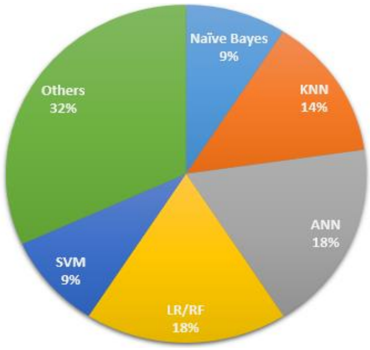


Fig. 2 Summary of various classifiers

A challenge in machine learning techniques is that no single classifier works best for all types of crops. Even though MLP provides the best results, there is a need to use bio-inspired approaches or **develop other meta-heuristics** to effectively predict the crop yield of various crops. Gangde [12] point out that more effective classifiers are required to predict yield with greater accuracy.

Developing **cost-effective** IoT solutions for farmers with fragmented landholding is another research challenge. The cost factor is not delved into in most research work. The cost involves the cost for deployment and maintenance of equipment and usage of the cloud.

There is a need to develop IoT systems and DSS for **post-drought or flood scenarios.** In most research work, the parameters considered for predicting crop yield are stable climactic factors or the soil type depending on the region. More research is required to consider adverse soil and climate conditions following a natural disaster.

There are very few research works that take into account the **season as a dependent variable** in predicting crop yield. Farmers understand seasons and it will be valuable to develop a solution as that proposed by Incant et al [26] to give solutions to farmers that they can use and understand easily.

VI. Conclusion

The IoT system and the various prediction models that have been used both nationwide and worldwide for predicting crop yield in agriculture are presented in this paper. Though the technological innovations in IoT and machine learning algorithms have helped us make strides in giving the agricultural sector a competitive edge, the technical, as well as the social-economic factors, have limited the reach of such technology to medium or small-scale farmers.
The awareness of the existence of such systems has increased in recent years but recommendations from such systems are not reaching the farmers at an affordable cost. It is expected that researchers will continue working on cost-effective solutions and develop user-friendly apps to support the agricultural sector.

References

[1] K. Muhd Khairulzaman Abdul, M. Zaki Ayob, and Nadaraj Miniappan, "Wheat yield prediction: Artificial neural network based approach," *in 4th International Conference on Engineering Technology and Technopreneuship (ICE2T). IEEE*, 2014.

[2] G. Niketa, P. Owaiz, and A. Leisa J.. "Rice crop yield prediction using artificial neural networks," *IEEE Technological Innovations in ICT for Agriculture and Rural Development (TIAR)*,2016.

[3] G. Niketa, A. Leisa J., P. Owaiz, and T. Amiya Kumar, "Rice crop yield prediction in India using support vector machines," in *13th International Joint Conference on Computer Science and Software Engineering (JCSSE)*, pp. 1-5., 2016.

[4] A. A. Majid, and S. Mohd Noor Md, "An intelligent system based on kernel methods for crop yield prediction," in *Pacific-Asia Conference on Knowledge Discovery and Data Mining,* pp. 841-846. Springer, Berlin, Heidelberg, 2006.

[5] B. Shivam, Rajat Bishnoi, C. Ankit Singh, D. Akshay Kumar, and C. Indu, "Fuzzy logic based crop yield prediction using temperature and rainfall parameters predicted through ARMA, SARIMA, and ARMAX models," in *2019 Twelfth International Conference on Contemporary Computing (IC3),* pp. 1-6. IEEE, 2019.

[6] I. Tanhim, C. Tanjir Alam, and C. Amitabha, "A deep neural network approach for crop selection and yield prediction in Bangladesh," in *IEEE Region 10 Humanitarian Technology Conference (R10-HTC),* pp. 1-6. IEEE, 2018.

[7] Bhosale, Shreya V., Ruchita A. Thombare, Prasanna G. Dhemey, and Anagha N. Chaudhari. "Crop yield prediction using data analytics and hybrid approach," in *Fourth International Conference on Computing Communication Control and Automation (ICCUBEA),* pp. 1-5. IEEE, 2018.

[8] Ahamed, AT M. Shakil, Navid Tanzeem Mahmood, Nazmul Hossain, Mohammad Tanzir Kabir, Kallal Das, Faridur Rahman, and Rashedur M. Rahman, "Applying data mining techniques to predict the annual yield of major crops and recommend planting different crops in different districts in Bangladesh," in *IEEE/ACIS 16th International Conference on Software Engineering, Artificial Intelligence, Networking and Parallel/Distributed Computing (SNPD),* pp. 1-6. IEEE, 2015.

[9] P. Monali, V. Santosh K. Vishwakarma, and V. Ashok, "Analysis of soil behaviour and prediction of crop yield using data mining approach," in *International Conference on Computational Intelligence and Communication Networks (CICN),* pp. 766-771. IEEE, 2015.

[10] Y. Kumar, Y. Jeevan Nagendra, V. Spandana, V. S. Vaishnavi, K. Neha, and V. G. R. R. Devi. "Supervised Machine learning Approach for Crop Yield Prediction in Agriculture Sector, in *5th International Conference on Communication and Electronics Systems (ICCES),* pp. 736-741. IEEE, 2020.

[11] G. Niketa, A. Leisa J., and P. Owaiz, "Proposed decision support system (DSS) for Indian rice crop yield prediction," in *IEEE Technological Innovations in ICT for Agriculture and Rural Development (TIAR),* pp. 13-18. IEEE, 2016.

[12] G. Yogesh. "A study on various data mining techniques for crop yield prediction," in *International Conference on Electrical, Electronics, Communication, Computer, and Optimization Techniques (ICEECCOT),* pp. 420-423. IEEE, 2017.

[13] A. Manjula and G. Narsimha. "XCYPF: A flexible and extensible framework for agricultural Crop Yield Prediction," in *IEEE 9th International Conference on Intelligent Systems and Control (ISCO),* pp. 1-5. IEEE, 2015.

[14] J. Jig Han, R. Jonathan P., M. Nathaniel D., F. David H., Y. Kyungdahm, B. Ethan E., and T. Dennis J, "Random forests for global and regional crop yield predictions." *PLoS One 11*, no. 6 (2016): e0156571.

[15] C. Mayank, & C. Chaitanya., C. Darpan, R. Mansing, "Crop Yield Prediction using Machine Learning," *International Journal of Science and Research (IJSR),* April 2020.

[16] M. Ananthara, Gunasundari, T. Arunkumar, and R. Hemavathy. "CRY—an improved crop yield prediction model using bee hive

clustering approach for agricultural data sets," in *Proc. of International Conference on Pattern Recognition, Informatics and Mobile Engineering*, pp. 473-478. 2013.

[17] S. Kapil, (2021, January), Agri Share in GDP hit 20% after 17 years: Economic Survey, https://www.downtoearth.org.in/news/agriculture/agri-share-in-gdp-hit-20-after-17-years-economic-survey-75271, Accessed on 4.03.2021

[18] Rice Production Estimated At Record 102.36 Million Tonnes In 2020-21 Kharif Season: Government, https://www.bloombergquint.com/business/rice-production-estimated-at-record-102-36-mln-tonnes-in-2020-21-kharif-season-govt, Accessed On 3.03.2021

[19] S. Tarul, H. Vittal, K. Subhankar, and G. Subimal Ghosh, "Increasing agricultural risk to hydro-climatic extremes in India," *Environmental Research Letters* 15, no. 3, 2020.

[20] M. Puja., 10 Major Agricultural problems of India and their possible solutions. https://www.yourarticlelibrary.com/agriculture/10-major-agricultural-problems-of-india-and-their-possible-solutions/20988 Accessed on 2.03.2021

[21] G. Sushanth, and S. Sujatha, "IoT based smart agriculture system," in *International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET)*, pp. 1-4. IEEE, 2018.

[22] S. Prathiba, H. Anupama Mongol, and M. P. Jyothi. "IoT based monitoring system in smart agriculture," in *International conference on recent advances in electronics and communication technology (ICRAECT)*, pp. 81-84. IEEE, 2017.

[23] L. Meonghun, H. Jeonghwan, and Y. Hyun, "Agricultural production system based on IoT," in *IEEE 16Th international conference on computational science and engineering*, pp. 833-837. IEEE, 2013.

[24] G. Laura, P. Lorena, J. Jose M., L. Jaime, and L. Pascal, "IoT-based smart irrigation systems: An overview on the recent trends on sensors and IoT systems for irrigation in precision agriculture," *Sensors* 20, no. 4, 1042, 2020.

[25] O. Elijah, R. Tharek Abdul, O. Igbafe, L. Chee Yen, and MHD Nour Hindia. "An overview of Internet of Things (IoT) and data analytics in agriculture: Benefits and challenges," *IEEE Internet of Things Journal* 5, no. 5, 3758-3773, 2018.

[26] N. Potnuru Sai, V. Pinapa Sai, B. Lakshmi Avinash, and B. Jabber. "Crop Yield Prediction based on Indian Agriculture using Machine Learning," in *International Conference for Emerging Technology (INCET)*, pp. 1-4. IEEE, 2020.

[27] S. Geetha, P. Deepalakshmi and S. Pande, "Managing Crop for Indian Farming Using IoT," in *IEEE International Conference on Clean Energy and Energy Efficient Electronics Circuit for Sustainable Development (INCCES)*, 1-5, 2019.

Consumer and Industrial IoT: A Systematic Review

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Abstract — **The Internet of Things can be explained as the connection among millions of devices around us using various sensors and actuators, which results in endless applications such as industrial applications, smart city development, agriculture, automation, devices used for entertainment, and many others. Since IoT is a broad term and includes various applications, to avoid confusion divisions in IoT originated such as consumer IoT and industrial IoT. Some of the main applications in consumer IoT are smart home/city automation, health care devices and fitness trackers, personal asset tracking, VR Headsets, and many others. Earlier, International Data Corporation (IDC) in 2017 stated that consumer IoT / CIoT will be the highly used sector among IoT by 2020. Likewise, CIoT has been highly developed and benefitted by everyone around the globe. In a survey taken to understand the usage of CIoT, the smart home application is ranked first followed by wearables and smart city applications in the next two positions. This paper presents an overview of consumer IoT, various fields associated, and devices related to the consumer IoT. The comparison and trade-offs among devices are produced and also a short review on security issues in consumer IoT devices is brought out.**

Keywords— actuators, assets, CIoT, wearables, Internet of Things, comparisons.

I. INTRODUCTION

Internet of Things (IoT) tethers various devices around the globe using the internet as a medium. With the help of the internet, the devices also exchange data among them [8]. In the 1980s the first IoT device was found by David Nichols. He invented a system that would report the contents of the coke machine to his fellow members. From there IoT tremendously developed year by year and has now covered all the sectors including ingestible sensors. It consumed an enormous effort to bring industrial IoT to existence. This is because, though IoT has various advantages there are few crucial points such as data storage, security, and analytics challenges. Likewise, different sectors in IoT have various advantages and fewer short comes which are to overcome in the nearing future.

The main reason for the origin of IoT devices is to reduce the human interference in operating devices around us. Home automation is a perfect example of this illustration. Instead of operating the appliances by people themselves, CIoT / consumer IoT provides automated applications which reduces time as well as gives notifications to people on every necessary operation it does [2]. As CIoT devices are user-friendly, people can configure the operations done by the device (for instance, switching ON light for a particular period of time). This reduces energy wastage and enables the appliances to be used effectively.

The Internet of Things connects millions of devices around us. In order to connect these devices effectively, there are certain protocols that need to be adhered to. They are Wi-Fi, Bluetooth, Zigbee, MQTT, Near Field Communication (NFC), Z wave, Sigfox, and some others [1]. Among these, Wi-Fi, Bluetooth, and Zigbee are general-purpose protocols used in all kinds of wireless communication systems. MQTT is a message protocol that is also important in the smart city/home appliances When designing devices protocols should be mainly considered because they pave the way for the devices to be flexible, user-friendly, scalable, and high quality with optimum power/energy consumption.

According to a survey by Statista in 2021 [4], In 2018, around 22 billion internet of things (IoT) devices were in use around the globe. As there are more people showing interest towards home automation and the need for smart appliances increases day by day, Forecasts implies that by 2030 around 50 billion IoT devices will be in use around the world. In an article [5], it is illustrated that IoT growth rates have been affected due to the pandemic situation in 2020. However, IDC expects the rates to return to normal in 2021 and also attain the Compound Annual Growth Rate of 11.3% during the period 2020 – 2024. According to an article published in June 2020 [6], industrial IoT ranks first among the applications of IoT followed by transportation, energy, smart city, healthcare, and some others. This survey taken by the article is based on the criteria excluding the consumer products such as wearables and smartphones. Whereas in [7], the growth of productivity and interest towards wearables is explained and said that by 2022, the wearable technology market is expected to be USD 51.60 Billion.

Despite the various benefits provided by IoT devices, there are few challenges in common to all IoT sectors. One such disadvantage is issues in interoperability [9]. Since IoT devices have their own hardware and software architectures, there may be a few restrictions among the devices to communicate. This can be solved by selecting a common standard for all operating devices in that particular network. By selecting this standard, it may also lead to the limitations in the functions performed by the system.

The hardware challenges pertaining to IoT are processing power, battery life, and memory/storage. The network challenges include scalability and bandwidth issues. Software challenges faced are fault tolerance in operating systems and dynamic security updates [10]. Among all these challenges the most important threat for IoT is its security. [10] has provided a few security issues and solutions for the same. The security issues concerning IoT applications such as home automation devices, health care devices are software bugs, web services, data, and cloud security. The solutions may include an end to end encryption, user authentication, and authorization. The issues in protocols such as ZigBee, sensors, and actuators are data sniffing and terminal security. The solutions are data encryption and providing sensor data security.

The foremost goal of this paper is outlined below:

- To provide a clear view on the basic concepts of IoT and its evolution.
- To list out the applications and various divisions in IoT.
- To explain some of the devices associated with health care and industrial applications.
- To provide a tradeoff/comparison among various fields in IoT.

II. RELATED WORKS

This element in the paper provides a description of the works associated with the applications in IoT.

Li et al. [11] discussed the problems involved in constructing reliable network computing signatures with numerous sources in the network and also proposed a method called multisource homomorphic network coding signature which can be used in decentralized IoT systems. Furthermore, an analysis on network coding signature, its construction, architecture was presented to understand the concepts more clearly. The forte of this study is to provide authentication of network coding in the standard model with a high-security scheme and to guarantee the availability in the multisource IoT system. The main disadvantage of this paper is that they didn't provide any experimental results besides mathematical proof.

Talavera et al. [12] directed an evaluation on the application of IoT in the fields of industrial and environmental agriculture. This paper studies the four main technological domains like monitoring (62%), control (25%), prediction (7%), and logistics (6%). It deals with two important subjects; the one is technological solutions that are mentioned and the other is about infrastructures. Based on the second study infrastructure and technology in industrial and environmental agriculture are grouped into sensing variables, storage strategies, power sources, communication technologies, edge computing technologies, actuators, and visualization strategies. For the mass advocacy in IoT, stronger standardization, scalability, security, power management, and the cost stand as barriers. The authors put forward the architectural diagram of the IoT-based industrial and environmental approach in the field of agriculture. The proposed model includes four layers: application, physical, service, and communication. The backbone of this paper is the detailed explanation of the infrastructures, technologies, and architecture of the IoT context. The delicacy of the paper is that related works are not explained in detail. Khan et al. [13] presented an analysis on IoT security issues regarding architecture, protocols, communication, and networking in the field of blockchain and provided a solution for the challenges faced. The authors tabulate the issues from low level to high level with a solution. In addition to this, the background of blockchain, structural design of chained blocks, authentication, and privacy of the solution was explained. The implementation of the architecture is done with low power devices and cost Although they fail to establish redundancy, the trade-off between reliability and cost for the whole infrastructure.

Hassija et al. [14] focused on the security-related challenges and threats in the applications of IoT. The authors discussed the high trust in emerging and existing technologies that can be implemented to resolve security-related threats. Blockchain, fog computing, edge computing, and machine learning are the technologies that are discussed in this paper. The visualization of present and future architectural diagrams is a remarkable one. It mentioned the sources of threat that are involved in the security threats: sensing layer, application layer, network layer, and middleware layer. Security issues in all these four layers were explained in a detailed manner. The supremacy of the review is proposing four different types of solutions; however, the affinity of each approach was not considered.

Chettri and Bera [15] reviewed low-powered WANs (wide-area network), its application in the outline of 5G IoT and challenges faced. Elaborately pointed out the seven main challenges and vision on 5G technology besides providing statistical data regarding IoT and its users in recent years. The architectural layers involved in 5G were network, application, sensor, communication, and architecture which are involved in piling up data, analyzing, refining, and exchanging them between gadgets and communication networks. Each layer and its respective models were elucidated in a precise manner. The main advantage of the paper is it discusses the research gap and future conduct. The main downside of the paper is that the authors failed to discuss the numerous hurdles in well-organized controlling and management of versatility in IoT networks.

Asghari et al. [16] give a detailed overview of the application of IoT in the fields like industry, smart city, healthcare, and the environment. Besides, the author provided the taxonomy of the IoT applications. The primacy of the review is that the author tabulated the review in a brief manner that is easy to read. The weakness of the work is that it fails to concentrate more on related works. Fig.1 depicts the divergent application of IoT casting-off in our day-to-day life, especially in the field of healthcare, industries, smart cities and home automation.

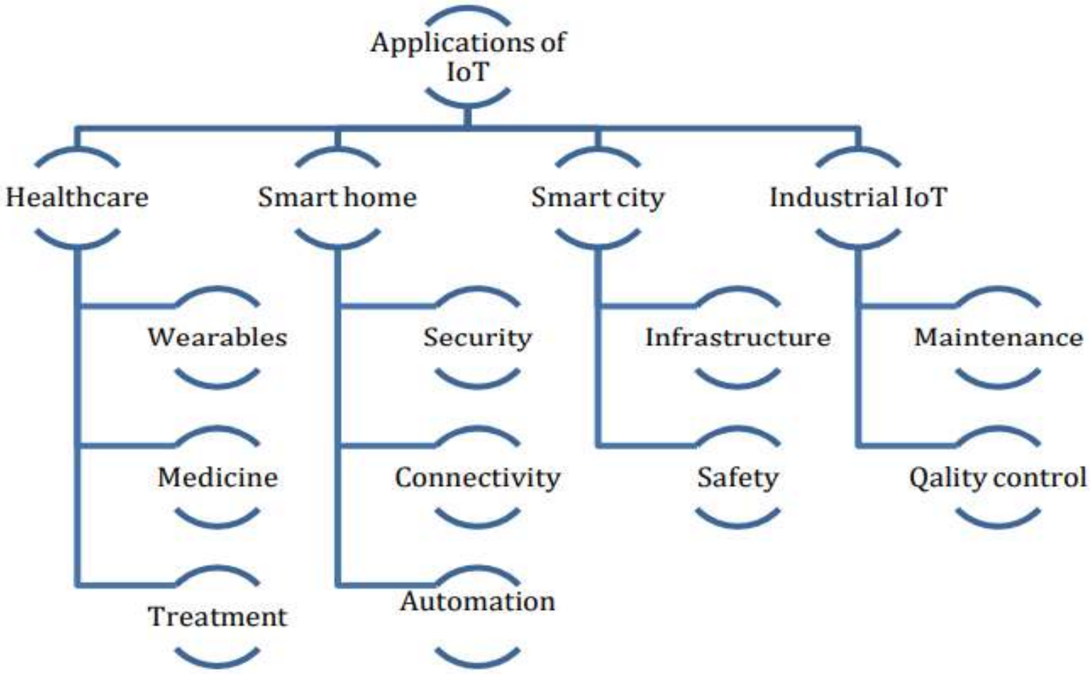

Fig. 1. Classification of applications of IoT

III. IoT Applications

A. Smart city applications

Zia et al. [17] developed a constructive digital forensic methodology which instead of strengthening the safety and security of IoT, finds the provenance of attack and brings the offender in the due process with a proper digital affirmation. It approached four phases in the digital forensics: collection phase in which material data is spotted out, examination phase to find any piece of details which is relevant to the occurrence, analyzing phase which the most important one that helps to explicate the findings, and the final phase reporting where results acquired from the third phase were presented. The model discussed can be helpful in any kind of forensic analysis to gather and investigate the evidence.

Lingling et al. [18] developed an intelligent vehicle monitoring system that works on IoT. The architectural schematic of the proposed system contains five layers: application, network, data, object, and sensing layer. The system was first installed in the city of China for testing purposes. The technologies used here are GPS, RFID, video recognition to provide the information of the vehicle to the user.

Akbar et al. [19] come about with hail for estimating and contrasting diverse data flows for a dependable, effectual and expandable solution in the applications of IoT. In this manuscript, an architecture with two layers was put forward which has a layer to provide a synapse for a look into data from heterogeneous IoT structures in an expandable scheme, and the other layer for giving a probabilistic solution based on Bayesian network and CEP to relate high-level events. In Naranjo et al. [20] a novel architecture entitled Fog Computing Architecture Network (FOCAN) was developed. This architectural schematic involves a multitier organization where the applications can be able to carry out on objects and communicate among them in the smart city conditions. The developed architecture decreases the delay and raises the productivity of services between objects with numerous provisions by refining energy provisioning. Alrashdi et al. [21] addressed the threats related to IoT cybersecurity in smart city applications and proposed solution anomaly detection which is based on machine learning algorithms. The smart city architecture proposed is based on fog computing to decrease latency between the cloud and the sensor. In [27] proposed an IoT testbed on all sides of the street lights using an architect. The advantage is that the model ensures end-to-end security.

B. Industrial applications

Abdullah et al. [22] developed an IoT code that schedules texts for appraising QoS recognition. In this work, texts are divided into two depending upon the urgency as high precedence and the best-effort messages. The main focus of this paper is to give a strengthened QoS-aware routing code in accordance to reduce power consumption. To decrease the delay of end-to-end broadcasting of information, the provided algorithm manages the fundamentals of IoT applications and initially, schedules abrupt demands with the highest supersede and then arranges the non-duty urgent messages concerning preventing famine in the dispersal of messages. MATLAB simulation was demonstrated to show the execution of the given retort.

Kiran and Rajalakshmi [23] proposed a novel Markov chain systematic model for unslotted CSMA/CA and PCA which can be used for industrial purposes. The above-mentioned model is additionally reached out to obtain the systematic model for slotted CSMA/CA and PCA. The advantage of the model is that it shows only 5% error during real-time testing. Huang et al. [24] provided a credit-based proof-of-work model used in IoT devices that ensure the security of the system and transaction regulation concurrently.Wang et al. [26] designed a method based on edge computing to choose truthful and dependable service providers which solve the security and privacy-related issues. The proposed architecture consists of three parts namely, trust evaluation, record criterion, and service selection. Lightweight, implementation, and better security are the limitations of the system in edge computing methods.

Zhou et al. [25] depicted a structured way to acquire threshold by estimating the performance divergent computing manners that can be useful in real-time IIoT applications. The model provided is an efficient way to acquire threshold in the stochastic fluid model which can be further implemented in practical IIoT. Although it can be applied to small-scale applications.

C. Healthcare applications

Y. Lin et al [28] proposed a digital stethoscope that can be used to measure the ECG of a person and can envision the signals of the heart sound. ECG measuring device and heart sound measuring device are used along with a microphone and a circuit to record the sound and filter the external noises. The heart sound signal and ECG are transmitted to a person's smart device via an app and Bluetooth module. Using the app, a person can view the ECG signals and heart sound signals. The advantage of the model is the consumption of power is low and can be used to identify cardiovascular diseases.

In [29] the authors have developed an IoT monitoring system for health care. This model checks the biological factors of the patients using suitable sensors and transmits the data through the existing IoT usually available in homes. The proposed model is of low cost and alerts the doctor and the patient's relatives in case of any emergency. They used a smart chest strap for measuring the heart rate of the person. The presented prototype in [30] is used to monitor the health of the person by considering the predominant factors such as heartbeat and temperature. If there are any abrupt changes in the above-mentioned two factors the patient is alerted via smartphone using IoT technology. LCD, Wi-Fi, and Arduino Uno microcontroller are used in this model.

In [31] presents a secure healthcare monitoring system. The model uses a WMSN system and RFID body sensor because of its ability to allow smart solutions for many problems and the medical data of the person is wirelessly sent to the local workstation and the doctors can access the information whenever needed and the abnormalities in patient's condition are alerted to the doctor via SMS. The advantages of the proposed system are its security, reliability, and the patient's real-time monitoring.Ding et al [32] proposed a system of smart monitoring of health based on IoT technology. The model is an alarm-based monitoring system that alerts the doctor about the state of the person in case of any emergency conditions. The information during the critical emergency is recorded in the hospital database. The advantage of the system is it is rapid and the power consumed by the devices in the system is low. The drawback of the system is the cost of the model is not taken into consideration.

S.M.R.Islam [33] described the broad overview of the contribution of IoT in the healthcare field. The authors have examined the recent development in IoT healthcare devices and have given a clear overview of their architecture, applications, and so on. And also, the paper evaluates the security threats in all those devices and the authors have come up with the model to reduce the risks related to privacy and security, etc. The author has proposed the algorithm to solve the security problems and also presented the challenges faced while implementing and developing the healthcare devices. The strength of this paper is the authors have depicted many images to make the readers understand the concept. The weakness of this work is that only an algorithm is given and the model is not implemented and verified.

D. Home automation

In [34] presented an IoT-based smart home system using two functionalities Philips's hue light bulb and Nest thermostat which can be used to do all the activities when we are away from home such as locking the door, switching on/off the light. This prevents home security-related issues. When the user gives the command to the JSON interface SHClient verifies the received information and executes the operation. There are many services such as alarm service, sensor service, lock service for changing the home smart. In [35] the author presented an organized methodology of smart homes based on IoT technology. Smart lighting, control of home appliances, home safety safeguard measures have been included in the design. The system functions have also been tested and with this system along with connectivity between several home appliances, the information between home and network can be shared by connecting the full system to the internet.

M.Al-Kuwari et al [36] presented a home automation design by sensing and monitoring some parameters like humidity, comfort lighting, temperature, etc based on IoT technology. For collecting the data and controlling the home appliances this design uses EmonCMS. A.Khan et al [37] proposed an IoT-based smart home design that uses a Wi-Fi-based microcontroller. Smartphones are used to control the smart home by turning on/off the AC depending on the temperature value. This design also gives remote control for those who can't use smartphones. The advantage of the design is it is very much useful for aged people and special persons. Table 1 gives a quick overview of the papers discussed. A brief description, advantages, and disadvantages of the systems reviewed have been listed below.

TABLE I. OVERVIEW OF THE STUDIES IN IOT APPLICATIONS

Reference no.	Brief description	Merits	Demerits
[17]	Digital forensic development	Helpful in investigations	IoT protocols
[18]	Intelligent vehicle monitoring system	Manage traffic	High cost
[19]	Bayesian network	Data management	High cost
[20]	FOCAN	Energy efficiency	Incompatible
[21]	Machine learning algorithm	Speed	Accuracy
[22]	Message sending algorithm	Performance	-
[23]	Markov chain	Less percentage of error	Low scalability
[24]	Blockchain transactions	Decreasing latency	Storage
[26]	Edge computing for security	Reduce workload	Implementation
[25]	Stochastic fluid model	Increasing service availability	High response time
[28]	Digital stethoscope	Low power consumption	Cost is not considered
[29]	Health monitoring system	Low cost	
[30]	Heart and temperature monitoring	Reduced time of sensing	Implementation
[31]	Secured health monitoring	Security, reliability	response time is not considered
[32]	Smart monitoring through smart devices	Rapid and low power consumption	Not considering cost
[33]	Overview of IoT healthcare devices	Simple and understandable	Only algorithm is mentioned
[34]	Smart Bulbs	Security	Cost is not considered
[35]	IoT based smart home	Storage	Implementation
[36]	Emon CMS based smart home	Simpler in design	Larger hardware
[37]	Home automation using Wi-Fi	Helpful for aged persons	-

IV. CONCLUSION

Since we are in the modern era there are an enormous number of applications/sectors in IoT. This paper tries to bring out the main sectors of IoT like smart city, health care, industrial, and home automation applications. In the course of this study, an extensive understanding of basic concepts of IoT is achieved, and also impact on the society by the major sectors in IoT is studied. By reviewing around 35 papers, this paper set forth 35% of smart city applications, 25% of healthcare devices, industrial applications, and 15% of home automation. Among the all reviewed, papers it is seen that huge importance is given to smart city applications, followed by equal share to healthcare and industrial IoT applications and some overview on home automation application. Form this study it is able to view the development of IoT in the past and future. Fig.2. displays pie chart of the content covered in this paper i.e., after analyzing the basic concepts of IoT and its applications. From the study it is clear that nearly 35% of paper deals with smart city applications followed by Health care and IIoT each 25% and Home automation constitutes the remaining 15%.

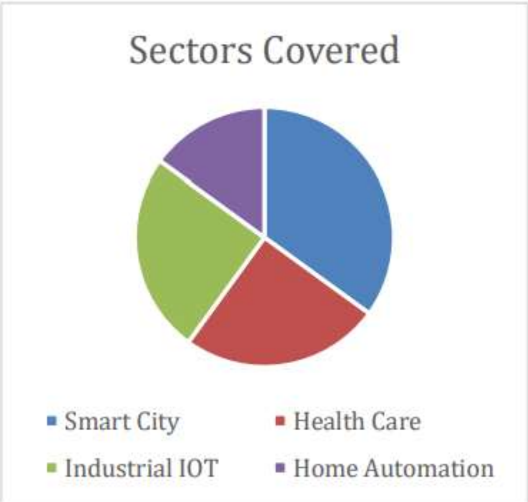

Fig.2. Sectors of IoT are covered in this paper.

REFERENCES

[1] Y. Meng, W. Zhang, H. Zhu and X. S. Shen, "Securing Consumer IoT in the Smart Home: Architecture, Challenges, and Countermeasures," in IEEE Wireless Communications, vol. 25, no. 6, pp. 53-59, December 2018, doi: 10.1109/MWC.2017.1800100.

[2] “Consumer Internet of Things (CIoT) - what is it and how does it evolve?” i-scoop / (accessed: Mar. 08, 2021).

[3] International Journal of Electronics and Communication Engineering and Technology (IJECET) Volume 8, Issue 2, March - April 2017, pp. 103–108, Article ID: IJECET_08_02_014

[4] “Number of connected devices worldwide 2018,2025 and 2030 | Statista.” statista./ (accessed: Mar. 08, 2021).

[5] “Internet of Things Statistics · Information Matters.” Jan. 01, 2021 (accessed: Mar. 08, 2021).

[6] “Top 10 IoT applications in 2020 - IoT Analytics.” IOT Analytics. Jul. 08, 2020 (accessed: Mar. 08, 2021)

[7] “IoT Wearables – Wearable Technology • The Internet of Things.” Infinite Information and Technology (accessed: Mar. 08, 2021)

[8] Sharma, Nikhil. (2020). “Evolution of IoT to IIoT: Applications & Challenges”, *SSRN Electronic Journal*.

[9] Ali Shah P.A., Habib M., Sajjad T., Umar M., Babar M., “Applications and Challenges Faced by Internet of Things - A Survey”, In: Ferreira J., Alam M. (eds) Future Intelligent Vehicular Technologies. Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering, Springer vol 185, 2018.

[10] Jain A., Singh T, “Security Challenges and Solutions of IoT Ecosystem”, In: Tuba M., Akashe S., Joshi A. (eds) Information and Communication Technology for Sustainable Development in Intelligent Systems and Computing, Springer, Singapore vol. 933, 2020.

[11] Tong Li, Wenbin Chen, Yi Tang, Hongyang Yan, “A Homomorphic Network Coding Signature Scheme for Multiple Sources and its Application in IoT, Security and Communication Networks,” vol. 2018 pp.1-6, 2018.

[12] J.M. Talavera, et al. “Review of IoT applications in agro-industrial and environmental fields”, Computer and Electronics in Agriculture,vol.142 (7) pp.283–297, 2017.

[13] Minhaj Ahmad Khan, Khaled Salah, “IoT security: Review, blockchain solutions, and open challenges”, Future Generation Computer Systems, vol. 82, pp.395-411, 2018.

[14] Hassija, V. Chamola, V. Saxena, D. Jain, P. Goyal and B. Sikdar, “A Survey on IoT Security: Application Areas, Security Threats, and Solution Architecture”, in *IEEE Access*, vol. 7, pp. 82721-82743, 2019.

[15] L. Chettri and R. Bera, “A Comprehensive Survey on Internet of Things (IoT) Toward 5G Wireless Systems,” in *IEEE Internet of Things Journal*, vol. 7, pp.16-32, 2020.

[16] Parvaneh Asghari, Amir Masoud Rahmani, Hamid Haj Seyyed Javadi, “Internet of Things applications: A systematic review”, Computer Networks, vol. 148, pp.241-261, 2019.

[17] T. Zia, P. Liu, W. Han, “Application-Specific Digital Forensics Investigative Model in Internet of Things (IoT),” in: Proceedings of the 12th International Conference on Availability, Reliability and Security p. 55, 2017.

[18] H. Lingling, L. Haifeng, X. Xu and L. Jian, “An Intelligent Vehicle Monitoring System Based on the Internet of Things,” *2011 Seventh International Conference on Computational Intelligence and Security*, pp. 231-233, 2011.

[19] A.Akbar et al., Real-time probabilistic data fusion for large scale IoT applications, IEEE Access 6, pp.10015-10027, 2018.

[20] P.G. Naranjo, Z. Pooranian, M. Shojafar, M. Conti, R. Buyya, “FOCAN: a fog supported smart city network architecture for management of applications in the internet of everything environments,” J. Parallel Distrib. Computer networks, pp.274-283, 2018.

[21] Alrashdi, A. Alqazzaz, E. Aloufi, R. Alharthi, M. Zohdy and H. Ming,"AD-IoT: Anomaly Detection of IoT Cyber Attacks in Smart City Using Machine Learning," 2019 IEEE 9th Annual Computing and Communication Workshop and Conference (CCWC), Las Vegas, NV, USA, pp. 0305-0310, 2019.

[22] S. Abdullah, K. Yang, “A QoS aware message scheduling algorithm in the internet of things environment,” in: Proceedings of the IEEE Online Conference on Green Communications (GreenCom), IEEE, 2013.

[23] M. P. R. S. Kiran and P. Rajalakshmi, "Performance Analysis of CSMA/CA and PCA for Time Critical Industrial IoT Applications", in IEEE Transactions on Industrial Informatics, vol. 14(5), pp. 2281- 2293, 2018.

[24] J. Huang, L. Kong, G. Chen, M. Wu, X. Liu and P. Zeng, "Towards Secure Industrial IoT: Blockchain System With Credit-Based Consensus Mechanism", in IEEE Transactions on Industrial Informatics, vol. 15(6), pp. 3680-3689, 2019.

[25] L. Zhou, D. Wu, J. Chen and Z. Dong, "When Computation Hugs Intelligence: Content-Aware Data Processing for Industrial IoT", in IEEE Internet of Things Journal, vol. 5(3), pp. 1657-1666, 2018.

[26] T. Wang, P. Wang, S. Cai, Y. Ma, A. Liu and M. Xie, "A Unified Trustworthy Environment Establishment Based on Edge Computing in Industrial IoT", in IEEE Transactions on Industrial Informatics, vol. 16(9), pp. 6083-6091, 2020.

[27] Amrutur et al., “An Open Smart City IoT Test Bed: Street Light Poles as Smart City Spines,” Second international conference on internet of things design and implementation, pp.323-324, 2017.

[28] Y. Lin et al., "An Intelligent Stethoscope with ECG and Heart Sound Synchronous Display," in 2019 IEEE International Symposium on Circuits and Systems (ISCAS), Sapporo, Japan, pp. 1-4, 2019.

[29] F. Jimenez and R. Torres, "Building an IoT-aware healthcare monitoring system," in 2015 34th International Conference of the Chilean Computer Science Society (SCCC), Santiago, Chile, 2015.

[30] S. R. Krishnan, S. C. Gupta and T. Choudhury, "An IoT based Patient Health Monitoring System," 2018 International Conference on Advances in Computing and Communication Engineering (ICACCE), Paris, France, 2018.

[31] Hesham A. El Zouka, Mustafa M. Hosni, “Secure IoT communications for smart healthcare monitoring system”, Internet of Things, Volume 13, 2021, 100036, ISSN 2542-6605.

[32] Y. Ding, S. Gang, J. Hong, “The design of home monitoring system by remote mobile medical”, in: Proceedings of the Seventh International Conference on Information Technology in Medicine and Education (ITME), IEEE, 2015.

[33] S. M. R. Islam, D. Kwak, M. H. Kabir, M. Hossain and K. Kwak, "The Internet of Things for Health Care: A Comprehensive Survey," in IEEE Access, vol. 3, pp. 678-708, 2015.

[34] Pătru, M. Carabaş, M. Bărbulescu and L. Gheorghe, "Smart home IoT system," 2016 15th RoEduNet Conference: Networking in Education and Research, Bucharest, Romania, pp. 1-6, 2016.

[35] L. Ma, Z. Li and M. Zheng, "A Research on IoT Based Smart Home," in 2019 11th International Conference on Measuring Technology and Mechatronics Automation (ICMTMA), Qiqihar, China, 2019, pp. 120-122.

[36] M. Al-Kuwari, A. Ramadan, Y. Ismael, L. Al-Sughair, A. Gastli and M. Benammar, "Smart-home automation using IoT-based sensing and monitoring platform," 2018 IEEE 12th International Conference on Compatibility, Power Electronics and Power Engineering (CPE-POWERENG 2018), Doha, Qatar, pp. 1-6, 2018.

[37] A.Khan, A. Al-Zahrani, S. Al-Harbi, S. Al-Nashri and I. A. Khan, "Design of an IoT smart home system," 2018 15th Learning and Technology Conference (L&T), Jeddah, Saudi Arabia, 2018, pp. 1-5.

Novel Applications of Neuralink in HealthCare - An Exploratory Study

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***Abstract*— Flexible electronics is most attractive in Internet-of-Things (IoT). Its footprint reaches various applications including healthcare application. Brain-Machine Interface (BMI) is a technology that offers unprecedented functionality for biomedical purpose in healthcare applications. Neuralink is recently popular that places more electrodes in our brain tissue. It is an implanted device on the brain to make the connection between human and computer. This paper focuses on the novel application of Neuralink to smart healthcare. These smart implantable devices send a prior notification to the doctors and guardian's smartphone regarding heart disease and paralysis.**

***Keywords* — Brain-Machine Interfaces, Neuralink, Healthcare, Internet of Things**

I. Introduction

Brain-Computer Interface (BCI) is a powerful technology that bridges the human brain and computer. It is otherwise called Neural Control Interface (NCI) or Direct Neural Interface (DNI), or Brain-Machine Interface (BMI). This domain is opted for researching, helping and repairing human cognitive functions [6]. It does not require any external devices to issue and complete the interaction. The research community first developed BCIs with bio-medical applications in mind, which led to the development of assistive devices. They facilitated the restoration of the mobility capacity of immobilized users and the replacement of the lossy motion feature.

The bright future of BCI has encouraged the research community to study the involvement of BCI in the lives of non-paralyzed humans. But the scope of the research has further expanded to include non-medical applications. More recent studies target individuals by exploring the use of BCIs as a novel input device and by investigating the generation of hands-free applications. The problem of BCI is poor information transfer rate (ITR). The BCI utilization for locked-in personas will not be able to manage ordinary communication. Even with the contribution of BCI in various domains such as advertising, industry, smart transportation, the BMI needs to defeat technical difficulties as well as challenges posed by user acceptance to deal with such newly discovered technology [2].

BMI is becoming increasingly popular as Big Name and successful Entrepreneurs like Elon Musk and a huge part of the scientific community is coming together to explore more about our Brain to advance current CPU technologies and open up the Pandora's Box i.e., our Brain. Throughout centuries Thinkers and Dreamers have always pondered over what our Brain is and its significance. Over the years, we have understood many mind-boggling facts about our CPU (the Brain) but as research progresses and BMI technologies become more channelized and transparent, we will understand the connection between our Brain and each part of our Body. This means we can solve the biggest of riddles in Healthcare and unlock our so-called Hidden potential in every human being.

II. Related Works

Innovations in the field of human brain research and its electrical activity by Han Berger are linked to the discovery of Brain-Machine Interfaces. He is also the reason for the development of EEG which leads to the breakthrough of recording human brain activity for the first time. This major discovery in Human Brain Mapping has made it possible to detect brain diseases. Berger's inspiration was Richard Canton who in 1875 discovered electrical signals in animal brains. EEG neuro-feedback has been in use ever since as one of the first common use of BCI technology.

When researcher Philip Kennedy implanted the first Brain-Machine Interface into a human being in 1998, it marked a significant development in Brain Mapping. But the BCI object was of very limited function and the only development technology-wise was the use of wireless di-electrode.

Cyberkinetics, a public traded company was formed by John Donoghue and his team, Brown University. The company aims to design a commercially viable BCI by the product name, BRAINGATE. Its first commercial product, NeuroPort was used by researchers from Columbia University Medical Center to monitor and record EEG with improved precision. The researchers noted that Neural Monitoring System (NeuroPort) has enabled them to identify micro-seizure activity before epileptic seizures among patients.

The number of developments that are taking place in the BCI domain is on course to make BCI a magic wand that can help us control objects with our mind by 2050. Maybe one day we can guide an outside object with our thoughts to consistently execute both our natural and our complex motions of daily life.

The concept of the Brain-Machine Interface is not new. There are already different forms of BMI that exist, like the ones that are implanted into your brain tissue and the ones that sit on top of your head. According to Zaza Zuilhof, nearly 220,000 hearing impaired has already been benefitted from Cochlear Implant (implants that translate audio signals into electrical pulses which are sent directly to our brain for sense) [5]. It is needless to say that most of the Brain-Machine Interfaces that were produced or developed first was for Medical Applications.In the article "The Brief History of Brain-Computer Interface", we can find the history of BCI and crucial information related to them. According to the article, BCIs research and development started after the Research on BCIs by the University of California in the 1970s. Neuroprosthetics applications continue to be the primary focus of BCI research and development as it promises the restoration of lost or damaged sight, hearing and movement. A Brain-Machine Interface doesn't measure the mind accurately; instead, it detects the change in energy radiation of Neuron's Activation Potential and uses them to recognize frequency patterns in the signals emitted by our brain. Matthew Nagle is the first human to ever receive a BCI implantation in June 2004; this marked a remarkable time in BCI development and increased hopes on BCI.BrainGate was implanted into him, a system composed of one hundred electrodes known as "invasive", that is to say, connected directly to the cerebral cortex, developed by Cyberkinetic the company in collaboration with Brown University's neuroscience department. This allowed Matthew Nagle to control a computer cursor and a robotic arm to control the TV and lighting, or to read his emails and play Pong. A research report on controlling a computer using BCI was demonstrated by Jonathan Wolpaw and his team of researchers at the New York State Department of Health's Wadsworth Center in December 2004. This study made participants hear a cap that contained electrodes that can capture EEG signals from our Motor Cortex (Movement). Wadsworth System monitors and detects EEG (ElectroEncephaloGraphic) activity from the scalp and records specific brain waves, from users wearing an electrode cap. An adaptive algorithm is made to analyze the output; it also focuses on signals that provide the greatest control as participants learn to use their thought to redirect a cursor on a monitor to a target screen. The algorithm adapts itself as the trainee improves in the task.

BCI has centred on control applications like cursors, paralyzed body parts, robotic arms, phone dialling, locking or unlocking etc., since the beginning of its development. In a recently published study by Dr Wolpaw's Lab real-time, two-dimensional cursor movement controls were achieved by a trained able-bodied and spinal cord-injured individual. This is comparable to studies that involved non-human primates with "implanted electrodes". It means a significant improvement in the performance of Non-invasive BCI which is because of improved changes in Signal Processing and the use of Adaptive algorithms. Studies also show that non-invasive BCI could one day support sophisticated tasks like controlling a neuroprosthetic arm or your phone. The four major components of BCI are signal acquisition, signal preprocessing, feature extraction, and classification. The architectures are shown in Fig. 1.

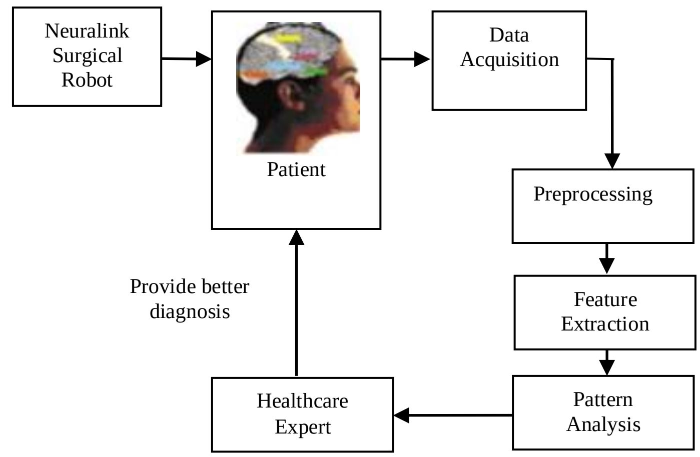

Fig. 1. Architecture of BCI

Diving deep into this, depression and similar disorders could be treated with deep electrical stimulation of the brain thus making the process of targeting specific parts of the brain viable to health professionals and diagnose which part of the brain is responsible. The stimulation of neural fibers carrying information from the primitive brain to the frontal lobe can be achieved by implanting an electrode into the brain while having a separate device incorporating a battery and a pulse generator implanted into the chest or abdomen with wires to the skull connecting the electrodes.

Thanks to the many advances made in recent years, a BMI not only restores lost faculties (movement, hearing and sight) but could also soon expand.

III. BRAIN-MACHINE INTERFACE

The brain-machine interface performs recording of brain signals and feeds to the machine to perform the intentional task. These signals are used for controlling an object or expressing an idea. The Brain-Machine Interface eliminates the need for typical information delivery methods by building a connection bridge between the human brain and the world. Employing this communication protocol, the Brain-Machine Interface manages the message transmission from the human brain and decodes their quiet thoughts. This is why the Brain-Machine Interface can help handicapped people in telling or writing their opinions via various methods such as in silent speech communication, or semantic categorization.

Earlier, BMI applications aimed at providing an alternative communication channel for persons with disabilities who have mobility or speech issue. But today, the Brain-Machine Interface has also entered the world of healthy people. It is now functioning as a physiological measurement instrument that uses a variety of information such as cognitive, emotional, or efficacy status [4]. Various research contributions to BCI are given in Table I.

TABLE I.
RESEARCH CONTRIBUTIONS TO BCI

Year	Contribution to BCI
1970	Implantation of BCI sensors in rats, mice, monkeys, and humans [13]
1990	The implantation of an electrode in the motor cortex of a paralyzed patient [13]
1999	Trained rats using their brain signals to move a robotic water-dispensing arm [15]
2009	Honda, ATR and Shimadzu Jointly Developed Brain-Machine Interface Technology Enabling Control of a Robot by Human Thought Alone [16]
2009	Built a wireless implantable microelectronic device for transcutaneous transmission of cortical signals [9]
2015	Functional Electrical Stimulation(FES) and BMI technologies provide solutions for paralyzed individuals [14]
2017	Implanting tiny brain electrodes that can upload and download thoughts one day [10]
2017	"Neural lace" improves people's cognitive abilities [12]
2021	Implants in the brain and spinal cord seek to correct paralysis and cure Alzheimer's disease [11]

The BCI is classified into three namely Invasive, Semi invasive and Non-invasive. The invasive type of BCI can be applied to people with paralysis. It is implanted directly in the brain. The quality of the signal produced was high. The signal is most accurate. But the risk is, it can cause damage to the brain, leaves the brain exposed. The semi-invasive type of BCI devices is implanted inside the skull. It produces better resolution signals. Here the risk is less. Because the brain is not exposed, there is less risk to overall health. The non-invasive type of BCI is wearable and produces the signal. It disperses the electromagnetic waves generated by the neurons [7][8].

IV. APPLICATIONS OF BMI

Brain-Machine Interfaces can work seamlessly with IoT system to create Smart Environments like Houses, Transportation etc., this has got the attention of Marketing Giants to invest in BMI technologies. Brain-Machine Interfaces can help to find what kind of advertisements do people watch and their watch time, age demography and even their attention spans.

To overcome misuse or exploits, Cognitive Biometrics can be set up to provide security and authentication, thus working as an expansion of existing BMI technologies. As previously mentioned, Brain-Machine Interface can monitor attention spans and measure the lack of attention thus it can be used in the Education field to provide better and fulfilling education to students and stop malpractices during a test.

Even at this stage, the applications of BMI are overwhelming, with more research and proper implementation, it can become increasingly versatile and with improvement in the equipment used within BMI sensors, we can read and write more signals emitted by neurons. Thus, it is clear that the scope of the Brain-Machine Interface is only limited to our imagination and the domain we will be deploying BMI.

Some of the applications of BMI as of now include Direct Communication between the Human Brain and Computer interfaces. Better living standards and ease of control over IoT devices.

Domains where BMI can be deployed [7][8].

a. Medical

b. Bioengineering

c. Brain operated wheelchair

d. Games

e. Military

f. Manufacturing

g. Multimedia and Virtual Reality

h. Remote control of devices through the brain

It is clear that each of the mentioned domain has many applications for BMI and yet to be discovered applications of BMI in that particular Domain. We are focusing on Medical Benefits to help people who are crippled with genetic disorders, Autoimmune and other neural degenerative diseases. To enable them to interact with the physical world through prosthetics which are controlled by the thought of motion which occurs in our brain (several neurons' fires to animate the thought of motion) rather than the motion created by our muscles.

V. NEURALINK

Musk and its company "Neuralink" have published a paper since the launch of Neuralink, last year. The paper was submitted to the Journal of Medical Internet Research, in October. Musk uses this paper to describe the development of a robotic arm to insert hundreds of thin threads (which are about a tenth of the width of a human hair) into the brain, without damaging nearby neurons or brain tissue nearby. It has since been dubbed as the "sewing machine", it can insert around six threads per minute. Each thread composed of flexible plastics with 192 electrodes.

The company targeted Rodent Brain for early research purposes, Musk and Neuralink has set up two systems, A and B and tested them on rats. A can insert 1,500 electrodes while B can insert 3,000 electrodes. After setup, the rat can move freely without restriction with a USB-C slot sticking out of its head. In the same paper, it is acknowledged that some significant technological hurdles still exist and must be addressed to have a high-bandwidth device that can be employed in clinical trials [1].

Neuralink is under development but it has been approved by FDA after the demonstration by Elon Musk et al., on the 28th of August 2020 [3].

Neuralink claims to be different from other BMI technologies by developing far advanced brain implants compared to the current generation. Those advancements are thinner and lighter electrode threads of 4 – 6 μm in width, even thinner than a normal thinner. Another innovative idea is the introduction of a Robot to insert threads along with wireless hardware that operates those threads. An array of small and flexible electrode threads (as many as 3072 per array distributed across 96 threads) is also created by Musk and Neuralink. These threads are individually inserted by the neurosurgical robot with micro precision to avoid vascular damage and to keep special brain regions safe.

Six threads with a total of 192 electrodes can be inserted using the robot per minute. A small implantable device that contains custom chips that provide low power onboard amplification and digitization is where the electrode array is packaged. Along with a USB-C cable allowing data streaming of bandwidth from the device and recording of all channels simultaneously.

A device called "The Link", Bluetooth radio and a battery is connected to the implant through the skull. Software and system updates can be easily made with this configuration. Elon claims that compared to the other FDA approved Brain-Machine Interface, Neuralink is by far the most advanced and can be used to treat Parkinson's disease through Deep Brain Stimulation. Reading and Writing of thousands of more electrodes is possible if publicly approved [2].

VI. NEURALINK IN SMART HEALTHCARE

The patient's life is rescued when the Neuralink integrated into IoT. Over many types of research, Machine Learning and Deep Learning algorithms play a vital role in assisting the physician regarding disease forecasting from the patient's symptoms. But when Neuralink becomes Smart Neuralink in healthcare IoT application, the computer may receive huge data captured at every second. But it is a great challenge to analyze this stream of data. These data must be processed on the fly in IoT. Either online or incremental learning algorithm can be used to process this data [17]. Even though the smart Neuralink gives neuron's spike signals to the doctor's machine; the human's emotions also are recorded. There are much research work is going on in emotion recognition from speech signals [18]. To interpret or recognize the emotions from the recorded signals, good algorithms could be developed in future. Hence smart Neuralink integration will advance the concept of recognizing speech emotion from a human voice. The wearable clothes and wearable watches send signals about the wearer's health to their physician. Few wearables can be implanted into the body with the help of Neuralink. The wearable Link from Neuralink improves the cognitive function of disabled people. For non-disabled people, it connects the surrounding devices such as smart home, car, and other electronics devices [19].

CONCLUSION

In the future, Neuralink can help us understand our brain better by actually interacting with our neurons near larger bandwidth and data collection. We can use this data to discover new leads on various diseases like Parkinson's, Alzheimer's and dementia even have the potential to cure them or decrease their potential. By learning more about our brain, we can focus on expanding our memory or making our precious memories permanent. By doing extensive research and closely observing our brain and how it functions, we can create better AI systems and make them more creative instead of repetitive. Using AI-based algorithms we can predict what a person is thinking and use the data to allow people with disability to have prosthetic arms which feel and responses like a real arm. Potentially there might come a day whereof fusing soft prosthetics and bio-organics, we will be able to replace limbs easily and with great flexibility. Neuralink enabled smart devices also can predict stroke, heart attack and other ailments.

REFERENCES

[1] Shankland..S,"Elon Musk shows Neuralink brain implant working in a pig", CNET, 2020. www.cnet.com/news/elon-musk-shows-neuralink-brain-implant-working-in-a-pig/

[2] Sarah N. Abdulkader, Ayman Atia, Mostafa-Sami M. Mostafa, "Brain-computer interfacing: Applications and challenges", Egyptian Informatics Journal, Volume 16, Issue 2, Pages 213-230, 2015.

[3] Cate Lawrence, "Neuralink Reveals Their Brain-Machine Interface",IoTZone,Analysis,July22,2019.www.dzone.com/articles/neuralink-reveals-their-brain-machine-interface

[4] Musk E; Neuralink, "An Integrated Brain-Machine Interface Platform With Thousands of Channels", Journal of Medical Internet Research. 2019 Oct 31;21(10):e16194. doi: 10.2196/16194

[5] Alexandre Gonfalonieri, "A Beginner's Guide to Brain-computer Interface and Convolutional Neural Networks", Towards Data Science, November 25,2018. https://towardsdatascience.com/a-beginners-guide-to-brain-computer-interface-and-convolutional-neural-networks-9f35bd4af948

[6] Krucoff, Max O., Rahimpour, Shervin, Slutzky, Marc W. et al., "Enhancing Nervous System Recovery through Neurobiologics, Neural Interface Training, and Neurorehabilitation", Frontiers in Neuroscience, 10:584,2016. doi:10.3389/fnins.2016.00584

[7] H. S. AlZu'bi, N. S. Al-Zubi and W. Al-Nuaimy, "Toward Inexpensive and Practical Brain-Computer Interface," Developments in E-systems Engineering, Dubai, United Arab Emirates, pp. 98-101, 2011. doi: 10.1109/DeSE.2011.116.

[8] A. Vourvopoulos and F. Liarokapis, "Robot Navigation Using Brain-Computer Interfaces," IEEE 11th International Conference on Trust, Security and Privacy in Computing and Communications, Liverpool, UK, pp. 1785-1792, 2012. doi: 10.1109/TrustCom.2012.247

[9] Song YK, Borton DA, Park S, Patterson WR, Bull CW, Laiwalla F, Maslow J, Simeral JD, Donoghue JP, Nurmikko AV. "Active microelectronic neurosensory arrays for implantable brain communication interfaces", IEEE Trans Neural Syst Rehabil Eng., Aug;17(4):339-45, 2009. doi: 10.1109/TNSRE.2009.2024310.

[10] Rolfe Winkler, "Elon Musk Launches Neuralink to Connect Brains With Computers". Wall Street Journal. Archived from the original on May 5, 2017.

[11] Español, Entrepreneur en, "Neuralink Could Begin Testing Human Brain Implants This Year, Says Elon Musk", Entrepreneur. Retrieved February 6, 2021.

[12] Newitz, Annalee, "Elon Musk is setting up a company that will link brains and computers", Ars Technica, May 19, 2017. https://arstechnica.com/information-technology/2017/03/elonmusk-is-setting-up-a-company-that-will-link-brains-and-computers/

[13] Vidal, JJ, "Toward direct brain-computer communication", Annual Review of Biophysics and Bioengineering. 2:157–80, 1973. doi:10.1146/annurev.bb.02.060173.001105

[14] Ethier, C. & Miller, L. E, "Brain-controlled muscle stimulation for the restoration of motor function", Neurobiology of Disease, 83, 180–190, 2015. doi:10.1016/j.nbd.2014.10.014

[15] S. Ortiz, "Brain-computer interfaces: where human and machine meet" in Computer, vol. 40, no. 01, pp. 17-21, 2007. doi: 10.1109/MC.2007.11

[16] Honda, ATR and Shimadzu Jointly Develop Brain-Machine Interface Technology Enabling Control of a Robot by Human Thought Alone, March 31, 2009. https://hondanews.com/en-US/releases/honda-atr-and-shimadzu-jointly-develop-brain-machine-interface-technology-enabling-control-of-a-robot-by-human-thought-alone#:~:text=In%20May%202006%2C%20Honda%20and,special%20training%20of%20the%20user.

[17] Alex S.A. and Nayahi J.J.V, " Deep Incremental Learning for Big Data Stream Analytics", In: Pandian A., Senjyu T., Islam S., Wang H. (eds) Proceeding of the International Conference on Computer Networks, Big Data and IoT (ICCBI - 2018). ICCBI 2018. Lecture Notes on Data Engineering and Communications Technologies, Springer Cham, vol 31, 2020. https://doi.org/10.1007/978-3-030-24643-3_72

[18] Kumaran, U., Radha Rammohan, S., Nagarajan, S.M, and A.Prathik, "Fusion of mel and gammatone frequency cepstral coefficients for speech

emotion recognition using deep C-RNN", International Journal of Speech Technology, 2021. https://doi.org/10.1007/s10772-020-09792-x

[19] Kaygusuz, Pelçim. "Smart Wearables: About the Liability Question for Smart Wearables for Health Purposes." Available at SSRN 3701262, 2020.

3DP-FAS: An Intelligent Quality Assurance System for 3D Printer

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***Abstract*—3D printing or Additive Manufacturing is one among the key technologies of the decade, mainly used for rapid prototyping and experimental learning. Apart from its traditional usage, now 3D printing has be adapted by the Industry 4.0 for real time production. Hence, the future scope of 3D printing lies in industrial environments, where industrial manufacturing tools are replaced by 3D printers. Identifying the quality of the printed object and detecting the failures during printing are essential needs in industrial environments as well as in rapid prototyping. This paper proposes an architecture named 3D Printer Failure Analysis System(3DP-FAS) for remotely control, monitor and analyze 3D printing process. 3DP-FAS monitor the printing process with the help of a camera module and analyze the the 3D printing process with the fine-tuned models available in the model library. 3DP-FAS is also capable of controlling the 3D printer as well as making intelligent decisions based on the analysis. It also provides a web-based monitoring interface for a remote user to monitor the printing process. The system and experiments are implemented in IoT Cloud Research Laboratory of IIIT Kottayam.**

***Index Terms*—Industry 4.0, IoT, 3D Printing, IoT 3DP Ecology**

I. Introduction

3D printing or Additive Manufacturing creates 3D shapes from a 3D model with the help of 3D printers. 3D printers turned out to be extremely well known in the most recent years, in light of a few reasons like lapse of key licenses, simplicity of production, and the availability of moderate machines and materials. The 3D object is printed by additive procedures in which objects are fabricated layer by layer. Every one of these layers can be expected as a thinly cut flat cross-segment of the inevitable object. 3D slicing software is used to produce thin layers from a 3D model and the number of layers for each model differs based on the quality of the print.

One of the main advantages of 3D printing is that it uses less material consumption as compared to traditional material fabrication techniques. Everything begins with a 3D model, which can be made by ourselves or download it from a 3D store. 3D printing utilizes numerous types of advances and materials as 3D printing is being utilized in practically all businesses. The application area and research space of 3D printing includes, but not limited to: 3D Drug Delivery Systems [1]–[4], 3D Food manufacturing [5]–[7], 3D Concrete Structure Manufacturing [8], [9], Electrochemical Energy Device(EES) Manufacturing [10], [11], Bioink Development [12]–[15], Power Consumption Analysis [16]–[18] and so on. 3D printing is well known for its traditional usage:rapid prototyping, but it is now used in industrial sectors for rapid manufacturing. In rapid manufacturing, a large number 3D printers are used to run the production in an industry. 3D printers also eliminate the cost of industry-related specific tools since any complex designs can be printed with 3D printers. The new IOT 3DP Ecology, in which 3D printers are available remotely through a web interface, is helping 3D printing technologies to be popular with normal users who do not own a 3D printer.

In this emerging 3D printing era, assuring the quality of the printed 3D model and predicting the possible failures during printing are key factors to be monitored closely. In an industrial environment, where mass production is done using 3D printers, automatic quality assurance systems are vital. When users are remotely printing the 3D models through a web interface, an assurance should be given about their final printed model to get customer satisfaction. In both industrial and remote 3D printing scenarios, manual by-hand quality checking is a hectic task. A recent open source ecology, named IoT 3DP proposes Internet of Things enabled remote 3D printing using web bases tools. In this ecology, a remote user can execute printing jobs as well as monitor its status with the help of a web cam.

Extending the IoT 3DP open source ecology, this paper proposes a new architecture named 3D Printer Failure Analysis System(3DP-FAS) to monitor, control, and analyze the 3D printing process through the internet with help of IoT devices, camera modules and Web APIs. 3DP-FAS is also capable of making intelligent decisions upon different scenarios like filament damage, out-of filament, power failure, improper printer configurations etc. The rest of the paper is organized as follows: Section II presents a wide survey on the topic of 3D printer-related quality assurance systems. Section III explains the proposed 3DP-FAS architecture: its components, functionalities and working. And, finally, Section IV presents a few conclusions.

II. Related Work

Assuring the quality of the 3D printed object is one of the challenging areas in 3D printer-related research. Most of the existing research in this area uses Image Analysis and Deep Learning. [19] proposed Automated Testing and Quality Assurance of 3D Printing using a hardware setup. They compare the projected(CAD object in printing software) and sensored(using camera) objects for identifying defects in the 3d printed objects. Both internal and external defects are identified and they have developed an expert system taking decisions based on the the result of comparison during the print process. [20] suggested the requirement of video feedback with texture based image analysis to monitor the quality of 3D printing process to stop the printing upon decreased quality to save the filament and time. The proposed method uses the Gray-Level Co-occurrence Matrix (GLCM) and chosen Haralick features to determine the defects. One drawback of this method is that it depends on the availability of light. [21] developed a Convolutional and Artificial Neural Network for Additive Manufacturing Prediction using Big Data (CAMP-BD) for the analysis of thermal images captured during 3D printing. The model is well suited for the newly emerged Industry 4.0 focused additive manufacturing. Model contains a Convolutional Neural Network (CNN) for analyzing the thermal images with a concatenated Artificial Neural Network (ANN) at the end for including relevant process/design parameters as well as the final point wise distortion prediction. [22] introduces a deep learning framework for real time stress prediction for bottom-up SLA printing using labelled CAD 3D model database. Their framework consist of 3 convolutional layers and 2 fully connected layers which forms a 2-stream CNN.

[23] proposed a monitoring system for the detection of interlayer imperfections which causes delamination and warping in FDM printing process. The extent of delamination of printed parts is classified using real-time camera images and Convolutional Neural Network Model. The proposed system also does strain gauge measurements which determines the extent and tendency of warping before it actually occurs in the printing process. In the case of delamination, the focus is on the calibration of the nozzle height and the model achieves an accuracy of 91.0% testing accuracy. [24] presents a user-friendly and cost-effective maintenance framework for partially damaged parts using 3D printing, without having complex manufacturing processes and expert technical support. The proposed framework has three systems which consists of 3D scanning, maintenance support system, and 3D printing. A system for automatic error compensation in 3D printing based on Deep Neural Network is proposed in [25]. One of the methods for error compensation proposed here trains a prediction network with nominal models as input and deformed models as output. The model approximates the deformation function and gives error prediction results. In this system the deformation is approximated by the combination of translation, rotation and scaling operations.

A system for the prediction and compensation of errors in 3D printed objects using Convolutional-Auto Encoder architecture is proposed in [26]. There are two ways for error compensation. In the first method, a prediction network is trained by taking nominal models as input and printed models are taken as output. The second way is to train the compensation network by giving the printed models as input and nominal models are taken as output. The proposed system tests for four linear deformations and two nonlinear deformations using the CAE architecture which consists of an encoder and decoder part. [27] proposed a lightweight 3D Convolutional Neural Network which is proposed for real-time 3D object recognition by multitask learning. LightNet has less training parameters compared to various existing models like FusionNet, VoxNet etc. Different types of auxiliary learning tasks are combined into a network to handle large and small data sets without over fitting. [28] a colour independent visual quality assessment method based on the assumption of increase in image entropy for irregular surfaces. The method is useful in detecting and identifying quality problems visible on the surfaces of objects manufactured by additive manufacturing. Instead of direct usage of entropy, a combination of local image entropy and its variance is used in the proposed system.

A Decision support system for identifying parts or assemblies in a repository which are eligible for AM, based on Machine Learning and suitable candidacy criteria is proposed in [29]. The system consists of three main sections which are candidacy criteria, data acquisition, and decision model. The candidacy criteria on which the system focused are geometric analysis, model analysis, economic analysis, and design potential analysis. Decision model which aims at predicting AM models are created using various ML models and analysed, of which Boosted Decision Tree Regression gave the best result. [30] presents a method for analysis of layer-wise 3D printing process to monitor manufacturing errors, and it also generates suitable printer actions to repair and improve the process. The Process is based on multiple stage monocular image examination which checks both global and local deviations in the printed models. The proposed method utilizes side-view height validation, an iterative closest point algorithm for analysing the virtual top view of outer layer, Gaussian Mixture Model for inner layer texture analysis and agglomerative hierarchical clustering algorithm for identifying structural anomalies. The proposed technique can be considered as a good printing suspension tool which saves time and material rather than a complete failure correction system. All the above mentioned works lack a well-defined working environment which is proposed in this paper. Suitable related works mentioned can be added to the Model Library of the proposed architecture and can be used upon needs.

III. 3DP-FAS Architecture

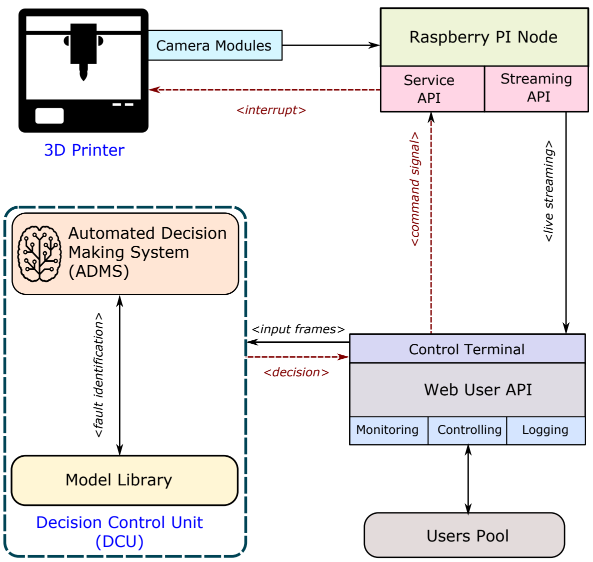

Fig. 1. 3DP-FAS Architecture

3DP-FAS in an automated decision control system to monitor and analyse 3D printers with the help of Machine Learning based tools. Figure 1 shows the architecture of 3D Printer Failure Analysis System(3DP-FAS) which can be attached to any 3D printer. The main components, functionality, and working of the 3DP-FAS is described below:

A. Components

Main components of 3DP-FAS architecture are the 3D Printer with an attached camera module(s), Raspberry Pi Node, Web User API, Decision Control Unit(DCU) and a User Pool. The camera modules are attached to 3D printer and are capable to monitor the printing process. Both the 3D printer and camera modules are connected to a Raspberry Pi Node which contains two Application Programming Interfaces(API) named Service API and Streaming API. Service API is used to control the 3D printer and Streaming API is used to monitor the 3D printer with the camera modules attached. Web User API is a programmable interface which is used to control the 3D Printer by a remote user as well as the Decision Control Unit(DCU). Decision Control Unit(DCU) receives inputs in the form of images and videos, processes it using the fine tuned machine learning models from the Model Library and based on the inputs, automated decisions are made. User Pool contains N number of online users who submits and monitors the printing jobs on 3D printer.

B. Functionalities

Functional usage of each components in the architecture is described below.

1) Camera Modules: Camera modules are attached to the 3D printer, captures images/videos and send it to Raspberry Pi. There can be N number of cameras depending up on the use cases. For example, there can be four primary cameras from all four directions of the bed as well as a fifth camera on the top.

2) Raspberry PI Node: Raspberry Pi node mainly provides two functionalities: through its service API, it controls the 3D printer and through its Streaming API, it provides a live image/video stream of all attached cameras. Stream API streams live recording of printing from Raspberry Pi with a unique URL and authentication token. Raspberry Pi node runs a media server like Plex to stream camera output to external worlds. The service API is built on OctoPrint to control the 3D printer from a remote interface. It allows the remote users to submit their 3D printing jobs as well as to monitor the status of currently printing jobs. Service API send and receive control commands like stop printing, start printing, preheat PLA and Bed, Move Nozzle, Printer information etc. with the help of Web User API.

3) Web User API: Web User API is used to manage user interactions, monitoring of jobs in the remote 3D printer, assigning and controlling jobs, logging, printing related incidents(faulty printing, low bed temperature, out of PLA, power failure, energy consumption etc.) in communication with Decision Control Unit(DCU). A Control Terminal in the Web User API is responsible for sending and receiving control signals from the service and streaming API as well as handling live streaming data.

4) Decision Control Unit: The main functionality of Decision Control Unit is to make automated decisions with the help of the machine learning models available in the Model Library. Automated Decision Making System(ADMS) in DCU makes automated decisions based on the output of machine learning model using streaming data as input and sends the necessary control signals to implement the decisions to the control terminal. Decision Control Unit contains a Model Library which contains fine tuned machine learning models to detect various quality related parameters. Different models are available in the Model Library for different use cases like detecting faulty prints, detecting filament shortage, identifying damaged filaments, estimating energy consumption, etc.

C. Working:

During 3D Printing, the camera module(s) records the printing process and passed to Raspberry Pi Node. Raspberry Pi node streams this live recordings through it Streaming API to the outside world. A Web User API reads this streaming through a unique URL and application key provided by the Streaming Server. Web User API pass each frames obtained from the live streaming to the Decision Control Unit which uses the Model Library to detect various events like faulty print, filament shortage, damaged filaments, improper layer height, energy consumption etc. Based on the machine learning model output, Automated Decision Making System generates decision commands like stop printing in case fault print and send to Web User API. Control terminal in the web user API send this command signal to the Raspberry Pi Node which has a dedicated Service API to handle such commands. Finally, Service API sends the interrupt signal to the 3D printer to stop the printing and sends the status back to the Web User API which indicates this action through notifications to the users whoever authorized to control the current printing job.

IV. Conclusion

Industry 4.0 has been adapted 3D printing as a key technology for modern manufacturing process. The new IoT-3DP ecology mixes the IoT with 3D printing through the internet which makes 3D printers more suitable for industrial sector. Assuring the quality of a 3D printed object and detecting the failures during the printing process without any human intervention is a challenging research topic, especially for industrial sector. This paper proposes a new architecture named 3DP-FAS, for detecting failures as well as assuring the quality of 3D printing. This architecture is built upon the IoT-3DP ecology of remote 3D printers connected through the internet, camera modules and Web APIs. Machine learning models and decision control system are integrated on the back end of this architecture to detect failures and to assure the quality. This architecture can be considered as a base for researchers and industrialists to build more complex systems. Numerous fine-tuned models can be added to the Model Library of the proposed architecture to extend the analysis capabilities.

References

[1] W. Zhu, X. Ma, M. Gou, D. Mei, K. Zhang, and S. Chen, "3d printing of functional biomaterials for tissue engineering," *Current opinion in biotechnology*, vol. 40, pp. 103–112, 2016.

[2] A. Goyanes, A. B. Buanz, G. B. Hatton, S. Gaisford, and A. W. Basit, "3d printing of modified-release aminosalicylate (4-asa and 5-asa) tablets," *European Journal of Pharmaceutics and Biopharmaceutics*, vol. 89, pp. 157–162, 2015.

[3] J. Goole and K. Amighi, "3d printing in pharmaceutics: A new tool for designing customized drug delivery systems," *International journal of pharmaceutics*, vol. 499, no. 1-2, pp. 376–394, 2016.

[4] J. Wang, A. Goyanes, S. Gaisford, and A. W. Basit, "Stereolithographic (sla) 3d printing of oral modified-release dosage forms," *International journal of pharmaceutics*, vol. 503, no. 1-2, pp. 207–212, 2016.

[5] F. C. Godoi, S. Prakash, and B. R. Bhandari, "3d printing technologies applied for food design: Status and prospects," *Journal of Food Engineering*, vol. 179, pp. 44–54, 2016.

[6] M. Lanaro, D. P. Forrestal, S. Scheurer, D. J. Slinger, S. Liao, S. K. Powell, and M. A. Woodruff, "3d printing complex chocolate objects: Platform design, optimization and evaluation," *Journal of Food Engineering*, vol. 215, pp. 13–22, 2017.

[7] F. Yang, M. Zhang, B. Bhandari, and Y. Liu, "Investigation on lemon juice gel as food material for 3d printing and optimization of printing parameters," *LWT*, vol. 87, pp. 67–76, 2018.

[8] C. Gosselin, R. Duballet, P. Roux, N. Gaudillière, J. Dirrenberger, and P. Morel, "Large-scale 3d printing of ultra-high performance concrete–a new processing route for architects and builders," *Materials & Design*, vol. 100, pp. 102–109, 2016.

[9] J.-Y. Lee, W. S. Tan, J. An, C. K. Chua, C. Y. Tang, A. G. Fane, and T. H. Chong, "The potential to enhance membrane module design with 3d printing technology," *Journal of Membrane Science*, vol. 499, pp. 480–490, 2016.

[10] F. Zhang, M. Wei, V. V. Viswanathan, B. Swart, Y. Shao, G. Wu, and C. Zhou, "3d printing technologies for electrochemical energy storage," *Nano Energy*, vol. 40, pp. 418–431, 2017.

[11] C. Zhu, T. Liu, F. Qian, W. Chen, S. Chandrasekaran, B. Yao, Y. Song, E. B. Duoss, J. D. Kuntz, C. M. Spadaccini, M. A. Worsley, and Y. Li, "3d printed functional nanomaterials for electrochemical energy storage," *Nano Today*, vol. 15, pp. 107 – 120, 2017. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S1748013217302426

[12] D. Chimene, K. K. Lennox, R. R. Kaunas, and A. K. Gaharwar, "Advanced bioinks for 3d printing: a materials science perspective," *Annals of biomedical engineering*, vol. 44, no. 6, pp. 2090–2102, 2016.

[13] S. Christ, M. Schnabel, E. Vorndran, J. Groll, and U. Gbureck, "Fiber reinforcement during 3d printing," *Materials Letters*, vol. 139, pp. 165–168, 2015.

[14] Y. Deng, S.-J. Cao, A. Chen, and Y. Guo, "The impact of manufacturing parameters on submicron particle emissions from a desktop 3d printer in the perspective of emission reduction," *Building and Environment*, vol. 104, pp. 311–319, 2016.

[15] Z. Weng, J. Wang, T. Senthil, and L. Wu, "Mechanical and thermal properties of abs/montmorillonite nanocomposites for fused deposition modeling 3d printing," *Materials & Design*, vol. 102, pp. 276–283, 2016.

[16] T. Peng, "Analysis of energy utilization in 3d printing processes," *Procedia CIRP*, vol. 40, pp. 62 – 67, 2016, 13th Global Conference on Sustainable Manufacturing Decoupling Growth from Resource Use. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S2212827116000706

[17] C. Griffiths, J. Howarth, G. D. Almeida-Rowbotham, A. Rees, and R. Kerton, "A design of experiments approach for the optimisation of energy and waste during the production of parts manufactured by 3d printing," *Journal of Cleaner Production*, vol. 139, pp. 74 – 85, 2016. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S0959652616310873

[18] J. Ajay, C. Song, A. S. Rathore, C. Zhou, and W. Xu, "3dgates: An instruction-level energy analysis and optimization of 3d printers," *SIGOPS Oper. Syst. Rev.*, vol. 51, no. 2, pp. 419–433, Apr. 2017. [Online]. Available: http://doi.acm.org/10.1145/3093315.3037752

[19] J. Straub, "Automated testing and quality assurance of 3d printing/3d printed hardware: Assessment for quality assurance and cybersecurity purposes," in *2016 IEEE AUTOTESTCON*. IEEE, 2016, pp. 1–5.

[20] K. Okarma and J. Fastowicz, "No-reference quality assessment of 3d prints based on the glcm analysis," in *2016 21st International Conference on Methods and Models in Automation and Robotics (MMAR)*, Aug 2016, pp. 788–793.

[21] J. Francis and L. Bian, "Deep learning for distortion prediction in laser-based additive manufacturing using big data," *Manufacturing Letters*, vol. 20, pp. 10 – 14, 2019. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S221384631830172X

[22] A. Khadilkar, J. Wang, and R. Rai, "Deep learning–based stress prediction for bottom-up sla 3d printing process," *The International Journal of Advanced Manufacturing Technology*, vol. 102, no. 5, pp. 2555–2569, Jun 2019. [Online]. Available: https://doi.org/10.1007/s00170-019-03363-4

[23] Z. Jin, Z. Zhang, and G. X. Gu, "Automated real-time detection and prediction of interlayer imperfections in additive manufacturing processes using artificial intelligence," *Advanced Intelligent Systems*, p. 1900130, 2019.

[24] H. Kim, M. Cha, B. C. Kim, I. Lee, and D. Mun, "Maintenance framework for repairing partially damaged parts using 3d printing," *International Journal of Precision Engineering and Manufacturing*, vol. 20, no. 8, pp. 1451–1464, 2019.

[25] Z. Shen, X. Shang, M. Zhao, X. Dong, G. Xiong, and F.-Y. Wang, "A learning-based framework for error compensation in 3d printing," *IEEE transactions on cybernetics*, vol. 49, no. 11, pp. 4042–4050, 2019.

[26] M. Zhao, G. Xiong, X. Shang, C. Liu, Z. Shen, and H. Wu, "Nonlinear deformation prediction and compensation for 3d printing based on cae neural networks," in *2019 IEEE 15th International Conference on Automation Science and Engineering (CASE)*. IEEE, 2019, pp. 667–672.

[27] S. Zhi, Y. Liu, X. Li, and Y. Guo, "Lightnet: A lightweight 3d convolutional neural network for real-time 3d object recognition." in *3DOR*, 2017.

[28] K. Okarma and J. Fastowicz, "Improved quality assessment of colour surfaces for additive manufacturing based on image entropy," *Pattern Analysis and Applications*, pp. 1–13, 2020.

[29] S. Yang, T. Page, Y. Zhang, and Y. F. Zhao, "Towards an automated decision support system for the identification of additive manufacturing part candidates," *Journal of Intelligent Manufacturing*, pp. 1–17, 2020.

[30] A. L. Petsiuk and J. M. Pearce, "Open source computer vision-based layer-wise 3d printing analysis," *arXiv preprint arXiv:2003.05660*, 2020.

Serverless Functions for IoT Applications – An Analysis

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***Abstract*—Internet of Things (IoT) refers to an ever-expanding network that characterizes an IP address for internet connectivity and inter-communication. It extends network connectivity and computing abilities to sensors and objects which can be used in day to day life. With the increasing growth of IoT, a promising approach to address these IoT devices is serverless computing. Serverless is a cloud-based infrastructure that cherishes upon pay as you use rather than pay as you go. It allows the user to have minimal visibility and control over the server aspects in turn establishing a platform to optimize the infrastructure utilization. This paper analyzes some of the applications and challenges of serverless function for IoT.**

Keywords—Serverless, IoT

I. Introduction

A report says that by 2020, there will be 30 billion IoT devices worldwide in 2025, the number will exceed 75 billion connected things. This surge has resulted in the production of huge amounts of data with the promise of making the user's life smarter and easier. Cloud computing has seamlessly integrated with IoT for good. It provides a robust way to connect all the devices, process all the data generated by those devices and make available the processed data anywhere in the world at any point in time. Serverless is a type of deployment model of cloud services where the service provider dynamically allocates and manages the servers and are stateless. It allows the user to build and deploy the core logic of the application instead of worrying about all the hardware and software required. Serverless cloud model bills you based on the number of times that particular function is executed instead of billing you for the hardware you hire for a certain amount of time like in Infrastructure as a service or Platform as a service. So, some of the advantages of using serverless are cost efficiency, easy deployment, high scalability and improved latency. But there are some disadvantages as well. Deploying very long-running and complex codes becomes very costly but most of the IoT applications are not so complex. Also, these serverless functions can only be accessed through APIs instead of traditional IP. Testing and debugging becomes more complex and also gives rise to new security concerns. Many vendors provide this serverless functionality to users. One of the biggest vendors is AWS under the name AWS Lambda. In contrast to an Elastic Compute Cloud (EC2) instance, a Lambda function has one dedicated purpose and deliberately only runs for up to a few minutes. Other service providers include IBM Openwhisk, Google cloud functions, Azure functions by Microsoft etc. Many communication protocols are used and one of the most popular one used in IoT is the MQTT (Message Queuing Telemetry Transport) which is a lightweight messaging protocol which doesn't require very high bandwidth to work efficiently. So, this becomes very much suitable for resource-constrained environments such as the case in most IoT applications. The paper is designed as follows. Section I gives an introduction to the contents of the paper. Section II deals with the various applications and III deals with some important characteristics related to IoT applications. Section IV provides a conclusion of the analysis carried out in the paper.

II. APPLICATIONS

A. Human Activity Recognition

The paper [1] talks about a Human Activity Recognition system that proposes to use a modified convolution based deep residual network, IoT node devices and AWS (which provides Function as a Service) to implement it. This deep neural network performs better than the traditional ML models which don't need the feature extraction to take place on the data. Some places which the paper proposes to deploy this is in shopping malls where customer activities can be analyzed to make a better offer and in hospitals to monitor patients who have undergone surgery recently who need proper rest and therapy to recover. This technology can be used to smartly monitor patients so that nurses can provide better care for their patients. This application uses the accelerometer and gyroscope present in smartphones to detect the motion of the user. Smartphones don't have the computing power to run complex algorithms. Thus all the sensor data is sent to the Cloud which facilitates functions of IoT such as periodic automation or an alarm system through MQTT protocol and complex programs can be deployed easily using serverless computing.

B. Disaster Management

The paper [2] presents IoT is based approaches and applications for disaster management. IoT supported protocols for disaster management are also illustrated by segregating into seven types such as Infrastructure, Discovery. Data, Communication, Semantic, Multi-layer Framework, and Security. The Paper also addresses IoT based cost effective applications for disaster management like BRINCO, BRK, GRILLO, FLOOD BEACON, MYSHAKE etc. The state of the art IoT based Applications for disaster management and ongoing research work is also presented. Different use cases like Flood, Earthquake, Landslide, Forest Fire etc. are addressed.

Early warning, notification, data analytics, knowledge aggregation, remote monitoring, real-time analytics, and victim localization are the important phases in Disaster Management. IoT, Cloud and Serverless technology can be applied to cater disaster management more effectively. In this context, a state of the art disaster management system for Flood is described below.

A flood is a common disastrous event that takes place in different parts of the globe every year. Water level sensors can be placed in critical points based on the ground levels. If the water level is greater than a threshold height in a critical point it can be mapped to nearby regions, alerts are to be generated in the form of SMS, Tweets etc. which will contain the alert level(red, yellow, etc.) and the location. Further, a map can also be generated based on the estimated flood levels. This will be useful to the Disaster Management Force to analyze the priorities and attend to the affected areas without delay.

The occurrence of floods is very infrequent. Data logging, Analysis, Alert generation etc. are to be performed only when the water level crosses a particular threshold. "Deliver on demand, never pay for idle" policy of Serverless computing fits very well for this application Other characteristics of serverless computing which fits well are Automatic Provisioning and utilization, Faster Availability, Fault tolerance, Auto Scaling, Easy Operations and management.

C. Smart home and Workspaces

The paper [3] proposes a smart home control system using a coordinator-based ZigBee networking. A smart energy control system that can optimize the energy consumption of household appliances by controlling the unnecessary energy demands are described. It also illustrates the smart management control system to efficiently control the operating time of the electronic appliances.

It is evident that 70-80% of Living and Working spaces are not enabled with technology to monitor critical events, provide alerts, reduce energy consumption etc. The only solution is to fit in additional micro modules to enable IoT which will bring in some intelligence so that resources are managed efficiently and securely. Some of the issues in homes and workplaces are as follows:

1)AC is to be typically operated in 27-29 Degrees, which is not taken care of in many Places 2) AC's / Fans/Lights are switched on unnecessarily when no one is occupied 3) Server Rooms/ Computing Facilities which is to be maintained in AC are not taken care of and may lead to huge losses, 4. Remotely Located Overhead Tank filling resulting in water spillage/power wastage, 5. Unattended UPS Battery Water Level Monitoring, 6. Un-attended Water spillage, 7. Un-attended parking of Vehicles, 8) Parking Vehicles in No parking Zones.

D. Intelligent Transportation System (ITS)

The paper [4] proposes an idea to implement a bus route transit planning using IoT and cloud computing. There are a lot of challenges as far as transportation is concerned in developing and developed cities. Having a smart transportation system can bring in significant improvements in areas such as avoiding traffic jams, fuel consumption and air pollution, travel time etc. The paper [4] tries to implement an automatic construction of origin/ destination (O/D) trip matrix using Bluetooth technology. The O/D matrix is fundamental to carry out traffic planning. There are four steps described to automatically generate the O/D matrix and make the information available to the clients. The appropriate and necessary information is collected from the Bluetooth devices constructed using microprocessors such as Raspberry Pi. The collected data is filtered out as the amount of data collected at this step would be quite vast. The collected data is preliminarily stored in a database and to be particular the Firebase database. Then this data is processed and the O/D matrix is generated automatically upon the client's request using the AWS Lambda services which is the serverless function of the AWS cloud services. The microservice architecture is used to achieve two functionalities: client device management and matrix generation as stated above. The client who is generally administrative authorities can trigger the matrix generation using an HTTP request to the particular AWS server. This paper clearly points out the use of microservices and serverless functions for its advantages such as scalability, cheap cloud services, fault isolation, flexibility etc.

E. Traffic Monitoring system

The paper [5] talks about developing a system to improve the punctuality of transit buses. When a bus arrives at a traffic signal, in-road induction sensors, GPS etc. are used to track the bus number, traffic signal ID and the time of arrival which is sent to the data buffer- AWS Kinesis. Kinesis triggers many lambda functions so as to check the punctuality of the bus with the preset schedule of that bus present in Dynamo DB and accordingly changes the state of the signal. These computations need to occur only when buses reach the traffic signal which indicates that it is event-driven. So serverless is the best fit for this application. This application can be further extended to detect ambulances for clearing out a way for them and to detect personnel who are on the run from law enforcement agencies.

TABLE 1: Summary of Applications

S. No.	Application	Platform	How Serverless?	Characteristics	Sensors Used	Communication Protocols
1	Human Activity Recognition	IBM Openwhisk	Need for a decrease in complexity, lead time, operational costs	The data from the smartphone can be used to determine the kind of activity the user is doing	Accelerometer, gyroscope in smartphones	HTTP, MQTT, COAP
2	Disaster Management	AWS Lambda, IBM open whisk	Sensor values are critical and are to be logged when there are disasters, So resource allocations are infrequent	Data from the sensors can be used to provide early warnings and prioritize the rescue operations	Water level sensors, WSN, Microcontroller, GPS and GSM integration,	HTTP, MQTT, COAP
3	Smart Home/Working Space	AWS Lambda, IBM open whisk	Data logging, Analysis, Voice Detection, Alert generation etc. are to be performed only during critical events	The system can help to monitor the resource utilization in living and workspaces effectively. The resources include electricity, water, space, human resources etc.	Temperature, Water level, Pyroelectric, LDR and Camera Sensors	HTTP, MQTT, COAP
4	Transportation Service	Google Cloud Platform (GCP) punctually Firebase AWS	It is based on pre-execution bases and resources are allocated for each execution.	Origin-destination matrix is generated using which administrative authority generates the planning for BRT.	Pressure, ultrasonic, infrared and image sensors	HTTP
5	Traffic Monitoring	AWS	An event is triggered when the buses arrive at the traffic signal or bus stop	Most transit buses run late	Induction, GPS sensors	MQTT, ZigBee
6	Pest Control	AWS	Update the changes obtained from the several sensors placed in the plant	The changes in plants can be detected from the dataset.	Temperature Sensors	MQTT
7	Smart Vineyard	TelosB Open-source platform	Out of the 3 databases, one resides in the firebase.	Monitoring system to improve the yield and detect diseases.	Temperature, humidity, atmospheric pressure and rainfall, wind speed and direction sensor	MQTT
8	Smart Mirror	AWS and Google Cloud Services	Efficient biometric authentication as well as manage the resources according to the triggers	Data Streaming and several processes.	Camera, microphone	MQTT
9	Waste Management	Azure functions	Only violations need to be stored. So azure functions facilitate storage in a SQL database.	>To ease separation of waste >To monitor violation	Ultrasonic sensor, Camera	MQTT

F. Pest Control

The paper [6] proposes a low cost-effective sensor system for farmers to collect agricultural data efficiently, monitor and detect the pest which helps to take necessary actions by building predictive models based on AWS IoT API. Models can predict outbreaks of diseases in farmland beside the practice of the Amazon ML algorithm in the agriculture domain. We achieved to eliminate the complexity of data bottleneck by putting into service the cloud serverless to manage data and devices successfully. In future, we have to consider the characteristics of each sort of pest and disease to detect, relations between measurements of IoT, pest and disease as well as real-time prediction.

G. Smart Vineyard

The system discussed in the paper [7] called SEnviro for Agriculture is used for designing and developing a system that monitors the farm fields, mostly the vineyards, and improves the quality and also the yield of the production. The major approach used is WSN where the nodes take the images of the field and using image processing techniques any defects or disease in the leaf is detected. It includes a smart embedded system that monitors the temperature and humidity and sends an SMS of the values. Thus the alerts sent can be either data or the state of the node.

H. Smart Mirror

The smart mirror discussed in paper [8] is a voice-assisted interactive IOT device with added Alexa skills and multimedia capabilities that offers unique features to improve system security through biometric authentication. The authentication is implemented with multi-factors, facial and voice which is ensured through serverless computing in AWS. Additionally, the voice assistant and the multimedia display implemented in the mirror make users enjoy the intelligence of the smart home.

I. Waste Management

The paper [9] discusses a serverless IoT framework for smart waste management system where disposal bins can be turned into smart edge IoT devices which is capable of detecting in real-time disposal violations and provides an interface that can be used to monitor the disposal behaviour reducing costs associated with source separation and prevents pollution. Recyle.io takes advantage of edge computing capabilities reducing costs associated with source separation and achieving sustainable consumption or production patterns.

III. IMPORTANT CHARACTERISTICS

A. Security

IoT has penetrated each and every domain possible with the promise of making things better. Lots of personal and vulnerable data like a person’s health-related information are being generated in a very short amount of time. The consequences could be fatal if this data falls into the hands of people whose sole purpose is to create harm. Arguably, security must be the most important factor to be considered while designing such systems.

B. Real Time Data Processing

This refers to the processing and execution of data instantaneously. This requires a continuous stream of input data. This kind of processing is very much required in areas like radar systems and traffic signals

C. Scalability

Scale, by definition, refers to “the capability of a system, network, or process to handle a growing amount of work, or its potential to be enlarged in order to accommodate that growth." As we know that IoT is expanding at a rigorous pace and while designing an IoT system, scalability becomes one of the important factors to consider.

D. Data Streaming

Data streaming refers to the continuous and steady transfer of data at high rates. This is usually associated with a good internet connection and high bandwidth.

E. Cost Efficiency

Cost efficiency is a vital factor for a public user or an average private company. They don't have high enough funding to spend lavishly. So, each and every system that they put to use must be very much cost-efficient even if it takes some hit on performance.

TABLE 2: Most important characteristics needed for each application

Application name	Security	Real time Processing	Scalability	Data streaming	Cost effectiveness
Human Activity recognition	✓	✓	X	X	X
Disaster Management	✓	✓	✓	X	X
Smart Home or working space	✓	✓	✓	X	✓
Intelligent Transportation service	X	X	✓	X	✓
Traffic Monitoring System	✓	✓	✓	X	X
Pest Control	✓	X	X	X	✓
Smart Vineyard	X	X	X	X	✓
Smart Mirror	X	✓	X	✓	X
Smart Waste Management	X	X	✓	X	X

IV. Conclusion

Thus this paper talked about various advantages and disadvantages of using serverless cloud architecture in IoT. IoT does not need a lot of computational power and serverless architecture steps in perfectly to exploit this characteristic of IoT. Cost efficiency being the best advantage also serves with many more advantages such as reduction in design complexity and scalability.

References

[1] *A. Keshavarzian, S. Sharifian, S. Seyedin, Modified deep residual network architecture deployed on serverless framework of IoT platform based on human activity recognition application, Future Generation Computer Systems. 101 (2019) 14–28. doi:10.1016/j.future.2019.06.009.*

[2] P. P. Ray, M. Mukherjee and L. Shu, "Internet of Things for Disaster Management: State-of-the-Art and Prospects," in IEEE Access, vol. 5, pp. 18818-18835, 2017

[3] M. Khan, B. N. Silva and K. Han, "Internet of Things Based Energy Aware Smart Home Control System," in IEEE Access, vol. 4, pp. 7556-7566, 2016.

[4]L. F. Herrera-Quintero, J. C. Vega-Alfonso, K. B. A. Banse and E. Carrillo Zambrano, "Smart ITS Sensor for the Transportation Planning Based on IoT Approaches Using Serverless and Microservices Architecture," in IEEE Intelligent Transportation Systems Magazine, vol. 10, no. 2, pp. 17-27, Summer 2018.

[5] W. Tärneberg, V. Chandrasekaran and M. Humphrey, "Experiences Creating a Framework for Smart Traffic Control Using AWS IOT," 2016 IEEE/ACM 9th International Conference on Utility and Cloud Computing (UCC), Shanghai, 2016, pp. 63-69.

[6]N. Materne and M. Inoue, "Potential of IoT System and Cloud Services for Predicting Agricultural Pests and Diseases," 2018 IEEE Region Ten Symposium (Tensymp), Sydney, Australia, 2018, pp. 298-299.

[7] Sergio Trilles Oliver, Alberto González-Pérez, and Joaquín Huerta Guijarro. 2018. An IoT proposal for monitoring vineyards called SEnviro for agriculture. In Proceedings of the 8th International Conference on the Internet of Things (IOT '18). ACM, New York, NY, USA, Article 20, 4 pages.

[8]Charles Njaka, Adokiye & Li, Na & Li, Lin. (2018). Voice Controlled Smart Mirror with Multifactor Authentication. 1-8. 10.1109/ISC2.2018.8656932.

[9]E. Al-Masri, I. Diabate, R. Jain, M. H. L. Lam and S. R. Nathala, "A Serverless IoT Architecture for Smart Waste Management Systems," 2018 IEEE International Conference on Industrial Internet (ICII), Seattle, WA, 2018, pp. 179-180.

SMART DETECTION SYSTEM FOR FRUIT RIPENESS

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***Abstract*-With the increasing growth of world population, the agricultural industry is demanding technological solutions focused on growth of food production and farming to enhance the farm yield. Nowadays, technology is constantly improving to solve human problems more easily. The manual experimentation and assessment through trial and error etc are no longer practicable. The intelligent system can be established for fruits that can permit the quality analysis. The proposed system will provide a much better and convenient way for farmers to get the maturity of fruit. This includes a series of steps from capturing the image of fruit to identify whether the fruit is fully ripened or moderately ripened or immature through the implementation in Raspberry Pi. The camera module is interfaced with Raspberry pi and the captured images are examined by various steps like preprocessing and segmentation. The status of the fruit has been sent by GSM module through SMS and displaying the status on the monitor display of the owner of the system. This in turn reduces the need for labor in fruit farms. This smart way of analyzing the fruit will enable growers and farmers and helps them to understand the potential of IoT market for agriculture by installing smart technologies to increase competitions and sustainability in their production. This will further help for the automatic fruit harvesting system using robotic arm.**

Keywords- Fruit Ripeness, IoT, Foldscope, MATLAB, Raspberry pi, OpenCV- Python, GSM.

I. INTRODUCTION

Plants have become a primary source of energy and to solve the global warming problem. Nowadays, automation plays an major role in various fields. Majority population in India dependent on agriculture and becomes their fundamental point of income. In India, fresh fruits exportation is increased. Agriculture is considered as an art and because of science, agriculture is easier and efficient for farmer to attain greater output at the terminating stage of growing time [1].

As the competition is increased in international and domestic fruit markets, it is compulsory to improve ripeness evaluation techniques to decrease the loss occurred to the cultivator and packer from fruit spoilage. Fruits are now available at both fresh and artificial processed forms. Processed forms include jam, paste and juice. The exportation of those processed foods yielding more income for the country.

People are very conscious about their health; they prefer only fresh, good quality fruit. In order to get good quality of processed products the quality of fruits should be good. Identifying good and bad quality fruits in industries manually is the main barrier since it is time consuming and requires high labor cost. Therefore high priority is given in fruit industries for various necessities to identify the quality of fruits.

The agricultural industry is demanding technological solutions focused on increasing production and benefits while reducing cost and time. Automation of agriculture tasks has improved all phases of the industrial process, from pre-harvest to harvest and post-harvesting stages, fruit plucking and collections of plucked fruits is the most important task.

The project describes an approach to image processing method in industries now become a major source in the last few years. By using Image processing tools in MATLAB software [2], we can find the quality of Fruits using various algorithms. During various ripening stage, the color of lemon differ from mature green, green and yellow. Most of them were based on color feature because the color is as an effective factor of the fruit quality. The fruit ripeness can be calculated by its surface color of fruit and it is a majority factor while finding a fruit ripeness.

The purpose of the present work is to analysis the age factor of the fruits using the technique mentioned that which will try to decrease the labor work and maintain the accuracy at its maximum, also the proposed technique is allow the process to become faster as compare to the manual system. It uses the various sub image processing algorithms to perform analysis.

It is very difficult task to categorize and ordering the fruits in a production farm. In order to solve this problem, MATLAB software and also python programming with some image processing methods are adopted widely. It is very necessary to maintain the proper quality of fruit for maximum profit for growers while marketing the fruits. Hence the proposed model compacts with the valuation of ripeness using image processing methods.

The hardware verification about the ripeness state using Raspberry pi attached with a Raspberry pi camera that used to capture the image of the fruit and the color sensor is used to find the color level estimation of the fruit. The captured image undergoes various techniques and the status of the fruit which is fully ripened or moderately ripened or immature will be send to the user via SMS using GSM module. This system will be very convenient to find the ripeness state of the given fruit and instantly the user will receive the message of the fruit ripeness which makes the system much better to use.

II. PROPOSED DESIGN

Fig. 1 shows the Block Diagram of the Proposed System.

- The proposed system will take input as fruit and checks whether the fruit is fully ripened or moderately ripened or immature.
- The first system will take the picture of fruits and gives whether the fruit is in fully ripened or moderately ripened or immature state using MATLAB Image processing tools.
- The second system will be real time ripeness detection of fruit using Raspberry pi interfaced with camera module
- The third system requires the fruit sample as input and the samples is observed in foldscope to find out whether the fruit is immature or mature.

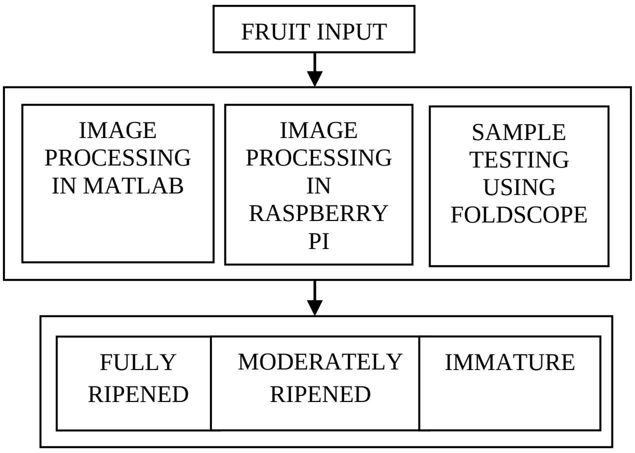


Fig.1 Block Diagram

2.1 ASSESSMENT OF MATURITY USING MATLAB

The proposed algorithm is implicit for the assessment of maturity. The RGB values of the image are retrieved. In this algorithm B value is considered to be zero based on the RGB color coding of different shades of green and yellow color. The ratio between the R and G value is computed for a variety of sweet lime fruits [3]. The RG ratios for different samples were obtained. A region of interest (ROI) is a portion of an image that need to focus for further analysis. Here, three cases of maturity assessment is formulated,

1. Maturity analysis based on “Red &Green (R/G)” ratio.
2. Maturity analysis based on Hue Mean.
3. Maturity analysis based on Hue Median.

After Reading the image, the required part of the region is selected and the value of RGB is estimated.

2.1.1 MATURITY ANALYSIS BASED ON “Red &Green (R/G)” RATIO

Based on the findings, the RG ratio threshold for ripe fruit is fixed as greater than 0.95, and that for unripe fruit is less than 0.85, and between 0.85 and 0.95 is moderately ripened fruit. Fig. 2.1.1 shows the flowchart for assessment of fruit ripening based on (R/G) Ratio.

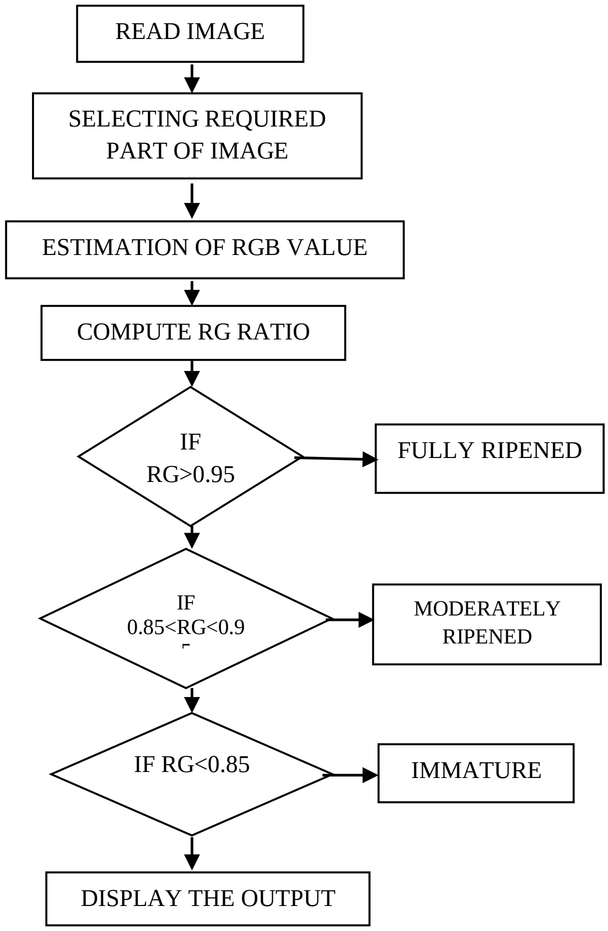


Fig 2.1.1: Flow chart based on R/G Ratio

2.1.2 MATURITY ANALYSIS BASED ON HUE MEAN

Convert the RGB to HSV color space. Calculate the Hue value of the selected region of image. The Hue Mean threshold for ripe fruit is fixed as less than 0.20, and that for unripe fruit is greater than 0.24 and between 0.20 and 0.24 is moderately ripened fruit. Fig. 2.1.2 shows the flowchart for assessment of fruit ripening based on Hue Mean.

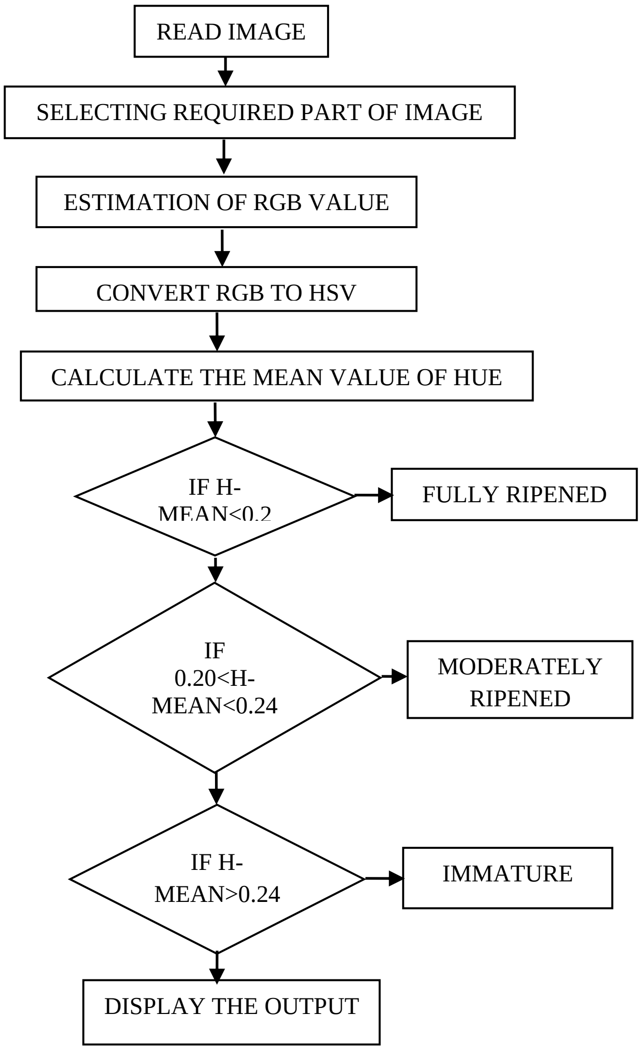


Fig 2.1.2: Flow chart based on Hue Mean.

2.1.3 MATURITY ANALYSIS BASED ON HUE MEDIAN

Convert the RGB to HSV color space. Calculate the Hue value of the selected region of image. The Hue Median threshold for ripe fruit is fixed as less than 0.19, and that for unripe fruit is greater than 0.22 and between 0.19 and 0.22 is moderately ripened fruit. Fig. 2.1.3 shows the flowchart for assessment of fruit ripening based on Hue Median

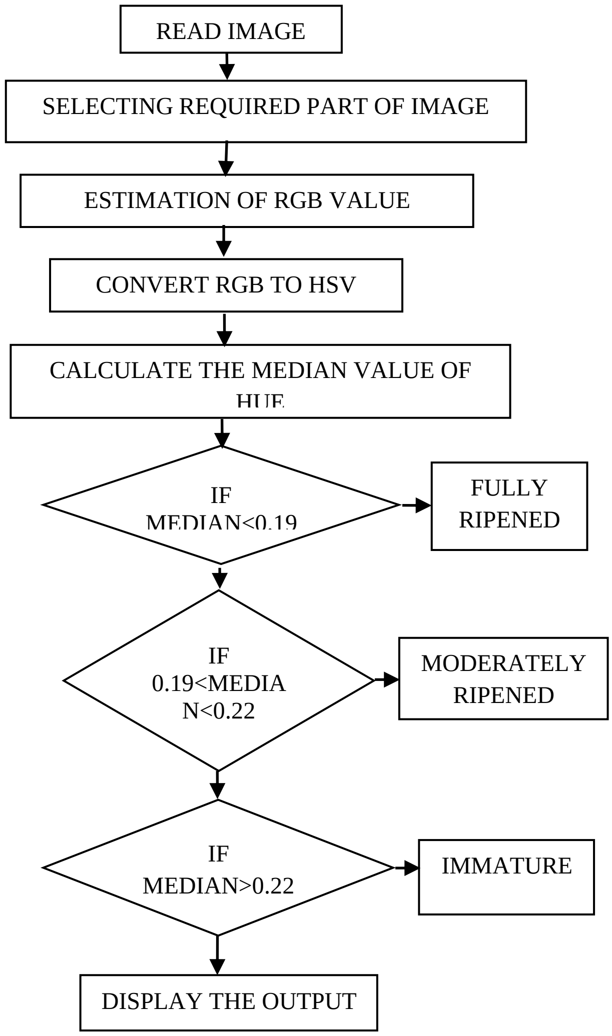


Fig 2.1.3: Flow chart based on Hue Median.

2.2 ASSESSMENT OF MATURITY USING RASPBERRY PI

A powerful small single board computer called Raspberry Pi using Raspbian as its Operating system which is a version of the GNU/Linux. The processor of Raspberry Pi system is a Broadcom BCM2835 system-on-chip (SoC) multimedia processor, consist of a Videocore4 GPU and 64 bit Advanced RISC Machine (ARM) CPU core, specifically ARM Cortex - A53 and it runs at 1.2 GHz with RAM of 1 GB.

An open library that has more number of algorithms in computer vision is OpenCV (Open Source Computer Vision Library). The OpenCV allows for automatic memory allocation and memory de-allocation and reduces the total programming complexities for programmers. OpenCV-Python is the OpenCV integrated with the programming language Python. The syntax of python is simple and easy to use. OpenCV-Python provides common functions for computer vision applications and to increase the use of machine approach in the commercial products. OpenCV-Python focuses mainly on real-time image processing [4].

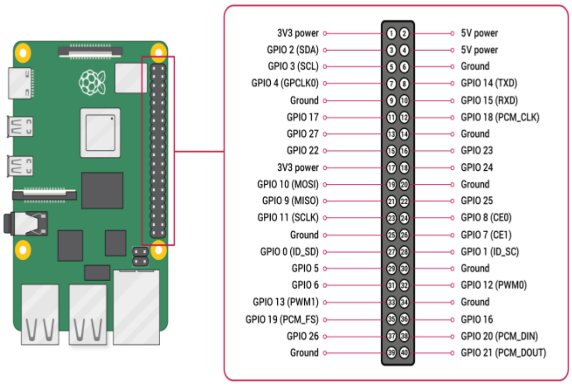


Fig.2.2.1. Raspberry Pi 3 B

Fig.2.2.2 Raspberry Pi camera

Fig. 2.2.2 shows the camera module for Raspberry Pi, it has the resolution of 5MP.

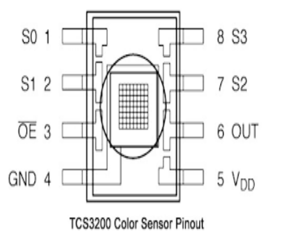


Fig.2.2.3

Fig.2.2.4

Fig.2.2.3 shows the Color Sensor TCS3200 and Fig. 2.2.4 shows the Pinout of TCS3200

Figure (2.2.3) shows the color Sensor TCS3200 which exactly a color detector. It consists of four white LEDs and a RGB sensor chip of TAOS TCS3200. It will detect visible colors and measure colors within limitless range to a certain degree. This sensor has filter types which are: red filter, green filter, blue filter and clear with no filter. With the high and low value of pin S2 and S3 on the module the filter is selected. The GSM mobile telephone technology is the GSM module which is the hardware device, the remote network will get the data link using GSM. Figure (2.2.5) shows the GSM module SIM900A which is designed with a very powerful single-chip processor integrating AMR926EJ-S core.

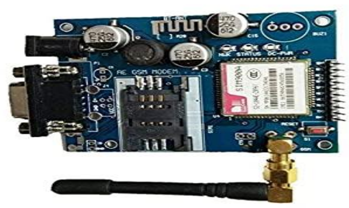


Figure 2.2.5: GSM module SIM900A

2.2.1 FLOW CHART

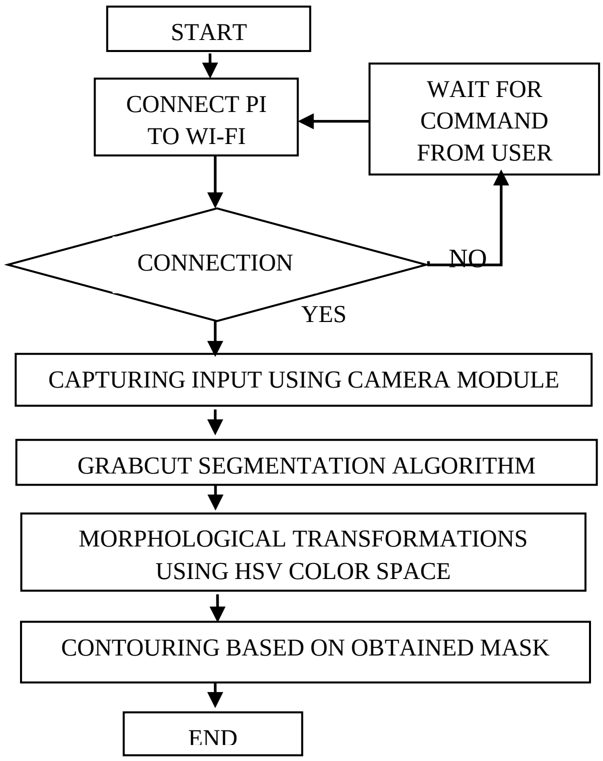


Fig 2.2.6: Flow chart for Raspberry Pi

The working of flowchart is first the pi connects to the Wi-Fi connectivity. If the connection is successful, it connects to Wi-Fi, and then camera module captures the input fruit. The captured image will undergo image segmentation. For this Grabcut image segmentation algorithm will segment the image background and the final segmented image undergoes morphological transformations using HSV color model. After that it contours based on obtained mask. The final result shows that given fruit is fully ripened or moderately ripened or immature. Fig.2.2.6 shows the flow of process for Raspberry Pi fruit ripeness detection technique.

2.2.2 FLOW CHART OF COLOR SENSOR

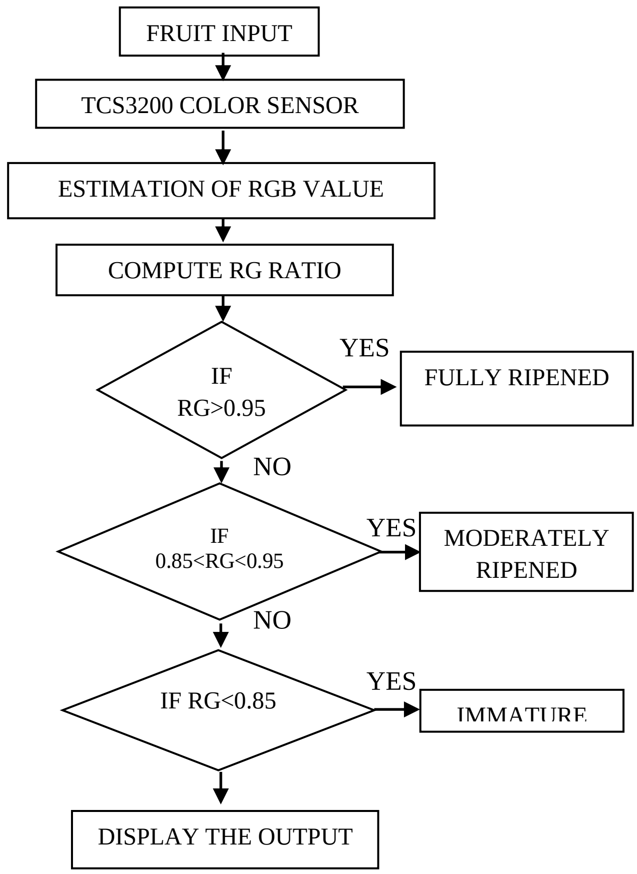


Fig 2.2.7: Flow chart for Color sensor

The flow chart for maturity assessment using Color sensor was shown in Figure 2.2.7. After placing the fruit input the color sensor which senses the color of the fruit. The RGB values of the image are retrieved. The ratio between the R and G value is computed for a variety of sweet lime fruits. The RG ratios for different samples were obtained. With the obtained findings, the RG ratio threshold for ripe fruit is fixed as greater than 0.95, and that for the unripe fruit is less than 0.85, and between 0.85 and 0.95 is moderately ripened fruit.

2.3 ASSESSMENT OF MATURITY USING FOLDSCOPE

A portable optical microscope and it will be assembled using a paper sheet and lens called Foldscope. The foldscope cost is very cheap and used to observe biological and a non-biological science. Foldscope is water-proof when compared to conventional microscope [5]. The biological samples such as fungi, bacteria, etc and also non-biological samples will be visualized using foldscope. The assembled foldscope with various parts is illustrated in Fig.2.3.1

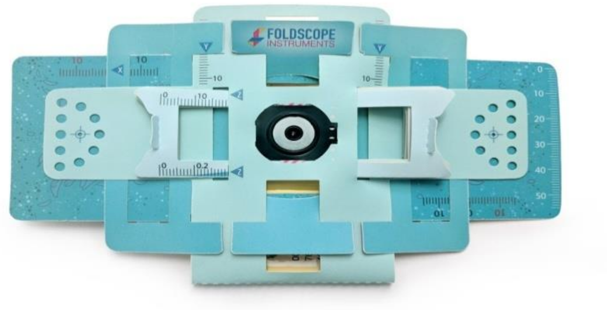


Fig.2.3.1. Foldscope

A foldscope includes a cardstock having punched sheet, a spherical lens and three magnetic couplers which is square in shape. The lens having the magnification of 140X and 2 microns resolution is used in foldscope. The Weight of Foldscope was 8 grams. Foldscope will be effortlessly attached with mobile phone to get images for further analysis. The foldscope attached with the mobile phone is illustrated in Fig.2.3.2

Fig.2.3.2. Foldscope attached with mobile phone

III. RESULTS AND DISCUSSION

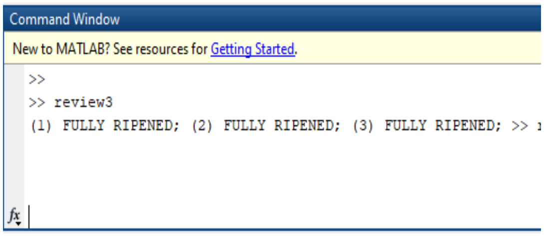
3.1 MATLAB RESULTS

The lemon images are taken which is green to yellow shades. After that selecting the required part of the image and simulated using three algorithms which are maturity analysis based on “Red &Green (R/G)” ratio; Hue Mean and Hue Median. The Algorithms are simulated by

MATLAB R2018a version. The outputs of these three algorithms are displayed in Command window of MATLAB whether fully ripened or moderately ripened or immature.

3.1.1 FULLY RIPENED SAMPLE

A Input image B Selecting Region C Required Image



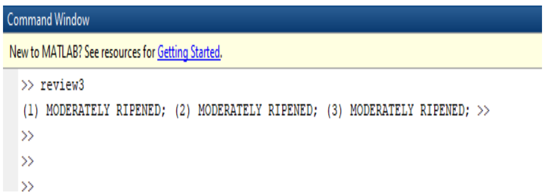
D Output Display

Fig.3.1.1. Fully ripened sample

Fully Ripened Lemon images are taken which as illustrated in the Fig.3.1.1 A Input image; selecting the region required as illustrated in Fig. 3.1.1 B Selecting Region; selected image as illustrated in Fig.3.1.1 C Required image ; output of three algorithms are displayed as illustrated in Fig.3.1.1. D output display

3.1.2 MODERATELY RIPENED SAMPLE

A Input image B Selecting Region C Required Image



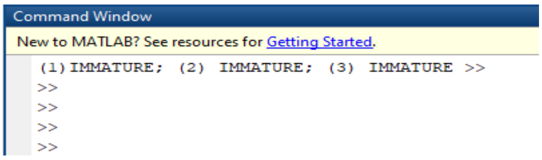
D Output Display

Fig.3.1.2. Moderately ripened sample

Moderately Ripened Lemon images are taken which as illustrated in the Fig.3.1.2 A Input image; selecting the region required as illustrated in Fig. 3.1.2 B Selecting Region; selected image as illustrated in Fig.3.1.2 C Required image ; output of three algorithms are displayed as illustrated in Fig.3.1.2. D output display

3.1.3 IMMATURE SAMPLE

A Input image B Selecting Region C Required Image



D Output Display

Fig.3.1.3. Immature sample

Immature Lemon images are taken which as illustrated in the Fig.3.1.3 A Input image; selecting the region required as illustrated in Fig. 3.1.3 B Selecting Region; selected image as illustrated in Fig.3.1.3 C Required image ; output of three algorithms are displayed as illustrated in Fig.3.1.3. D output display

3.2 RASPBERRY PI RESULTS

The Camera module and color sensor is connected to Raspberry pi. Raspberry pi connects to the Wi-Fi connectivity, if the connection is successful, it connects to Wi-Fi, then camera module captures the input fruit and it undergoes Grabcut segmentation and morphological transformations using HSV color space. After that it contours based on obtained mask. The final result shows the fully ripened region or moderately ripened or immature region via GSM module to user.

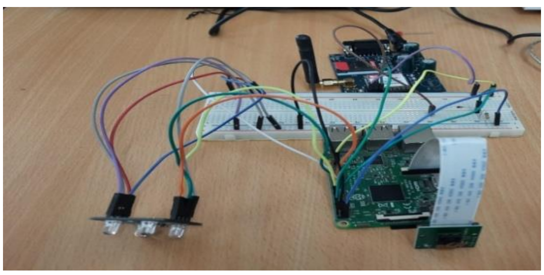


Fig.3.2.1. Hardware setup of Raspberry Pi

3.2.1 FULLY RIPENED SAMPLE

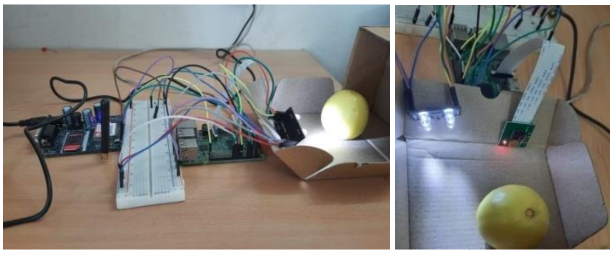


Fig. 3.2.1.1 A Fig. 3.2.1.1 B

Fig. 3.2.1.1: Fully Ripened fruit sample

(3.2.1.1 A) Side View of hardware setup, (3.2.1.1 B) Top View of sample

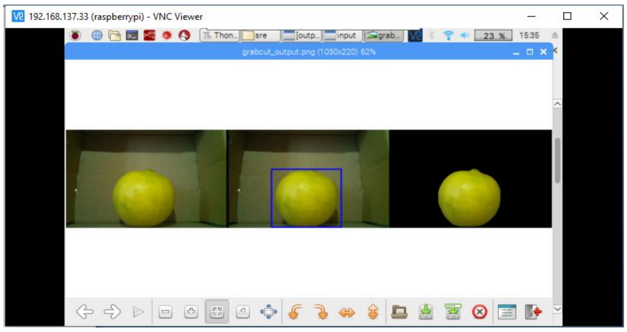


Fig.3.2.1.2 (a) Captured Fruit, (b) Rectangular region for grabcut segmentation, (c) After segmentation.

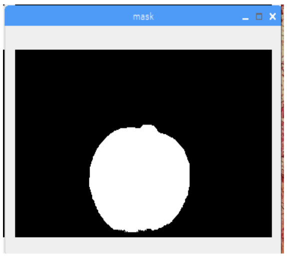


Fig. 3.2.1.3

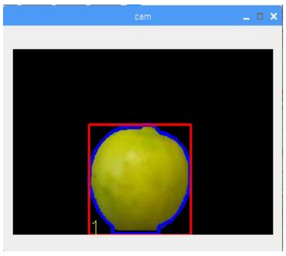


Fig. 3.2.1.4

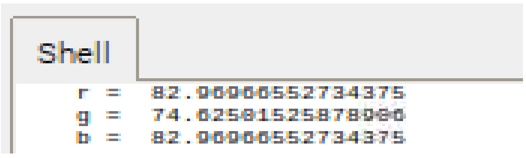


Fig. 3.2.1.5

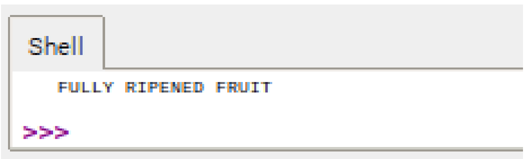


Fig. 3.2.1.6

Fig.3.2.1.3 Morphological transformation of HSV Color masked image, Fig.3.2.1.4 Output Contoured image, Fig.3.2.1.5 Color Sensor Result, Fig.3.2.1.6 Output Display.

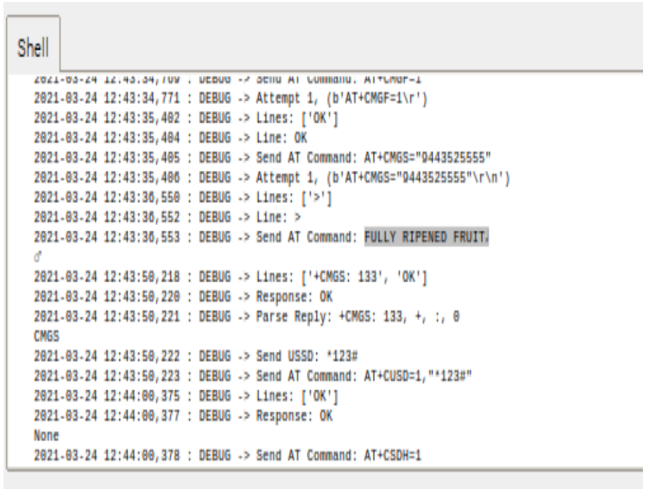


Fig. 3.2.1.7 GSM Monitor Display

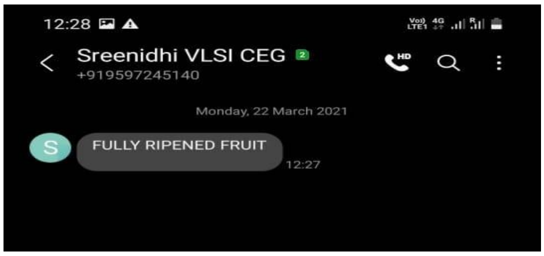


Fig. 3.2.1.8 Mobile Phone Result

Figure 3.2.1.1 A shows the full hardware setup for fruit ripening, Figure 3.2.1.1 B clearly shows the top view of the setup. In that Fully ripened Lemon fruit placed in front of camera module and the color sensor. Figure 3.2.1.2.a shows the captured fruit image and Figure 3.2.1.2.b shows the Rectangular region for Grabcut image segmentation algorithm. Figure 3.2.1.3 shows the Morphological operation of the segmented image using HSV color mask for green to yellow values and based on these color masking, contouring was done to detect the ripeness state and the contoured image is shown in Figure 3.2.1.4. Figure 3.2.1.5 shows the RGB value of the input image using color sensor. The final status of the fruit is shown in the figure 3.2.1.6. The Obtained result is transmitted to the user via GSM module and the Figure 3.2.1.7 Shows GSM module results and the Figure 3.2.1.8 Show the received message in mobile phone.

3.2.2 MODERATELY RIPENED SAMPLE

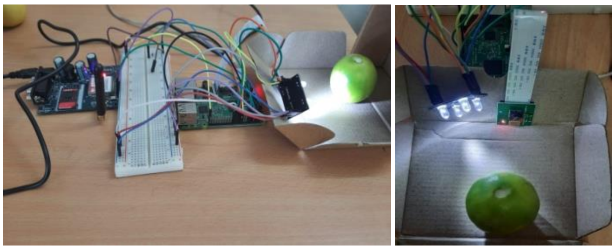


Fig.3.2.2.1 A Fig.3.2.2.1 B

Figure 3.2.2.1: Fully Ripened fruit sample

(3.2.2.1 A) Side View of hardware setup, (3.2.2.1 B) Top View of sample

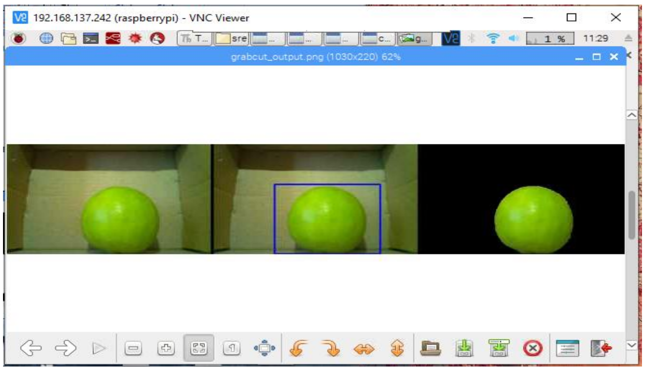


Fig.3.2.2.2 (a) Captured Fruit, (b) Rectangular region for grabcut segmentation, (c) After segmentation.

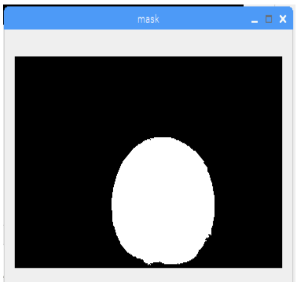


Fig.3.2.2.3

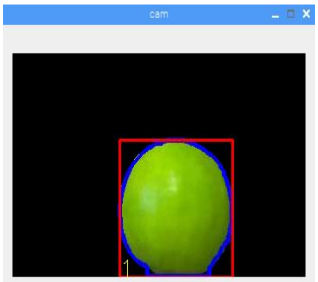


Fig.3.2.2.4

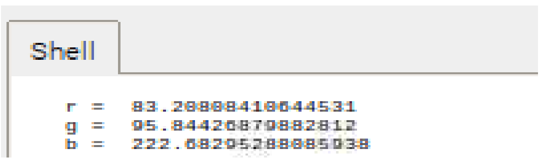


Fig. 3.2.2.5

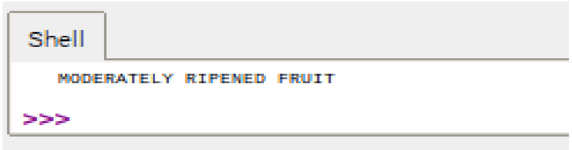


Figure 3.2.2.6

Figure (3.2.2.3) Morphological transformation of HSV Color masked image, Figure (3.2.2.4) Output Contoured image, Figure (3.2.2.5) Color Sensor Result, Figure (3.2.2.6) Output Display.

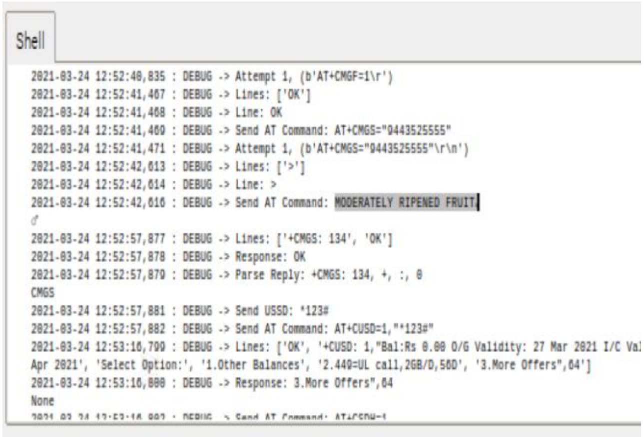


Fig.3.2.2.7 GSM Monitor Display

Fig.3.2.2.8 Mobile Phone Result

Figure 3.2.2.1 A shows the full hardware setup for fruit ripening, Figure 3.2.2.1 B clearly shows the top view of the setup. In that moderately ripened Lemon fruit placed in front of camera module and the color sensor. Figure 3.2.2.2.a shows the captured fruit image and Figure 3.2.2.2.b shows the Rectangular region for Grabcut image segmentation algorithm. Figure 3.2.2.3 shows the Morphological operation of the segmented image using HSV color mask for green to yellow values and based on these color masking, contouring was done to detect the ripeness state and the contoured image is shown in Figure 3.2.2.4. Figure 3.2.2.5 shows the RGB value of the input image using color sensor. The final status of the fruit is shown in the figure 3.2.2.6. The Obtained result is transmitted to the user via GSM module and the Figure 3.2.2.7 Shows GSM module results and the Figure 3.2.2.8 Show the received message in mobile phone.

3.2.3 IMMATURE SAMPLE

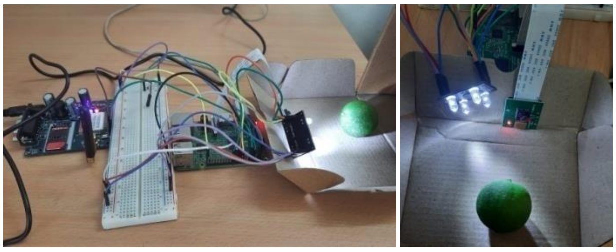


Fig.3.2.3.1 A Fig.3.2.3.1 B

Fig. 3.2.3.1: Fully Ripened fruit sample

(3.2.3.1 A) Side View of hardware setup, (3.2.3.1 B) Top View of sample

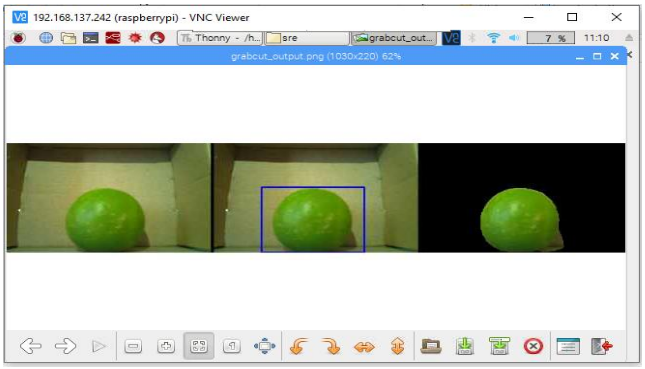


Figure 3.2.3.2 (a) Captured Fruit, (b) Rectangular region for grabcut segmentation, (c) After segmentation.

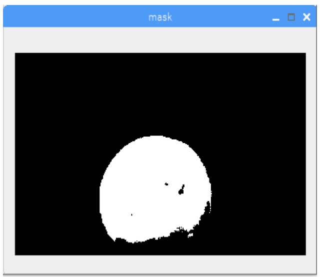


Fig.3.2.3.3

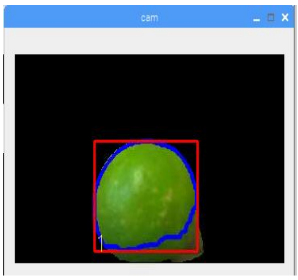


Fig.3.2.3.4

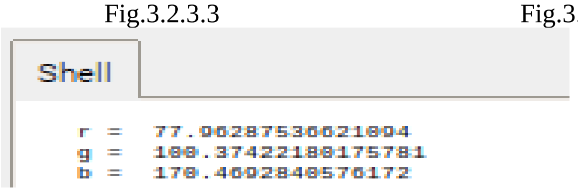


Fig.3.2.3.5

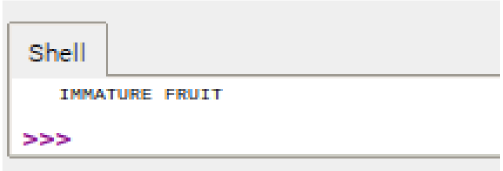


Fig.3.2.3.5

Figure (3.2.3.3) Morphological transformation of HSV Color masked image, Figure (3.2.3.4) Output Contoured image, Figure (3.2.3.5) Color Sensor Result, Figure (3.2.3.6) Output Display.

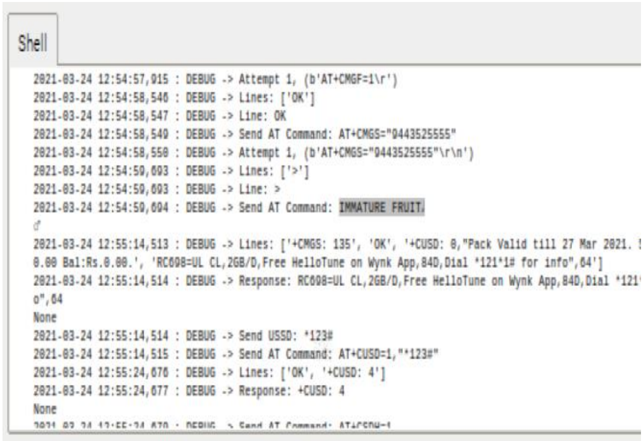


Fig. 3.2.3.7 GSM Monitor Display

Fig.3.2.3.8 Mobile Phone Result

Figure 3.2.3.1 A shows the full hardware setup for fruit ripening, Figure 3.2.3.1 B clearly shows the top view of the setup. In that Immature Lemon fruit placed in front of camera module and the color sensor. Figure 3.2.3.2.a shows the captured fruit image and Figure 3.2.3.2.b shows the Rectangular region for Grabcut image segmentation algorithm. Figure 3.2.3.3 shows the Morphological operation of the segmented image using HSV color mask for green to yellow values and based on these color masking, contouring was done to detect the ripeness state and the contoured image is shown in Figure 3.2.3.4. Figure 3.2.3.5 shows the RGB value of the input image using color sensor. The final status of the fruit is shown in the figure 3.2.3.6. The Obtained result is transmitted to the user via GSM module and the Figure 3.2.3.7 Shows GSM module results and the Figure 3.2.3.8 Show the received message in mobile phone.

3.3 FOLDSCOPE OBSERVATIONS

The sample of fully ripened lemon and over ripened lemon was taken. The juice of those taken samples are viewed in foldscope and captured via mobile phone. The observed images are shown in Fig.3.3.1 which is fully ripened lemon sample and Fig. 3.3.2 which is over ripened lemon sample.

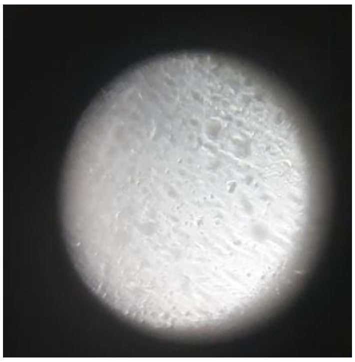


Fig.3.3.1 Fully Ripened

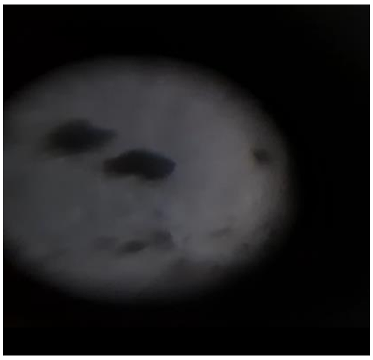


Fig.3.3.2 Over ripened

IV. CONCLUSION

Maturity of fruits acquired here is from fruit color. As color is the prime parameter for maturity evaluation, with the same variety of fruits and the color variations of the given fruit, color classification will find the fruit maturity. The project is mainly concentrating on reducing human effort and making human life easier. The first part of proposed system which is image processing will help to identify the ripeness especially citrus fruits, was implemented using MATLAB Image processing tools and second part was implemented by Raspberry pi and the third part is the verification internal quality by Foldscope. It's our responsible to improve agricultural yielding. Hence, this project is purely focusing on Agricultural side. This concept of identifying the fruit ripening using Raspberry Pi will later helpful to build automatic plucking of Ripened Fruit using robotic arm.

V. FUTURE WORK

Future work that can be added to this project may be,

- To store the data into the cloud and communicate to the IoT device.

REFERENCE

[1] P. P. Ray, S. Pradhan, R. K. Sharma, A. Rasaily, A. Swaraj and A. Pradhan, "IoT based fruit quality measurement system," 2016 Online International Conference on Green Engineering and Technologies (IC-GET), Coimbatore, 2016, pp. 1-5, doi: 10.1109/GET.2016.7916620.

[2] P. R. Gokul, S. Raj and P. Suriyamoorthi, "Estimation of volume and maturity of sweet lime fruit using image processing algorithm," 2015 International Conference on Communications and Signal Processing (ICCSP), Melmaruvathur, 2015, pp. 1227-1229, doi: 10.1109/ICCSP.2015.7322703.

[3] B. Öztürk, M. Kirci and E. O. Güneş, "Detection of green and orange color fruits in outdoor conditions for robotic applications," 2016 Fifth International Conference on Agro-Geoinformatics (Agro-Geoinformatics), Tianjin, 2016, pp. 1-5, doi: 10.1109/Agro-Geoinformatics.2016.7577641.

[4] I. B. Mustaffa and S. F. B. M. Khairul, "Identification of fruit size and maturity through fruit images using OpenCV-Python and Rasberry Pi," 2017 International Conference on Robotics, Automation and Sciences (ICORAS), Melaka, 2017, pp. 1-3, doi: 10.1109/ICORAS.2017.8308068.

[5] P. Maheswari, P. Raja and N. M. Ghangaonkar, "Intelligent Disease Detection System for Early Blight of Tomato Using Foldscope: A Pilot Study," 2018 IEEE 4th International Symposium in Robotics and Manufacturing Automation (ROMA), Perambalur, India, 2018, pp. 1-6, doi: 10.1109/ROMA46407.2018.8986736.

[6] A. Mueez, "A Cost-Effective Framework to Predict the Ripeness of any Fruit Based on Color Space," 2020 IEEE Region 10 Symposium (TENSYMP), Dhaka, Bangladesh, 2020, pp. 1729-1733, doi: 10.1109/TENSYMP50017.2020.9231002.

[7] G. Elavarasi, G. Murugaboopathi and S. Kathirvel, "Fresh Fruit Supply Chain Sensing and Transaction Using IoT," 2019 IEEE International Conference on Intelligent

Techniques in Control, Optimization and Signal Processing (INCOS), Tamilnadu, India, 2019, pp. 1-4, doi: 10.1109/INCOS45849.2019.8951326.

[8] S. Abe, M. Ishii, J. Ueta, H. Ito and K. Dohsaka, "Quantitative Determination of Optimal Harvest Time by Surface Color Analysis of Tree Fruits," 2020 IEEE 2nd Global Conference on Life Sciences and Technologies (LifeTech), Kyoto, Japan, 2020, pp. 185-186, doi: 10.1109/LifeTech48969.2020.1570619161.

[9] N. M. S. Iswari, Wella and Ranny, "Fruitylicious: Mobile application for fruit ripeness determination based on fruit image," 2017 10th International Conference on Human System Interactions (HSI), Ulsan, 2017, pp. 183-187, doi: 10.1109/HSI.2017.8005025.

[10] B. Öztürk, M. Kirci and E. O. Güneş, "Detection of green and orange color fruits in outdoor conditions for robotic applications," 2016 Fifth International Conference on Agro-Geoinformatics (Agro-Geoinformatics), Tianjin, 2016, pp. 1-5, doi: 10.1109/Agro-Geoinformatics.2016.7577641.

[11] Z. S. Pothen and S. Nuske, "Texture-based fruit detection via images using the smooth patterns on the fruit," 2016 IEEE International Conference on Robotics and Automation (ICRA), Stockholm, 2016, pp. 5171-5176, doi: 10.1109/ICRA.2016.7487722.

Development of Fish Feeder Bot for Aquaculture

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Abstract:

The present strategy involves automatic feeding devices and, more exactly, a revolutionary automatic feeder for fish, which can be encountered in aquariums, ponds or other infrastructure where fish are confined. The fish feeder is an autonomous moving bot that routinely and periodically feeds the fish. To bring more oxygen to the water, aerators are used, and the bubbles they create efficiently keep the water of the aquarium flowing. Poor water quality will lead to a loss of benefit, poor product quality, and possible human health risks. The consistency of water is dictated by factors, such as temperature, turbidity, PH, TDS and dissolved oxygen. The smart sensor kit comprises all sensors used to assess the consistency of the water. Using the IOT cloud, the quality parameters are seen regularly through the mobile app.

Keywords:

Fish feeder, blower, aerator, sensor kit, IOT cloud.

I. INTRODUCTION

Fish is considered as the most loveable food among the people of this civilized era. Because of its high protein content and its optimal nutrients, people have more attraction in having seafood. Fish caught alone in the oceans are not sufficient to fulfil this large potential, so fish are cultivated in a well-furnished tank where they enhance. In order to ensure the health and viability of the fishes in the aquarium, it is important to provide food on a frequent and reliable basis when maintaining an aquarium. The Fish Feeder Design Bot feeds the fish semi autonomously. The fish feeder is installed to the catamaran boat, which is propelled by Two propellers. The Fish Feeder is powered by the lithium ion battery. There's a solar panel charging the battery. The weight sensor tracks the quantity of food available in the feeder tank. It's a semi-autonomous bot capable of feeding the whole Fish Tank. The aerator is fixed under the bot that is used to provide fishes with oxygen. The water quality for successful fish farming is also checked by this Bot. This Bot Uses DHT 11 Sensor to Measure the Temperature, DO Sensors to Measure the Quantity of Dissolved Oxygen Present in The Water, PH Sensor to Measure The PH of The Water, Conductivity Sensor to Measure the Amount of Dissolved Ions Present in The Water. The sensor readings are seen through the blynk IOT cloud using GSM.

II CONSIDERATION AND DESIGN OF ROBOT COMPONENTS

A. *Mechanical System*

Hull:

A hull is the watertight body of the boat. The hull may open at the top or it may be fully or partially covered with a deck. The hull is hollow so that it can accommodate the electrical component and other equipment of the boat.

Hull terms:

- Bow is the front most part of the hull.
- Stern is the rear-most part of the hull.
- When facing the bow, the portside is the left side of the ships.
- When facing the bow, starboard is the right side of the port.
- The waterline is an imaginary line that circumscribes the hull and corresponds to the surface of the water when the hull is not moving. The LWL's midpoint is at amidships (see below).
- It is located halfway between the forward and backmost points on the waterline.
- A baseline is a fictitious reference line on which vertical distances are measured. It is normally found at the hull's bottom.

Frame:

Frames are ribs that are mounted or sewn to the keel transversely. Frame gives mechanical support to the hull and give the ship its shape and strength. The frame is used to fit the fish feeder components and the thrust on it.

Thruster:

A bow thruster is a propulsion device that provides lateral thrust to help with manoeuvrability. Bow thrusters propel a boat's bow or stern into the water in any direction. Bow thrusters may be used as standard equipment on new vessels or retrofitted on boats larger than 45 ft.

Design Description

While designing a yacht type hull it is important to determine the length, width and depth since the other could be given as a manufacturers guide.

- Length of the hull = 520mm.
- The length is assumed by the designer depending upon the travel area.
- The scaling factors provided to determine the beam and width of the hull is as follows.
- Depth = L0.70 (referred from principles of yacht design)

  By using this scale factors the beam and depth value is calculated as follows;

- Depth = 100mm

Using this basic value as primary considerations the profile is selected and designed as the hull.

As per the study from the above characteristics the following parameters are selected for the design of the hull

1. Hull profile is Shallow Arch
2. Length of the hull is assumed to be 520mm
3. Width of the hull is calculated as 160mm
4. Depth of the hull is calculated as 100mm

B. Feeding Mechanism

The feeder is the main component of this bot. The feeder tank is made up of a cylindrical hollow tube with a convergence arrangement at the rim. The feeder bot's core feature is the feeder tank. The weight sensor is connected to this feeder tank. The weight sensor tracks the quantity of feeds present in the feeder tank. The blower is mounted with a DC motor below the feeder tank. The blower blows the feed from the feeder tank to the vast distances that falls on the blower so that the feed can extend to the long range and that fish can take their food on a regular basis and efficiently.

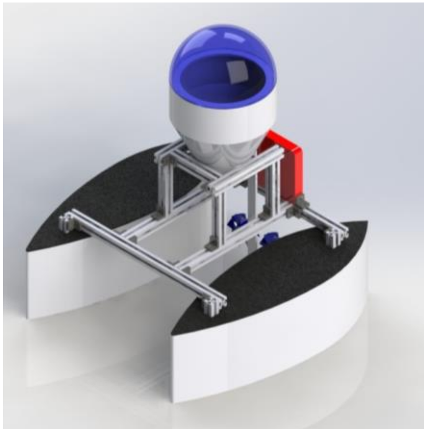

Fig: 1 Model fish feeder

C. Electrical and Electronic System

The electrical device is designed to be compact and reliable. A rechargeable 12V lithium-ion battery is used as the primary source of power for this bot due to its durability and compactness. A lightweight sheet type solar is mounted above the bot which is used to power the lithium ion battery. To control the voltage from the solar panel, a regulator is attached between the solar panel and the lithium ion battery. The voltage regulator is used to reduce 12V to 5V for Arduino. The voltage regulator circuit uses L7805 IC for voltage regulation. Two propellers are used for the bot movement. The propellers are connected to two 2200 RPM BLDC through a shaft, to make the motor as waterproof. ESP is used to control the BLDC in the propeller. ESP is an electronic speed controller which controls the speed of the BLDC motor. It converts the dc supply input to three output for the BLCD. The bot is controlled by an Arduino UNO microcontroller; the Arduino Uno uses ATMEGA328 IC. Since the Arduino can run at 5 - 12V, a voltage regulator circuit is used to decrease 12V to 5V.

D. Sensors and Microcontrollers

Sensors assist robots in perceiving their surroundings, making decisions, and acting appropriately. The temperature inside the hull is measured by a single DHT11 sensor on the designed bot. The exhauster is attached to the hull to keep the interior temperature constant. To conserve the water quality parameters for effective fish growth, a PH sensor, a DO sensor, and a TDS sensor are used to estimate the PH, Dissolved Oxygen, and Total Dissolved Solids in the water, accordingly. A turbidity sensor is used to measure the amount of TSS (Total Suspended Solids) for better fish culture. The readings from the sensors are stored in blynk IOT cloud using GSM.

Microcontroller is a controller that controls the machines according to our needs. Microcontrollers have built-in memory, input/ output pins. We use Arduino UNO as a microcontroller in this bot. As Arduino is an open source programme, it's simple to use. The Arduino UNO is based on the ATmega328.

E. Schematic and PCB

Figure 2 illustrates a graphical diagram of the fish feeder. The voltage regulator L7805 is mounted to a 12V LI ION battery to provide a continuous 5V supply to the Arduino Uno and sensors. The operating voltage of sensors used in 5V. The pH sensor signal pin is connected to analog input pin A0 of Arduino Uno. The DO, TDS and Turbidity sensors are connected to analog input pins A1, A2 and A3 of the Arduino Uno respectively. The pixhawk is a general purpose flight controller. It is used to find the vehicle state for the stabilization and to enable autonomous control. The pixhawk is interface with the Arduino Uno. Electronic Speed Controller(ESC) is used to control the movement and speed of the BLDC (Brushless DC Motor). The ground pin and the signal pin of the ESC is connected to the pixhawk. Two 2200 KV brushless DC motors are used as a propeller for the fish feeder. The BLDC is controlled by ESC. The GPS sensor is connected to the pixhawk to trace the position and location of the fish feeder.

Using conductive paths, plates, and other features engraved from one or more sheet layers of copper laminated onto and/or between sheet layers of a non-conductive substrate, a printed circuit board (PCB) physically supports and electrically links electrical or electronic devices. The PCB design of fish feeder is shown in figure 3. The PCB is used to minimise the complexity of the circuit so that we can eliminate short circuits.

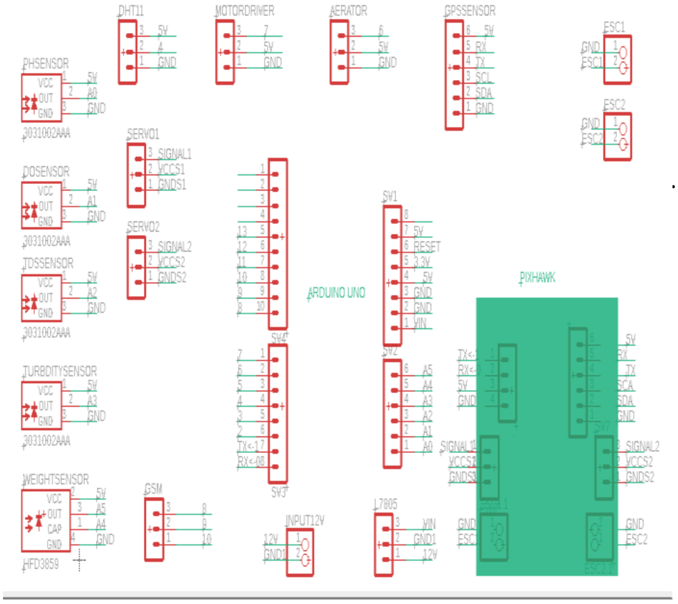

Fig.2 Graphical diagram of the fish feeder

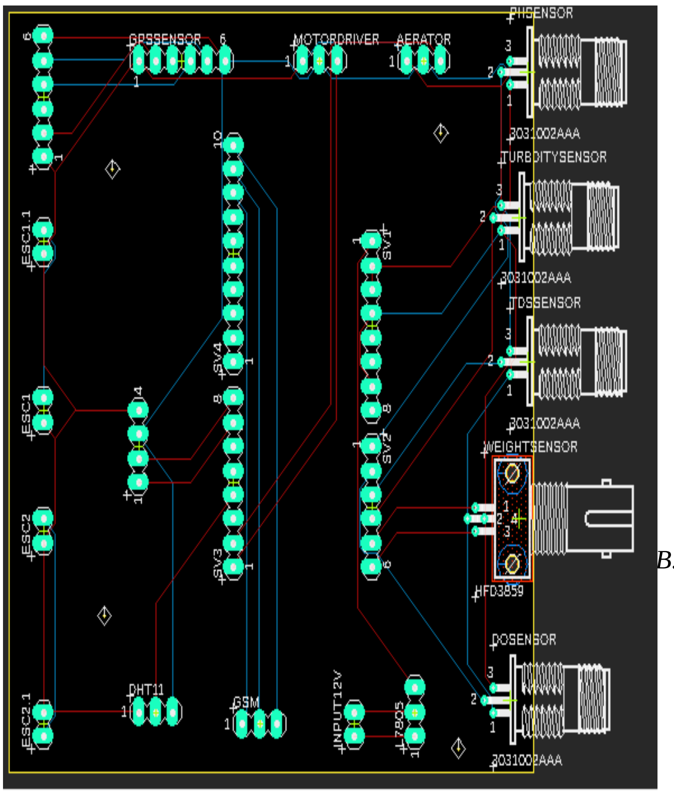

Fig 3 PCB design of fish feeder

F. Fish feeder navigation system

As the most of the fish feeders are moveable, the proposed fish feeder can move through the fish cultivating tank. The overall movement of the fish feeder is regulated by two propellers. The propellers are attached to 2200 RPM brushless DC motors. The BLDC motors are powered by a 12V battery and it is controlled by ESC and pixhawk. The direction of the fish feeder is controlled by two rudders and two servo motors. The servo motors used are a 5V operated and 90 degrees rotatable. The servo motors and the rudders are connected through a curved structured iron pin. automatic movement of the fish feeder is controlled by a pixhawk. Pixhawk is the autopilot flight controller.

III RESULTS AND DISCUSSION

. Operation of bot

The fish feeder is powered by a 12V lithium ion battery, which is connected to a thin sheeted solar panel. Voltage regulator circuit is used to reduce the 12V input to 5V for microcontrollers. The voltage regulator circuit uses L7805 IC to regulate the 12V supply to 5V. The main theme of the fish feeder is to regularly feed the fish. As a result, the feeder bot periodically feeds the fish through the blower, which will blast the feeds that land on it for a long range. The blower is powered by a DC motor. The DC motor is operated at 5V. The DC motor gets water proof by separating the motor from propellers by shaft. The weight sensor under the feeder tank measures the amount of feeds present in the feeder tank in kilograms. When the feeds in the feeder is below the certain limit, the feeder will intimate the user to fill the feeder tank. Since the aerator is installed under the feeder, it aids in the addition of oxygen to the water by moving the water from the surface to the deep of the tank. The aerator also helps in movement of feeder. Bot's movement is controlled by two 2200 RPM BLDC motors and two rudders. Two ESCs are used to control the BLDC motor. Two servo motors control the rudders. A pixhawk, which is a flight controller, controls the bot's movement. The sensor kit uses IOT to update the user's water parameters. The pH, DO, TDS, and turbidity of the water are all tracked using the blynk IOT cloud. The data is sent to IOT via GSM after the readings from the sensors are fed into the microcontroller Arduino Uno. When the amount of dissolved oxygen present in the water is reduced to a certain level, the aerator will turn on to increase the amount of dissolved oxygen in the water. These sensor data are seen in IOT cloud through a graphical representation for our better understanding. The DHT11 sensor in the sensor kit measures the inner temperature of the sensor kit. Whenever the temperature rises to above 100 degrees Celsius the exhauster fan in the sensor kit runs to reduce the temperature for the better performance of the sensors.

B. Performance evaluation of bot

The overall performance of the fish feeder is discussed in this part. The choice of catamaran shape for the base of the feeder pays the best performance. As catamarans typically have less hull volume, smaller displacement, and shallower draft than monohulls of comparable length. The combination hulls have lower hydrodynamic resistance than equivalent monohulls, requiring fewer propulsive power from sails or engines.

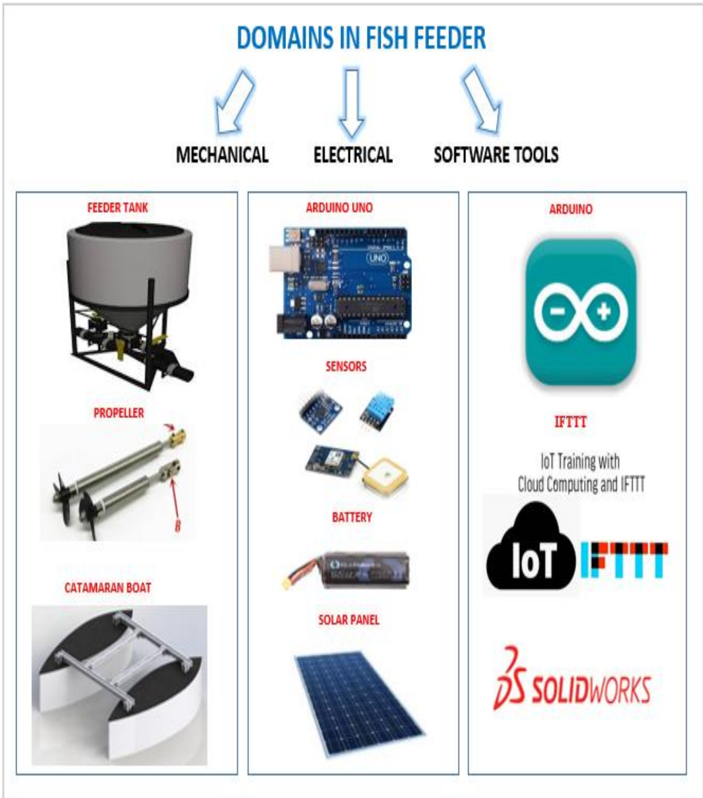

Fig: 4 shows the domains in the fish feeder bot.

The lithium ion battery is used because of its less weight and its rechargeable character. The feeder tank is placed between the two catamaran shapes so the feeder can effectively feed the fish, the feeder tank is cylindrical in shape, so the feeds can easily be dispatched. The aerator set up effectively adds the oxygen to the water. The sensor kit monitors the water parameters for better growth of fishes. The fig: 5 shows the pH readings of the water parameters. Fig: 6 represents the Dissolved oxygen present in the water. Fig: 7 Graph represents the Turbidity of the water. Fig: 8 Graph represents the temperature in the sensor kit. Fig: 9 Graph shows the weight of the feeder tank (i.e. amount of feeds present in the feeder).

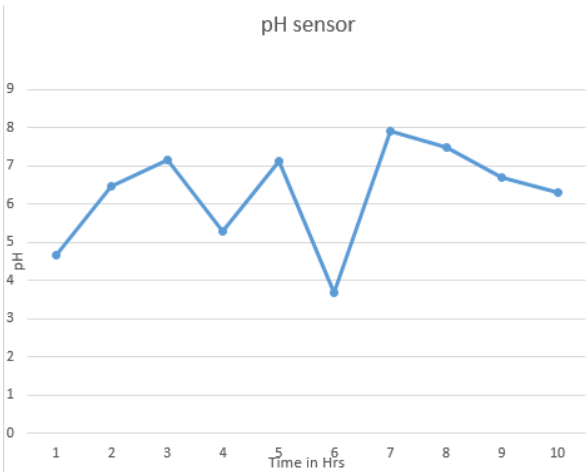

Fig: 5 Graph represents the pH of the water.

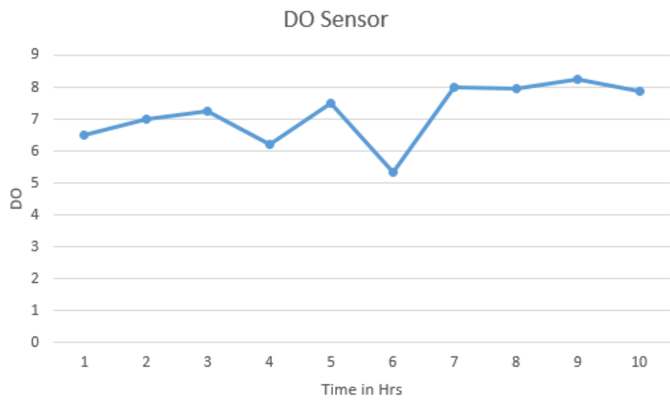

Fig: 6 Graph represents the Dissolved Oxygen present in the water.

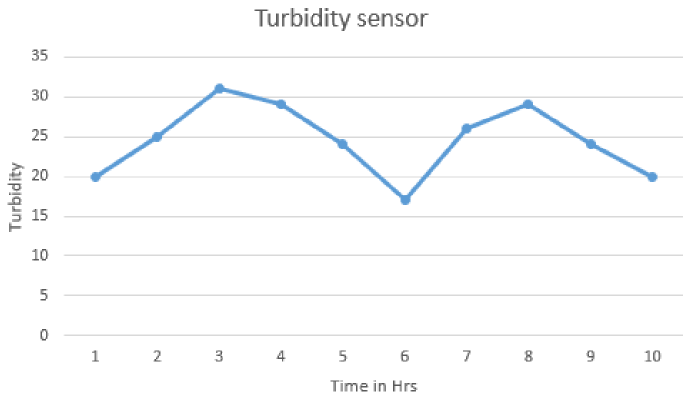

Fig: 7 Graph represents the Turbidity of the water.

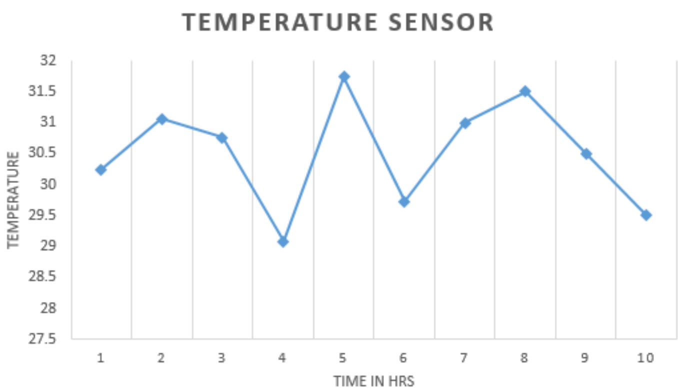

Fig: 8 Graph represents the temperature in the sensor kit.

C. Challenges and recommendation

The feeding capacity of the fish feeders is limited by the size of the feeder tank. It can be scaled up through the weight sensor at the bottom of the feeder tank. The place to fix all the sensors in the feeder tank takes much time. But finally a kit where all the sensors are kept and made water proof to avoid sensor damage. Fixing the aerator at the bottom in the beginning causes the lack of stability of the feeder. But finally the correct position and the angle is fixed to maintain the stability of the fish feeder. The first version of the bot is a remote controlled bot. But now the current version of the bot is a semi-autonomous bot that can run by pixhawk.

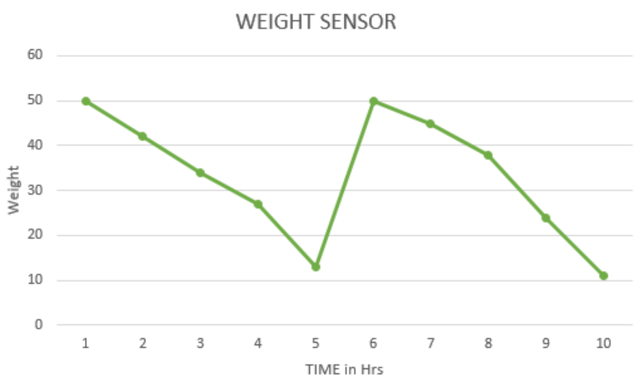

Fig: 9 Graph represents the weight of the feeder tank (i.e. amount of feeds present in the feeder).

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IV CONCLUSIONS

The fish feeder bot is designed, fabricated and tested. It is a catamaran shaped boat fitted with a hollow cylindrical feeder tank. It regularly feeds the fishes. The sensor kit regularly monitors the water parameters and updates the data in the blynk cloud. The aerator fixed will continuously add oxygen to the water. The fish feeder plays an important role in maintaining the water quality and feeds the fish regularly. The fish feeder diminishes cash as well as time just as an ideal opportunity for the client. It uses a 12V lithium ion integrated battery, and lasts for 5 hours of ceaseless working.

V REFERENCES

1. Md. Nasir Uddin, Development of Automatic Fish Feeder in Vol 16, No 2-A (2016): The Global Journal of Researches in Engineering.
2. Chui Wei1, S.M Salleh1, Abdullah Mohd Ezree3, I. Zaman1, M.H Hatta4, B.A. Md Zain1, S. Mahzan1, M.N.A. Rahman2 and W.A.W Mahmud1, Improvement of automatic fish feeder machine design, Volume 914, International Conference on Materials Physics and Mechanics.
3. D. Prangchumpol, A Model of Mobile Application for Automatic Fish Feeder Aquariums System, International Journal of Modeling and Optimization, Vol. 8, No. 5, October 2018.
4. AYODELE OLANREWAJU OGUNLELA, AYODELE OLANREWAJU OGUNLELA, DEVELOPMENT AND PERFORMANCE EVALUATION OF AN AUTOMATIC FISH FEEDER, Published by the American Society of Agricultural and Biological Engineers, St. Joseph, Michigan www.asabe.org.
5. Nur Dalila Abdullah, Smart Feeder Monitoring Devices with Mobile Application, VOL 1 NO 1 (2019): DESIGN FOR SUSTAINABLE AND ENVIRONMENT.
6. A. QAYYUM, M. AYUB AND A. B. TABINDA, Effect of Aeration on Water Quality, Fish Growth and Survival in Aquaculture Ponds, Pakistan J. Zool., vol. 37(1), pp. 75-80, 2005.
7. 7. Yovita John Mallya, THE EFFECTS OF DISSOLVED OXYGEN ON FISH GROWTH IN AQUACULTURE, P.O. Box 1390, Skulagata 4 120 Reykjavik, Iceland.
8. 8. OHAMADIKE, Okechukwu, Automated fish feeder using Internet of Things (IOT), http://hdl.handle.net/123456789/566.
9. 9. Muhammad Hazwan Md Jamal, Dr. Badrul Aisham Md Zain, Modelling And Control Fish Feeder System, Vol 1, No 1 (2017) > Md Jamal.
10. 10. Mackenzie Banker Charlie Brooks Jake Halverson Rachel Huntley, Automated Fish Feeder, http://www.wpi.edu/academics/ugradstudies/projectlearning.html.
11. 11. DONGA RAM SIRI BABU1, GUDUVAKA MAHESH2, Developing Fish Feeder System using Arduino, ISSN 2319-8885 Volume.08, Jan-Dec-2019, Pages: 647-651.
12. 12. Ozigbo Emmanuel, Anyadike Chinenye, Gbadebo Forolunsho, Okechukwu Richardson 2 and Kolawole Peter, Development of an automatic fish feeder, A Research Article in AJRTC (2013) Vol. 10 No. 1: Pages 27-32.
13. 13. Ananda Dwi Satrio, Smart Fish Feeder, http://hdl.handle.net/123456789/15752
14. 14. MUHAMMAD AQMAR IRFAN BIN MOHAMAD ZUBIR, MUHAMMAD SHUKRI BIN KHALID TENGKU MOHD AIZAN BIN TENGKU MOHAMMAD (EN/PN), Automatic Fish Farm Feeder, http://repository.psa.edu.my/handle/123456789/2631.
15. 15. Larry C. Nicholson, J. Y. Christmas III &Ronald R. Lukens, A Low Cost Live Food Feeder, https://doi.org/10.1577/1548-8640(1985)47<245:ALCLFF>2.0.CO;2.
16. 16. Jui-Ho Chen; Wen-Tsai Sung; Guo-Yan Lin, Automated Monitoring System for the Fish Farm Aquaculture Environment, 2015 IEEE International Conference on Systems, Man, and Cybernetics.
17. 17. Izzeldin Ibrahim Mohamed, Design and Development of Microcontroller Based Automatic Fish Feeder System, IJESC, April 2020 25380 http:// ijesc.org/ ISSN 2321 3361 © 2020 IJESC.
18. 18. Nisa Hanum Harani; Anggi Sholihatus Sadiah; Anny Nurbasari, Smart Fish Feeder Using Arduino Uno With Fuzzy Logic Controller, 2019 5th International Conference on Computing Engineering and Design (ICCED).
19. 19. I S Akila; P. Karthikeyan; Haran M.V. Hari; Krishnan J. Hari, IOT Based Domestic Fish Feeder, 2018 Second International Conference on Electronics, Communication and Aerospace Technology (ICECA).
20. 20. C.C. Anyadike1, M. Eze1 and G.N. Ajah2, DEVELOPMENT OF AN AUTOMATIC FISH FEEDER, Journal of Agricultural Engineering and Technology (JAET), Volume 18 (No. 2) December, 2010.
21. 21. B.c mohapatra, bikash s,.k.k. sharma and d.majhi.(2009) development and testing of demand feeder for carp feeding in outdoor culture system. agriculture engineering international: the cigr journal manuscript no 1352 vol xi.

22. M. F. Shaari, m.e.i zulkefly , m.s wahab f.esa(2011). Aerial fish feeding system international conference on mechatronics and automation, IEEE.
23. Stanley j.b . James d.i (2006). aquaculture feed buoy control – part 1: system ,IEEE.
24. Noor m.z.h., hussain a.k. saad m.f., ali m.s.a.m., zolkapli m.x. the design and Development of automatic fish feeder system using pic microcontroller. Control and system graduate reaserch colloquiom, 2012 IEEE.
25. Ali Mohammed, A. Y., & Maheta, V. dinesh. (2017). Smart Aquarium Kit. *Journal of Student Research*. https://doi.org/10.47611/jsr.vi.574.
26. Osueke, C.O. and Olayanju, T.M.A. and Onokwai, A. O and Uzendu, P (2018) *DESIGN AND CONSTRUCTION OF AN AUTOMATIC FISH FEEDER MACHINE.* International Journal of Mechanical Engineering and Technology, 9 (10). pp. 1631-1645.
27. Maria Cizel U. Deroy, Aeus Joshua Espaldon, Johanna Ericka F. Osa, Gian Paulo B. Macalla, Diogenes Armando D. Pascua. Design and Implementation of an Automated Fish Feeder Robot for the Philippine Aquaculture Industry, *Vol 15 No 1 (2017): Volume 15: (January - December 2017)*

IoT Security: A Brief Review

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Abstract—**The Internet of Things (IoT) is the rapidly developing technology that facilitates communication between devices in a network for collecting, processing, and exchanging data. This enables controlling and accessing the devices remotely. IoT figures a great advancement in almost all the fields as it finds application in various sectors like medical applications - Healthcare, Industrial applications – IIoT, smart city applications, environmental applications, consumer IoT and so on. When several devices are connected in a wide network where each device data is accessible by other devices in the same network. In such a case, data security hits the highest priority while designing an IoT system. This paper deals with a detailed survey on the architecture of IoT systems, security parameters of IoT systems security, security in various blocks of IoT systems, and the critical security applications in the areas of IoT.**

Keywords: Internet of Things, consumer IoT, IIOT, healthcare, critical security.

I. INTRODUCTION

IoT products are widely being implemented and allowing the development of new applications, with surveys predicting that there will be over 20 billion Internet of Things (IoT) devices by 2030 [1] and estimated global market size of $457 billion by 2030 [2]. These solutions cover a wide range of situations, from smart homes to smart manufacturing processes in the industry. IoT technologies should be secure by design to achieve such a degree of diffusion and control, as well as due to the close coupling with the physical realm [3]. This means that protection should be considered a key system-level property and factored into the actual design of IoT solutions architectures and approaches [4].

In recent years, we've seen an increase in attacks ranging from individual-targeted attacks, such as those triggered by IoT botnets, to nationwide attacks, such as those triggered by video baby monitors inside home automation [5]. While these cyber-attacks have helped to raise IoT risk awareness, vulnerable devices continue to be released into the market, resulting in privacy breaches, financial costs, and even death. Part of the issue is that manufacturers hurry to release revolutionary products that appeal to customers and gain a head start on the competition, but fail to protect a key functional necessity. Another reason is that many manufacturers in the IoT domain are dissatisfied with protection [6].

Main IOT Security includes [7],

- IoT devices need to be carefully provisioned with security measures.
- IoT systems are composed of devices having limitations in terms of their software and hardware.
- Only lightweight algorithms are preferred for security.
- IoT with heterogeneous technology produces a large amount of heterogeneous data increasing the attack surfaces.

The concept of IoT lies in internetworking of physical devices so that every device gets connected with the other devices without the intervention of the user or with minimal intervention of the user. Wherever we deal with processing data, security seems to be the first concern to avoid the disclosure of user's data.

The main goal of this paper is to emphasize the Architecture and layers used that for IoT security, primary needs for security, security parameters, Various levels of security for high-end devices, and Critical applications facing security issues using IoT taxonomy.

II. ARCHITECTURE OF IOT SECURITY SYSTEM

The research on IoT security architecture and its key technology [8] provides a clear-cut idea about the various layers of IoT systems based on their characteristics. It provides aresearch analysis on the classification of IoT systems into a four-layer model which builds a scientific and rational architecture for IoT systems. The IoT security architecture has four layers namely perceptual layer, network layer, processing, and application layer [8] which is classified based on the three main characteristics: Comprehensive perception to obtain proximity of the devices at anytime and anywhere, reliable transmission for accurate delivery of data between various devices in a network and intelligent processing to process massive data. [8]

III. ANALYSIS OF ARCHITECTURE AND THE VARIOUS LAYERS

The perceptual layer realizes the comprehensive perception of information [8]. This incorporates the information security at the level of collecting the data from sensors, RFID, GPS, any other input devices are to be secured. For this, a regular safety inspection, authentication, and secured transmission between sensor nodes are to be assured [8].

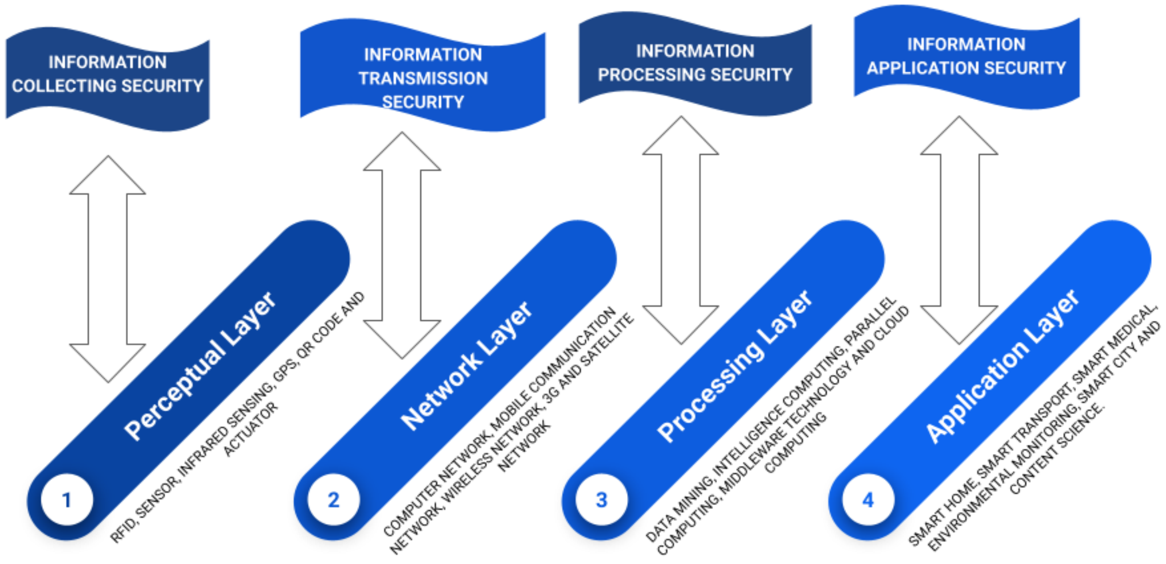

Figure 1: Security Layers

Next is the network layer which realizes the reliabletransmission of information through various transmission techniques such as long-distance cable communication, wireless communication, and network communication [8]. When this transmission occurs network layer can be corrupted by fake routing information, selective forwarding/non-forwarding, and black hole attacks. The processing layer realizes the intelligent processing of information based on data mining and cloud computing technologies to process massive data [8]. This enables intelligent decision-making and control and also ensures interoperability and scalability. The processed data reaches the application layer which realizes the authorization management to strengthen the data information as the cloud computing processes a large amount of heterogeneous data [8].

IV. Security Needs of IoT Systems and the Primary Technologies Involved

To maintain the security of systems: security, confidentiality, validity, and integrity of data information should be guaranteed to ensure information collection, information transmission, and information processing and information application security an outline of various security policies is provided [9].

Physical hardware security policy[8] involves the security of information collection at the sensor level. For this RFID technology which is used to store information on specification and interoperability and its security policy is mentioned. The asymmetric key cryptographic method has 2 keys to prevent the leakage of information due to hackers, a man-in-middle attack.

Wireless sensor network security[8] *policy* realizes the cooperatively collecting, processing information of the perceptual objects in the network. To establish sensor security at network levels integrated security policies are employed wherein the idea of multipath routing policy improves the security of the entire network with prevention of DOS, congestion, and node replication attacks.

Information collection security policy[8] realizes the authentication strategy used for preventing malicious users to access the database, further securerouting strategies and symmetric/asymmetric strategies used to strengthen perceptual layer information preventing attacks like eavesdropping, tampering, and replay attacks which are information collection attacks.

Finally, the *information transmission*[8] *and processing policy realize* data confidentiality and authenticity to prevent security risks such as denial of service attacks, a man-in-the-middle attack, unauthorized access. So, to ensure data security at this level various techniques like authentication, filtering, and detection mechanisms are employed.

V. Security Parameters of IoT Systems

To attain maximum level of security at each layer and levels of communication some security principles are to be followed to prevent serious hack attacks and also to prevent inevitable access of user's personal information [9]. Those parameters are discussed in the system testing methodology of IoT.

Confidentiality: In a wide network wherein, each node is connected to the other has a high chance of leakage of information to various other nodes. In that case authorization of data and the data management issues are to be addressed to maintain the confidentiality of data without leaking it to unauthorized nodes [9].

Integrity: To ensure the precision of data from the right sender in communication between various interconnected devices integrity plays a vital role. This can be achieved by ensuring end – end security of communication by imposing firewalls and other encryption techniques [9].

Availability: Various devices getting connected at the same time and accessible at any time is the primary aim of IoT. So, to ensure the data availability and the availability of devices that provide essential data in the IoT network is realized in this principle[9].

Authentication: In a large network with a large number of entities the identification and authentication seem to be challenging when there is manual intervention. It should be accurately done before disclosing information as they do not know each other (at the initial time)[9].

Lightweight systems and Heterogeneity: A single IoT network involves different kinds of devices and different communications are performed between various entities. This marks the heterogeneous system which connects various heterogeneous things. So the system should be designed in such a way that it gets connected to all devices at any time. So to guarantee security in such a dynamic environment an accurate encryption system is required with optimum security protocols[9].

*Policies and key management systems:*To ensure efficient data management, protection, and transmission in a dynamic IoT environment with various heterogeneous components, the establishment of policies leads to growth and scalability of IoT, developing trust in humans to use IoT devices. Encryption algorithms play a vital role in security in particular in the integrity of IoT systems. To ensure confidentiality in data between smart devices encryption keys are used for lightweight key management systems enabling trust between them [10].

VI. Security in IoT at various architecture levels

*Communication security in IoT:*To exchange the information between the users/devices we need security. Authentication [11] and access control are the security features and are privacy problems in networking. If we want to make information private without the nonexistence of a third party, mutual authentication is necessary for IoT devices[12]. Both the data receiver and data transmitter need to verify the data in the heterogeneity of the IoT environment. Authentication key establishment protocol, we need to establish the key while transferring the information, so that we can maintain our security. Access control[13] will ensure the new connection and establishes the quality of communication.

Security in end applications: To transmit a huge amount of data to a different location over the different networks there is a possibility of losing our privacy such as health care, transportations, smart cities, etc. But in IoT data from the user is sensed and then it is transported with their consent and knowledge. The privacy concern [14] include the fingerprint and heartbeat due to environmental aspects there is a possibility of reducing privacy.

Forensic challenges: When IOT infrastructure is used to carry the information, it will call for forensics' investigation of IoT that will make our information very private. In this, data is sensed and then it will transmit over the data holders[15]. IoT forensics is nothing but it is a combination of network, device, and cloud. The privacy model for IoT is an important model that has been the forensic model [16] for IoT. With the help of the ProFIT model, the information can be gathered by the end devices and it helps in the reconstruction of the scenes to an accurate level.

Application security in IoT:The Internet of changed people's lives in various applications such as health care, smart city, industry, manufacturing, security, and emergencies.

VII. Critical security application in the areas of IoT

Almost all IoT solicitations that have been situated or are in the process of being deployed need a high level of security. IoT technologies are increasingly expanding and infiltrating[17] the majority of existing industries. While existing networking technologies help operators support these IoT applications, many of them need more rigorous protection from the technologies they use. Various hostage-critical IoT solicitations taxonomy are deliberated in this division.

*Cities becoming smart nowadays – **Smart Cities**:*

To improve people's overall quality of life, smart cities make comprehensive use of new computation and connectivity resources [18]. Smart buildings, smart traffic management, smart disaster management, smart infrastructure, and so on are all part of it. Cities are being pushed to become smarter, and governments all over the world are fostering their production through various stimuli [19]. While the use of tingle apps is induced to enhance citizens' overall quality of life, it also poses a challenge to their solitude. Key card systems tend to place citizens' credit card information and purchasing habits at risk. Nevertheless, if such apps are compromised, the child's protection could be compromised come to take a chance. User's location traces can be leaked by smart mobility applications. There are apps that parents can use to supervise their children. Nevertheless, if such systems are hacked, the child's protection could be compromised.

*Environment teaches us a lot – **Smart Environment**:*

The taxonomy of the Smart Environment includes Smart animal farming, Smart agriculture, Wild vegetation monitoring, domestic waste treatment monitoring, Regional Climate change monitoring, etc… All of these Internet of

Things technologies are intertwined with the lives of people and animals in those regions. The knowledge from these IoT applications can also be used by government agencies working in these fields. Security flaws and vulnerabilities in any environment involving IoT applications can have disastrous consequences. Similarities can have catastrophic consequences for IoT applications in this sense. For instance, if the solicitations begin wrongly examining seismograph, the government and businesses will experience financial losses. If, for instance, the trenching is unable to anticipate the seismograph, that results in property and life loss. As a result, smart environment implementations must be extremely accurate, and data tampering and security breaches must be avoided. Monitoring soil moisture, controlling microclimate circumstances, selective drenching in dry zones, and controlling wet zones and inversion both are part of smart agriculture. The application of such advanced features in tillage makes farmers achieve high productivity and avoid financial losses. Fungus and other microbial contaminants can be prevented by controlling dryness and wetness levels in various kernel and vegetable production. Controlling the climate can also aid in increasing the production and quality of vegetables and crops. There are many emerging features in this field that help in controlling the activities and health conditions of farm animals by attaching agitator to the animals, comparable to crop keep track of organism's health. If such solicitations are hacked, it may result in the piracy of farm animals, as well as crop damage from adversaries.

*Machines are getting smart!! – **Smart Industries**:*

The main taxonomy of the industrial application includes Smart metering, Smart Grids, Scheduling systems, and many more… Smart metering covers a wide range of applications for various measurements, tracking, and management. Smart grids, where electricity utilization is constant and controlled, seem to be the most common application of smart metering. Smart metering may also be used to combat energy theft [20].Smart meters may also be used to measure the levels of gasoline and important parameters in water tanks and storage tanks Water grids are also available. It is necessary to keep track of and improve the efficiency of solar cells array energy from living organisms by adjusting angle with the sun in a dynamic way solar panels to get the most out of the sun zeal. Smart meters are often used in some IoT applications to calculate the water compulsion in water transport systems or the weight of products. Smart metering devices, on the other hand, are endangered to both physical and cyber-bombard, while traditional meters can only be tampered with physically. Smart meters, also known as advanced metering infrastructure (AMI), are designed to do more than just monitor energy consumption. All electric equipment in a home is connected to smart meters in a smart home area network (HAN), and the data obtained to control all the devices can be used for load and cost control. Intentional violation into such communication structure by a customer or a combatant can alter the information that is maintained and leads to the loss of consumer protection [21].

Commercial Application:

This taxonomy includes Shopping systems and retail. In the retail industry, IoT technologies are widely used. Several solicitations have been created to maintain the storage resources of products that travel across the different chains. Internet of Things has been emerged to control goods in warehouses so that restocking can be achieved as efficiently as possible. Various intelligent shopping apps are now being created to assist consumers to owe their tastes, behaviors, hypersensitivity to certain ingredients, and other factors. The use of the augmented reality that has changed the people's life to their extent. Security concerns have arisen in the deployment and use of various IoT applications by several retail companies [22]. Adversaries can attempt to compromise IoT applications related to goods storage conditions, as well as submit incorrect that gave many ideas about products to users to increase their sales. Customer's privacy details and other personal information can be stolen if security natures have not been in smart retail, resulting in monetary losses for both the customers and retailers.

*General Application –**Smart Home**:*

The trending technologies that have been implemented in IoT technologies are home automation. This contains applications where the people can monitor their equipment remotely and intruder detection systems installed on windows and doors, and so on. Energy and water use are being tracked using monitoring systems, and consumers are being encouraged to save money and resources. Many codes are developed to secure our privacy [23]. Intensions are identified by exchanging the user's behavior in key areas of the house to their usual activity in those areas[24]. Attackers can, however, gain unsophisticated to the Internet of Things devices in the home and attempt to damage users. For example, since the implementation of various home automation systems, the number of home burglaries has risen dramatically [25]. In the past, adversaries have attempted to measure the form and amount of Internet traffic to and from the smart home to assess the residents' actions and presence[25]

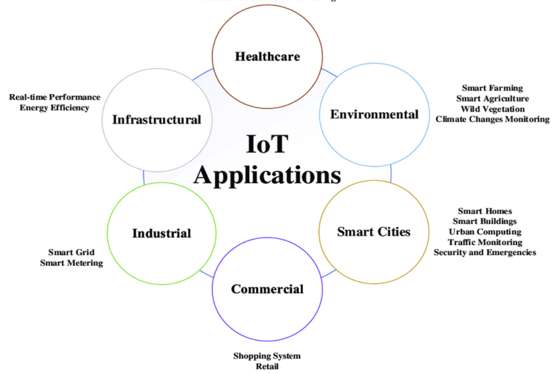

Figure 2: Application Taxonomy

VIII. Conclusion

The main contribution of this paper includes IoT system architecture, principles, and threats that have been occurred in the different layers of IoT architecture. It also focuses on security needs and requirements available in the IoT application. The security testing methods seem to be challenging when applied to real-world applications. The cyber-attacks have incorporated that these security standards and protocols have failed in providing security to the IoT device. Hence to tackle the current security in IoT application we need a novel and worthy IoT security system that should be very protractile and it should help to all the end-users and applications. To overcome these issues ML is an inherent tool that is blended with SDN, to make our privacy in a very secure manner. It can also solve the security issues using their trained Mathematical expression. In the future, by keeping the key of SDN and ML we can protect the IoT system against most security attacks.

References

[1] Gartner Inc., “Gartner Says 8.4 Billion Connected ‘Things’ Will Be in Use in 2017, Up 31 Percent From 2016,” 2018. [Online]. Available: https://www.gartner.com/newsroom/id/3598917.

[2] L. Columbus, “2017 Roundup of Internet Of Things Forecasts,” 2017 [Online]. Available: https://goo.gl/MCKCNa.

[3] D. Miorandi, S. Sicari, F. De Pellegrini, and I. Chlamtac, “Internet of things - Vision, applications and research challenges.,” Ad Hoc Networks, vol. 10, no. 7, pp. 1497–1516, 2012.

[4] B. Vogel and R. Varshney, “Towards designing open and secure IoT systems,” In 8th International Conference on the Internet of Things, pp. 1–6, 2018.

[5] J. Bugeja, D. Jonsson, and A. Jacobsson, “An Investigation of Vulnerabilities in Smart Connected Cameras,” In IEEE International Conference on Pervasive Computing and Communications Workshops (PerCom Workshops), pp. 537–542, 2018.

[6] Cloud Security Alliance, “Future-proofing the Connected World: 13 Steps to Developing Secure IoT Products,”. 2016.

[7] M. Frustaci, P. Pace, G. Aloi, and G. Fortino, ‘‘Evaluating critical security issues of the IoT world: Present and future challenges,’’ IEEE Internet Things J., vol. 5, no. 4, pp. 2483–2495, Aug. 2018.

[8]"The Research on IoT Security Architecture and Its Key Technologies", in *2018 IEEE 3rd Advanced Information Technology, Electronic and Automation Control Conference (IAEAC)*, 2018, pp. 2,3,4.

[9]"Security Testing Methodology of IoT", in *2018 International Conference on Inventive Research in Computing Applications (ICIRCA)*, Coimbatore, India, 2018, pp. 2,3,4.

[10]D. Dragomir, L. Gheorghe, S. Costea, and A. Radovici, “A survey on secure communication protocols for iot systems,” in 2016 International Workshop on Secure Internet of Things (SIoT). IEEE, 2016, pp. 47–62.

[11]H. Kim and E. A. Lee, “Authentication and authorization for the internet of things,” IT Professional, vol. 19, no. 5, pp. 27–33, 2017.

[12] R. H. Weber, “Internet of things: Privacy issues revisited,” Computer Law & Security Review, vol. 31, no. 5, pp. 618–627, 2015.

[13]S. Zawoad and R. Hasan, “Faiot: Towards building a forensics aware eco system for the internet of things,” in 2015 IEEE International Conference on Services Computing. IEEE, 2015, pp. 279–284.

[14]A. Banafa, “Iot standardization and implementation challenges,” IEEE Internet of Things Newsletter, 2016.

[15] O. Salman, S. Abdallah, I. H. Elhajj, A. Chehab, and A. Kayssi, “Identity-based authentication scheme for the internet of things,” in 2016 IEEE Symposium on Computers and Communication (ISCC). IEEE, 2016, pp. 1109–1111

[16] F. I. Khan and S. Hameed, “Software defined security service provisioning framework for internet of things,” arXiv preprint arXiv:1711.11133,2017.

[17] I. Farris, J. B. Bernabe, N. Toumi, D. Garcia-Carrillo, T. Taleb, ´ A. Skarmeta, and B. Sahlin, “Towards provisioning of sdn/nfv-based security enablers for integrated protection of iot systems,” in 2017 IEEE Conference on Standards for Communications and Networking (CSCN). IEEE, 2017, pp. 169–174

[18] A. Gharaibeh, M. A. Salahuddin, S. J. Hussini, A. Khreishah, I. Khalil, M. Guizani, and A. Al-Fuqaha, ‘‘Smart cities: A survey on data management, security, and enabling technologies,’’ IEEE Commun. Surveys Tuts., vol. 19, no. 4, pp. 2456–2501, 4th Quart., 2017.

[19] D. Eckhoff and I. Wagner, ‘‘Privacy in the smart city—Applications, technologies, challenges, and solutions,’’ IEEE Commun. Surveys Tuts., vol. 20, no. 1, pp. 489–516, 1st Quart., 2018.

[20] X. Xia, Y. Xiao, and W. Liang, ‘‘ABSI: An adaptive binary splitting algorithm for malicious meter inspection in smart grid,’’ IEEE Trans. Inf. Forensics Security, vol. 14, no. 2, pp. 445–458, 2019.

[21] V. Namboodiri, V. Aravinthan, S. N. Mohapatra, B. Karimi, and W. Jewell, ‘‘Toward a secure wireless-based home area network for metering in smart grids,’’ IEEE Syst. J., vol. 8, no. 2, pp. 509–520, Jun. 2014.

[21] N. N. Dlamini and K. Johnston, ‘‘The use, benefits and challenges of using the Internet of Things (IoT) in retail businesses: A literature review,’’ in Proc. Int. Conf. Adv. Compute. Commun. Eng. (ICACCE), Nov. 2016, pp. 430–436.

[22] A. C. Jose and R. Malekian, ‘‘Improving smart home security: Integrating logical sensing into smart home,’’ IEEE Sensors J., vol. 17, no. 13, pp. 4269–4286, Jul. 2017.

[23] I. Tudosa, F. Picariello, E. Balestrieri, L. De Vito and F. Lamonaca, "Hardware Security in IoT era: the Role of Measurements and Instrumentation," 2019 II Workshop on Metrology for Industry 4.0 and IoT (MetroInd4.0&IoT), Naples, Italy, 2019, pp. 285-290.

[24] N. M. Karie, N. M. Sahri and P. Haskell-Dowland, "IoT Threat Detection Advances, Challenges and Future Directions," 2020 Workshop on Emerging Technologies for Security in IoT (ETSecIoT), Sydney, NSW, Australia, 2020, pp. 22-29.

[25] A. Gharaibeh, M. A. Salahuddin, S. J. Hussini, A. Khreishah, I. Khalil,M. Guizani, and A. Al-Fuqaha, ‘‘Smart cities: A survey on data management, security, and enabling technologies,’’ IEEE Commun. Surveys Tuts.,vol. 19, no. 4, pp. 2456–2501, 4th Quart., 2017.

[26] E. K. Markakis, K. Karras, N. Zotos, A. Sideris, T. Moysiadis, A. Corsaro,G. Alexiou, C. Skianis, G. Mastorakis, C. X. Mavromoustakis, andE. Pallis, ‘‘EXEGESIS: Extreme edge resource harvesting for a virtualized fog environment,’’ IEEE Commun. Mag., vol. 55, no. 7, pp. 173–179,Jul.

Remote health monitoring for elder patients using wearable sensors

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Abstract— Life expectancy in maximum nations has been growing constantly over the numerous few spans a way to substantial enhancements in medicine, public fitness, in addition to non-public and environmental hygiene. However, expanded lifestyles expectancy mixed with falling beginning costs are predicted to engender a massive growing old demographic withinside the close to destiny that could impose full-size burdens at the socio-financial shape of those nations. Therefore, it's miles vital to develop value-powerful, easy-to-use structures for the sake of aged healthcare and well-being. Remote fitness tracking, primarily based totally on non-invasive and wearable sensors, actuators and contemporary-day communication and statistics technology gives a green and reasonable result that permits the aged to retain to stay of their homey domestic surroundings rather than high-priced healthcare facilities. These structures may also permit healthcare workers to screen essential physiological symptoms and symptoms of their sufferers in actual time, investigate fitness situations and offer comments from remote facilities. Internet of things (IoT) visualizes the way forward in solving in problem of medical aid for something anyplace by anyone at any time. So as realize pervasive healthcare system a foreign healthcare monitoring is important. Multiple physical signs like electrocardiogram (ECG), heart rate, blood pressure, blood glucose, arterial oxygen saturation (SpO2) with patient's location is designed to be sampled at different rates continuously using IoT with live Global Positioning System (GPS) location tracking system. The patient data recorded on remote measurement is compared with clinical trials.

Keywords— ***IoT (Internet of Things), patient monitoring, data acquisition, heartbeat sensor, electrocardiogram (ECG) sensor, SpO_2 sensor, blood pressure sensor, blood glucose, Global positioning system (GPS) and Global system for mobile communication (GSM).***

I. INTRODUCTION

In the new years remote innovation has expanding for the need of maintaining different areas. In these new years, IoT [1] dazzled the chief of business region uncommonly robotization and control. Biomedical is one among ongoing pattern to supply better medical services. In medical clinics as well as the private medical care offices are opened by the IoT innovation [3]. So having a reasonable framework different boundaries are seen that burns-through force, cost and increment effectiveness .In customary technique, doctor assume a vital part in checking old individuals. For this interaction, heaps of time is needed for enlistment, arrangement at that point observing. Likewise reports are created later, the report assortment and discussion requires two days for finding. To forestall this protracted interaction working individuals will in general disregard the observing or defer it if their wellbeing isn't fit. This contemporary methodology decreases time utilization inside the interaction.

As per this shrewd framework, Medical researchers attempt inside the field of advancement and examination since numerous a very long time to ask better wellbeing administrations and satisfaction in living souls. Their commitment in clinical region is critical to us and can't be ignored. The present network structures have the premise thoughts coming from the previous fundamentals. Far off checking, additionally alluded to as self-observing/testing, empowers clinical experts to watch a patient distantly utilizing different innovative gadgets. This strategy is basically utilized for overseeing ongoing illnesses or explicit conditions, similar to heart condition, diabetes mellitus, or asthma. These administrations can give practically identical wellbeing results to conventional in-person understanding experiences, supply more prominent fulfillment to patients, and ought to be financially savvy. In far off observing, sensors are important to catch and communicate biometric information, for example , a tele-EEG [2] gadget screens the electrical movement of a patient's mind at that point sends that information to a subject matter expert. This may be cleared out either ongoing [3] or the data may be put away at that point sent. This paper centers around how the android application is utilized to send the patient's boundaries to the worker [4]. Additionally helps the patient simply if there should be an occurrence of crisis by producing a ready when the edge esteems are crossed.

II. EXISTING SYSTEM

The present situation utilized for patient observing is that the fixed checking framework which might be utilized just the patient is on bed. The accessible frameworks are tremendous in size and just accessible inside the emergency clinics in Intensive Care Unit (ICU). Presently a-days numerous frameworks for nonstop observing of the patient are accessible. Be that as it may, the weakness in existing framework patient should be hospitalized. Normal checking of patient is preposterous once the patient is released from emergency clinic. These frameworks can't be utilized in singular level for homegrown drug. Existing frameworks are massive in size and their upkeep and cost is excessively high. The vast majority of the common frameworks [5] utilize wired correspondence which is simply excessively dreary for significant distance interchanges. They are not effectively carried out when patient is mobile.

III. PROPOSED SYSTEM

Our frameworks will be advantageous to all or any time of people particularly for the old matured or Intensive Care

Unit(ICU) patient. The gadget will quantify the heartbeat, electrocardiogram(ECG) [6], blood vessel oxygen saturation(SpO2), heartbeat and glucose of the patient and transfer the end in the instant message, web worker and versatile applications. Thusly, we have created site likewise as versatile applications during which individuals can get access and see the yield via looking through date and time. Besides, simply if there should be an occurrence of crisis, medical caretaker or patient's relative examine patient's condition by utilizing live screen choice. Our objective was to make a framework with high exactness with least expense all together that anybody can utilize and manage the cost of this framework.

Patients, guardians, specialists, clinical research centers, facilities and emergency clinics, orderlies, medical attendants, and public specialists were the fundamental players. On the off chance that medical services data is needed for affirmation and approval of any legitimate approving or reviewing, the overall population specialists are included. It assists you with gathering patient data and store it in the cloud utilizing IoT [7]. Cloud is accepted for its consistent data stockpiling of advanced data. The data will be shared to various clients all at once. The physical environment should be in excellent working order. The cloud server is also responsible for the protection of the data [8]. Cloud service providers are responsible for ensuring that information is still available on the market and that it is accessible from any place. The physical environment [9] should be in excellent working order. The hosting company also looks after the security of the information. This information can be read by the users at any time [10]. The patient is followed in this paper utilizing IoT gadgets with different sensors, and their data is put away in the cloud. With the exception of the patient, every entertainer is given a special RFID-empowered identifier . It's mandatory for the patient, specialist and in this manner the visitors to embrace to have the enlistment introductory. The emergency clinic the board can likewise get to the cloud subtleties by got patient id. The enlistment part comprises of subtleties like client name, email address, contact range. Once after enlistment, the clients are having the opportunity to be outfitted with ID. The ceaseless watching framework screens the information anyway it isn't shown on the observed till the verified patient logs in ID for distinguishing proof. The doctor enters the patients then the patient's subtleties like electrocardiogram(ECG), heart beat, SpO2 , beat, essential sign and blood glucose is shown on the screen. Likewise, the specialist's subtleties like name, login subtleties square measure hang on inside the information. The time, the specialist leaves the world is moreover hang on inside the information. This assists client with knowing the sum the doctor spent for a patient.

IV. METHODOLOGY

The sensors are interfaced with the Arduino and it senses the parameter from the body by sensor network [11]. The amount is set for every parameter and if it varies from the fixed limit it sends the alert message to the concerned physician and their belongings. The readings are continuously recorded and data's are stored through IoT module via Cayenne application. It's ready to view all the small print of the patients within the application and normal message is send via GSM module. Fig 1 shows the proposed organization structure .The health observing sensors are utilized to gather health related information for information securing data. Correspondence should be possible by regulator for sending information on web through the cloud. Information handling has been done at server. All information gathered and accumulated at server point [10]. To get health related data in justifiable organization it tends to be appeared on site page.

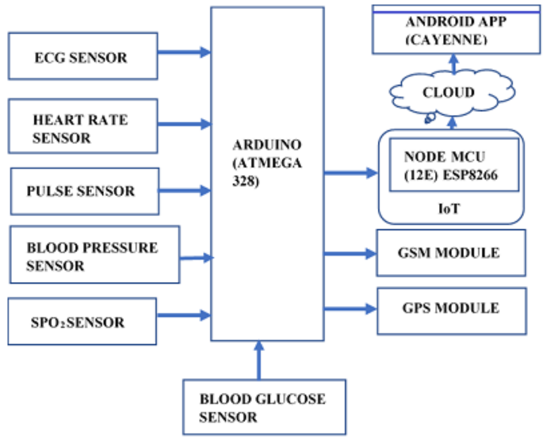

Fig.1 Remote Health monitoring System.

V. RESULTS AND DISCUSSION

The results are for instance that each one the modules are operating correctly with none data loss and every sub-module altogether modules are performing their function. The modules are extracting the accurate data and ready to send the info to the Arduino. The Wi-Fi module which is additionally a near by sensing module must send the values to the server with none delay and with none data loss. The cloud server must store all the info sent by the Wi-Fi module and disclose the info to the Cayenne application [12,13].

A. *Experimental Setup*

After checking all the pin connections and adding the library files to the Arduino IDE and uploading the source code, run the code.

Fig 2. Installation of remote health monitoring system

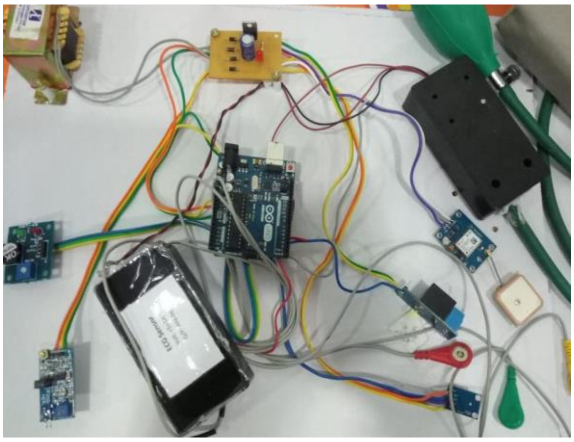

Fig.3 Simulation of program code on Arduino IDE

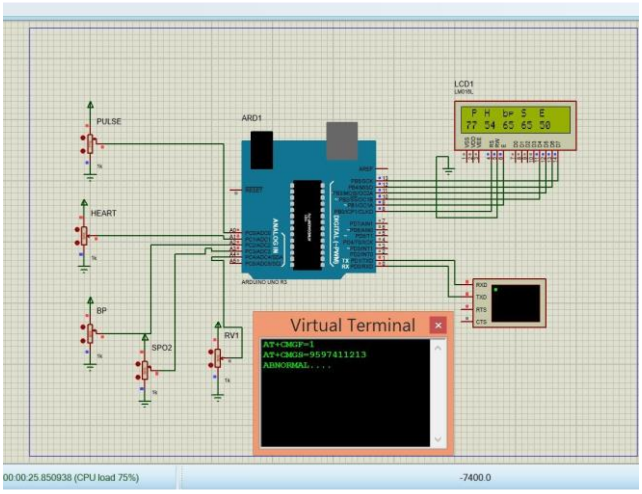

Fig.4 Simulation of prototype in Proteus

Fig.5 ECG waveform of a patient

The records of the patients are very critical because they involve the life risk, pertaining health on stake. So if any of the records get missed then it means a loss of health leading to mortality. Therefore, the proposed system is offering area memory storage in order that if there's any chance to disconnection of the medium of transmission then the information is stored within the local memory of the system like mobile. So whenever the connection get stabled then the batch will the sent to the CMS and can be get stored within the system.

Highlights of our project are as follows:

a. Highly smaller compact.
b. Low power utilization.
c. An alert will be raised when limit esteems are crossed.
d. In instance of crisis patient can be followed through GPS.
e. Real time checking of patient's fundamental boundaries like heartbeat, ECG, pulse, SpO2 and blood glucose.

Table 1 Tabulation of clinical values

S.NO	PATIENT	AGE	BLOOD PRESSURE	BLOOD GLUCOSE	SPO2	HEART BEAT
1	PATIENT1	52	120/83	78/140	96	92
2	PATIENT2	51	124/98	79/141	92	92
3	PATIENT3	70	134/98	84/134	92	89
4	PATIENT4	67	154/89	87/151	92	98
5	PATIENT5	54	134/80	81/142	92	92
6	PATIENT6	56	134/98	80/135	92	98
7	PATIENT 7	86	117/98	75/138	92	90
8	PATIENT 8	65	134/108	73/132	94	95
9	PATIENT 9	77	76/98	85/140	95	89
10	PATIENT 10	43	134/98	70/120	97	85
11	PATIENT 11	27	120/80	72/110	94	95
12	PATIENT 12	32	134/98	75/138	95	92
13	PATIENT 13	45	134/98	71/115	92	98
14	PATIENT 14	52	124/112	72/110	89	96
15	PATIENT 15	72	134/112	98/126	76	83
16	PATIENT 16	83	124/111	81/142	96	80
17	PATIENT 17	48	134/98	84/134	95	85
18	PATIENT 18	60	134/98	89/138	89	81
19	PATIENT 19	35	132/97	92/148	91	92
20	PATIENT 20	43	124/81	86/128	93	90

Table 2 Tabulation of measured values

S.NO	PATIENT	AGE	BLOOD PRESSURE	BLOOD GLUCOSE	SPO2	HEART BEAT
1	PATIENT1	52	129/87	89/139	95	91
2	PATIENT2	51	128/98	84/132	91	96
3	PATIENT3	70	128/99	87/137	92	87
4	PATIENT4	67	145/102	90/156	93	96
5	PATIENT5	54	138/98	86/147	94	95
6	PATIENT6	56	118/84	83/140	95	96
7	PATIENT 7	86	118/87	80/141	96	94
8	PATIENT 8	65	139/104	76/139	96	97
9	PATIENT 9	77	78/99	88/144	94	87
10	PATIENT 10	43	138/96	74/125	98	87
11	PATIENT 11	27	121/81	75/113	96	97
12	PATIENT 12	32	134/101	80/141	92	91
13	PATIENT 13	45	132/99	74/120	91	96
14	PATIENT 14	52	128/110	75/113	90	95
15	PATIENT 15	72	134/111	99/134	78	87
16	PATIENT 16	83	128/112	86/147	95	85
17	PATIENT 17	48	134/93	87/137	96	87
18	PATIENT 18	60	138/94	90/145	90	87
19	PATIENT 19	35	131/96	93/147	93	94
20	PATIENT 20	43	125/82	87/130	96	94

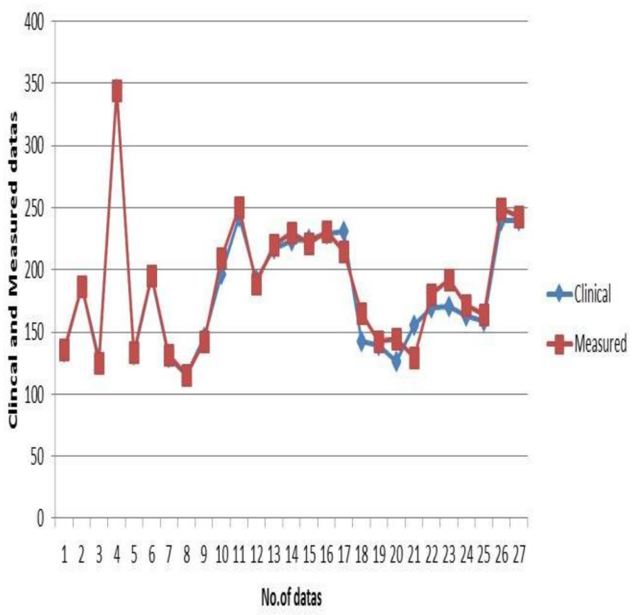

Fig 6. Comparison of in-vivo and non-invasive methods

The patient data of in-vivo measurements of pulse, heart beat, ECG, SpO2 and blood glucose measurement is compared with the remote monitoring recorded data. Therefore, fig.6 depicts the accuracy of the remote monitoring data in closeness to the clinical result.

VI. CONCLUSION

This paper gives the layout and improvement of an IoT device for the remote tracking of aged human beings dwelling in nursing homes, via a cell utility and a wearable device. The layout changed into primarily based totally on a contextual observe in geriatric residences, wherein semi-structured interviews have been implemented to the health care professionals liable for the care of the aged. IoT based medical care stage which associates with keen sensors connect with actual body for wellbeing observing for every day checking. In this paper, we examined about IoT based patient checking framework utilizing arising innovations empowered by advanced cells or devices henceforth has more benefits, faces difficulties and openings. Checking old individuals gadget can be manufactured and advertised at a compelling expense.

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REFERENCES

[1] J. H. Abawajy and M. M. Hassan, "Federated Internet of Things and Cloud Computing Pervasive Patient Health Monitoring System," *in* IEEE Communications Magazine, vol. 55, no. 1, pp. 48-53, January 2017, doi: 10.1109/MCOM.2017.1600374CM.

[2] E. Nemati, M. J. Deen and T. Mondal, "A wireless wearable ECG sensor for long-term applications," in IEEE Communications Magazine, vol. 50, no. 1, pp. 36-43, January 2012, doi: 10.1109/MCOM.2012.6122530.

[3] Kakria P, Tripathi NK, Kitipawang P. A Real-Time Health Monitoring System for Remote Cardiac Patients Using Smartphone and Wearable Sensors. Int J Telemed Appl. 2015;2015:373474. doi: 10.1155/2015/373474. Epub 2015 Dec 15. PMID: 26788055; PMCID: PMC4692989.

[4] P. Castillejo, J. Martinez, J. Rodriguez-Molina and A. Cuerva, "Integration of wearable devices in a wireless sensor network for an E-health application," in IEEE Wireless Communications, vol. 20, no. 4, pp. 38-49, August 2013, doi: 10.1109/MWC.2013.6590049.

[5] Majumder S, Mondal T, Deen MJ. Wearable Sensors for Remote Health Monitoring. Sensors. 2017; 17(1):130. https://doi.org/10.3390/s17010130

[6] Deen, M.J. Information and communications technologies for elderly ubiquitous healthcare in a smart home. Pers Ubiquit Comput **19,** 573–599 (2015). https://doi.org/10.1007/s00779-015-0856-x

[7] Aktas, F., Ceken, C. & Erdemli, Y.E. IoT-Based Healthcare Framework for Biomedical Applications. J. Med. Biol. Eng. **38,** 966–979 (2018). https://doi.org/10.1007/s40846-017-0349-7

[8] Min Woo Woo, JongWhi Lee, and KeeHyun Park. 2018. A reliable IoT system for Personal Healthcare Devices. Future Gener. Comput. Syst. 78, P2 (January 2018), 626–640. DOI:https://doi.org/10.1016/j.future.2017.04.004

[9] Durán-Vega, L.A.; Santana-Mancilla, P.C.; Buenrostro-Mariscal, R.; Contreras-Castillo, J.; Anido-Rifón, L.E.; García-Ruiz, M.A.; Montesinos-López, O.A.; Estrada-González, F. An IoT System for Remote Health Monitoring in Elderly Adults through a Wearable Device and Mobile Application. *Geriatrics* **2019**, *4*, 34. https://doi.org/10.3390/geriatrics4020034

[10] Santana-Mancilla PC, Anido-Rifón LE. The Technology Acceptance of a TV Platform for the Elderly Living Alone or in Public Nursing Homes. Int J Environ Res Public Health. 2017 Jun 8;14(6):617. doi: 10.3390/ijerph14060617. PMID: 28594386; PMCID: PMC5486303.

[11] C. F. Pasluosta, H. Gassner, J. Winkler, J. Klucken and B. M. Eskofier, "An Emerging Era in the Management of Parkinson's Disease: Wearable Technologies and the Internet of Things," in IEEE Journal of Biomedical and Health Informatics, vol. 19, no. 6, pp. 1873-1881, Nov. 2015, doi: 10.1109/JBHI.2015.2461555.

[12] Wan, J., A. A. H. Al-awlaqi, M., Li, M. *et al.* Wearable IoT enabled real-time health monitoring system. J Wireless Com Network 2018, 298 (2018). https://doi.org/10.1186/s13638-018-1308-x

[13] Varatharajan, R., Manogaran, G., Priyan, M.K. *et al.* Wearable sensor devices for early detection of Alzheimer disease using dynamic time warping algorithm. *Cluster Comput* **21,** 681–690 (2018). https://doi.org/10.1007/s10586-017-0977-2

Blue Ocean IoT Cloud based Early Warning System

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***Abstract*—Sumatra earthquake Tsunami of 2004 took 10,745 lives in India and 230,000 in fourteen countries. Govt. of India started Indian Tsunami Early Warning System (ITEWS) at INCOIS, Hyderabad. INCOIS and state coastal authorities deployed a sea-level network of coastal tide gauges and open ocean buoys to measure the changes in the water level, near the fault zone, where earthquake-triggered tsunami occurs. It started with 2 tsunami buoys in the Bay of Bengal and 1 in the North Arabian Sea and 25 Tide Gauges at 25 locations. This network now has 17 broadband seismic stations to detect tsunami-genic earthquakes, 90 national seismic stations, 7 open ocean tsunami buoys and 35 tide gauge stations. ITEWS also receives real-time data from 350 seismic stations, 50 tsunami buoys and 300** tidal gauges **of other international oceanic agencies. Also, more than 500 Argo floats capture temperature-salinity data at 20 levels, every 10 Days. Data from these Internet of connected things (IoCT) is ensembled and compared with satellite data from NOAA AVHRR, MODIS AQUA, and NCMRWF to generate multiple oceanic information products. Such integrated IoT Cloud system helps in creating an Integrated Ocean Observation System (OOS) which generates oceanic insights such as Potential Fishing Zone (PFZ), Wind speed and direction, Wave heights at the port level, and Tsunami warning. These services form part for an Early Warning System (EWS), which helps fishermen to take appropriate actions to avoid rough seas or take other preventive actions. ITEWS has successfully generated 101 IOR warnings, including 7 Tsunami warnings in last 10 years.**

Keywords*—*IoT, Ocean, Tsunami, Early Warning System, Wind Speed, Mobile application, Fishermen

I. INTRODUCTION

How big are the oceans? The Indian Ocean region (IOR) covers 73.56 million sq. km. or 20 percent of the world's surface. The IOR is subject to floods, droughts, cyclones, tidal surges, earthquakes, Tsunamis, etc. Hence it is also called the "World's Hazard belt". ESCAP report of 1995 highlighted that 50% of the global natural disasters occur in the IOR mainly driven by criminogenic and seismogenic (tectonically) disasters [1]. Asia-Pacific Disaster Report 2019 revealed that annualized economic loss potential of $675 billion due to various disasters [2].

Asia Pacific accounted for 2018's almost 50 percent of the worldwide natural disasters events (281). 2018's 8 out of the 10 deadliest disaster happened in this region, with Indonesia having two Tsunamis and one earthquake in quick succession, which resulted in nearly half of the region's deaths. A deeper analysis of these events indicates that these may not be an anomaly but rather a sign of things to expect in the future too. Hence, we need to create a holistic framework to study the IOR and associated oceanic weather patterns and seismic activities. 2004 Tsunami was an eye-opener in this direction, when the tsunami, one of the deadliest natural hazards in human history, killed more than 230,000 people in 14 countries, including 10,745 lives in India. After this disaster, in 2007 the Union Ministry for Earth Sciences set up The Indian Tsunami Early Warning System (ITEWS), at the Indian National Centre for Ocean Information Services (INCOIS), Hyderabad [3]. ITEWC focuses on detecting Indian Ocean tsunami-genic earthquakes and estimating their magnitude and direction of impact. It started with 2 tsunami buoys in the Bay of Bengal and 1 in the North Arabian Sea and 25 Tide Gauges at 25 locations.

A Real-Time Seismic Monitoring Network (RTSMN) was established. It is comprised of 17 Broadband seismic field stations. They use V-SAT communication satellites for data transmission. There is another global virtual subnetwork of IRIS Global Seismographic and GEOFON. Their 305 seismic stations transmit the raw data about earthquake epicenter, time of occurrence, and their magnitude. These are fed to a database system of all possible earthquake scenarios for the IOR. This helps in identifying the regions under risk at the time of the event.

Open sea tsunami buoys are used to detect the significant changes in sea-level at the time of occurrence of tsunamigenic earthquakes. These buoy systems can be equipped with bottom pressure sensor. Periodic readings of the waves can help generate a warning for coastal areas which will be potentially first impacted by a tsunami. This can be done even before the Tsunami waves reach nearby tidal gauges.

This internet of connected things (IoCT) helps in developing a decision support system aimed at monitoring the online input data from individual sensors, generating automatic alarms based on preset thresholds and decision rules for one or many of the input parameters. This could also

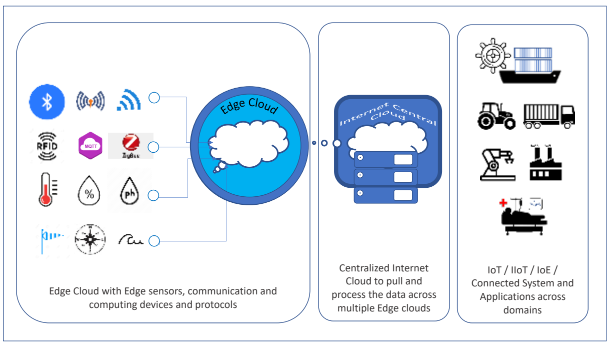

Figure 1 IoT Edge, IoT Cloud and application systems

execute criteria-based analysis for one or more input parameters or scenarios and generate online advisories.

These advisories were relayed through API systems to various end-user communication methods and applications such as mobile phones, web applications, and SMS alerts. These formed the early warning system (EWS) for the vulnerable community. They used the disseminated information and the threat levels such as Warning, Alert, Watch, or Information, to follow the standard operating procedure (SOP).

II. Internet of Things (IoT) Cloud

The Internet of things (IoT) is defined as the network of physical objects, called "things", which may have sensors and software to collect data and connect and exchange data with other devices and systems over the Internet [4]. Recommendation of ITU-T Y.2060 (06/2012) defined IoT as "a global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies" [5].

An IoT cloud is a big network of such IoT devices, software applications, messaging protocols, to achieve a particular objective. [6] Once the sensor data reaches the cloud, the software application processes it and then takes an action, such as sending an acknowledgment to the IoT sensor, or adjusting them automatically or raising an alert to the user. Hence, an IoT cloud forms the basis of an autonomous system, which can help manage the explosive growth of various operation technologies (OT), push time-critical and smart decisions to be taken at the edge that is devices itself, and only refer to the cloud when more intensive computation is needed or historical data analysis is required (see Fig. 1).

As shown in Fig. 2, INCOIS has established a comprehensive ocean observation system (OOS) program using a fleet of In-situ IoT sensor platforms and remote sensing data sources [7].

In-situ observations IoT cloud systems include,

- Argo Profiling Floats
- Data Buoys
- Current Meter Arrays
- XBT / XCTD, Gliders
- Tide gauges
- Bottom Pressure Recorders (BPRs)

Besides, it also collects the data from Remote Sensing Satellites such as

- Oceansat-1 (Ocean Color Monitor) and Oceansat-2 (Ocean Color Monitor, Scatterometer)
- Other International satellites such as NOAA AVHRR, MODIS AQUA, etc.

Hence, the mixing of the data from different IoT Cloud systems of Satellite Oceanography and National Oceanographic Data Centre is assimilated. These data are fed to Ocean Models running on high-capacity and high-performance computers (HPCs) to generate various value-added oceanic information services. It includes:

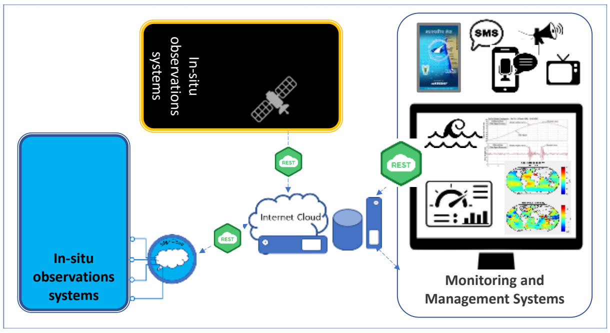

Figure 2 Integrated ocean observation system (OOS) – data Assimilation from different IoT Cloud systems to create a plural analytical and advisory service

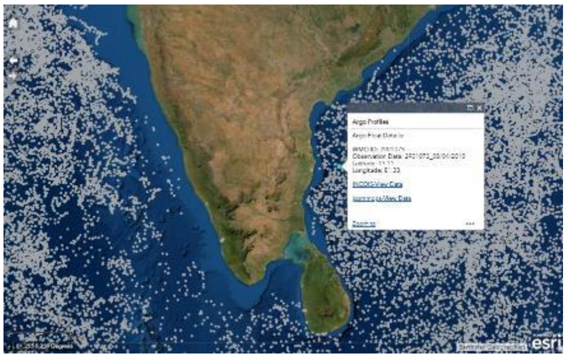

Figure 3 Argo Data view in the Indian Ocean

- Potential Fishing Zone (PFZ) information
- Ocean State Forecast (OSF) Services of Wind Speed and Direction, Wave height, Storm Surges
- Early Warning for Tsunami
- Ocean Modelling System, Ocean Data and Information System (ODIS), Web-based Services, Coastal Geospatial App and various APIs.

This information is distributed through multiple channels of Television, Radio, digital display boards, web app, mobile app, text, and voice SMS. Beneficiary stakeholders include,

- Fishing Community
- Ports and Harbors, Off-shore and Shipping, Navy
- Coast Guards, Coastal States extension services
- Research Institutions and Academia

A. *In-situ observations IoT Cloud system*

1) *Argo Profiling Floats*

Argo is an international program using profiling floats to collect ocean temperature, salinity, sea currents, pressure and other bio-optical properties. Some floats also collect biogeochemical data such as oxygen, pH, nitrates, chlorophyll. These are useful in climate and oceanographic research [8].

These are a cluster of robotic instruments. They keep drifting with oceanic currents. They move up and down between the surface and a mid-water level say at the depth of 2000 m. Every 10 days they come to the surface, transmit the data to the satellite and then return to the original position. There are approximately 4000 active floats across the globe, producing 100,000+ temperature/salinity profiles per year. INCOIS has approx. 400 active floats. Fig. 3 shows the all floats in the Northern Indian Ocean [9]

2) Data Buoy

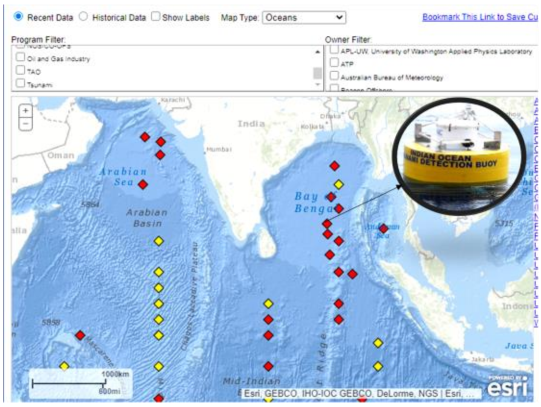

Figure 4 Data buoy in the Northern Indian Ocean. Inset – Station 23227 in the Bay of Bengal, managed by INCOIS. SAIC Tsunami Buoy SAIC Tsunami Buoy (STB) with DART II BPR, 6.255 N 88.792 E (615'17" N 88°47'31" E) Water depth: 3793 m

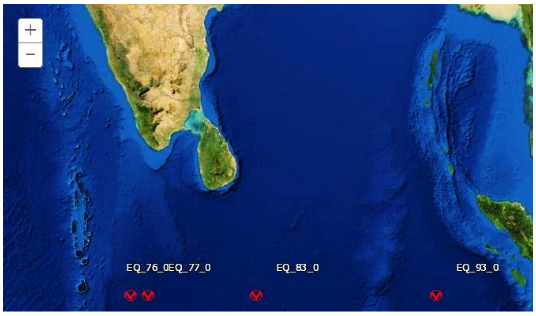

Figure 5 Current Meter Arrays

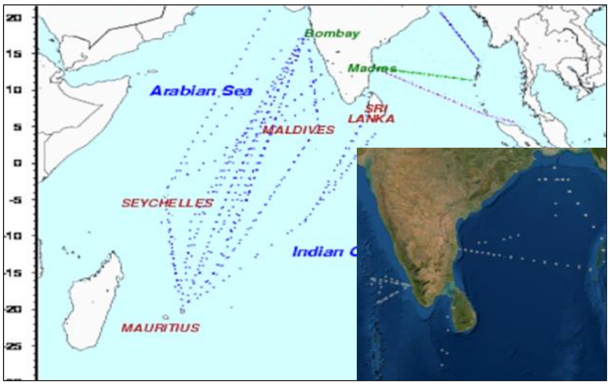

Figure 6 XBT / XCTD Observations in Northern Indian Ocean

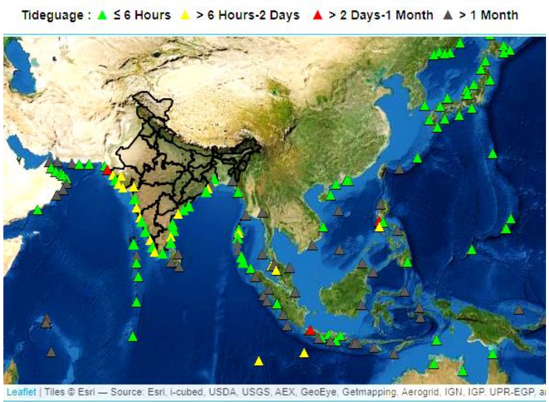

Figure 7 INCOIS – In-situ tidal data – Real-time

A data buoy contains various sensors to monitor and collect atmospheric and oceanographic data. They have sensors to measure wind speed and direction (WSD), air temperature, atmospheric pressure, sea surface temperature (SST), ocean current speed, and direction and wave parameters such as height. See Fig. 4. They are equipped with a global positioning system (GPS), beacon light, and satellite transceiver. Few buoys are fitted with sensors to measure radioactivity, turbidity, chlorophyll, and dissolved oxygen in the ocean waters and may have a camera too [10].

These buoys are IoT Cloud platforms, capable of data logging and processing at the edge. The data transmission is through two-way communication, through INMARSAT-C or other satellite terminals [11]. NIOT Chennai has a shore station to receive, store, process, and analyze the data. It also transmits and disseminate the data to other user agencies like INCOIS for further computation and analysis.

3) Current Meter Arrays (CMA)

As shown in Fig. 5, INCOIS has installed arrays of Current Meter Moorings (CMM) along the equator [12]. This helps in understanding the dynamics and the long-term variability of the ocean currents, deep-sea circulation in the equatorial Indian Ocean. CMA helps to study the upper ocean variability in the thermohaline structures, currents (VM-ADCP and LADCP), nutrients, chlorophyll, and primary production in IOR, especially in the Bay of Bengal.

4) XBT and XCTD

Expendable Bathythermograph (XBT) is a probe used to measure upper oceanic temperature throughout the water column up to 760m in depth. They are placed along selected shipping lanes across Mumbai - Mauritius, Chennai - Port Blair, Port Blair - Kolkata, Chennai - Singapore, and Kochi - Lakshadweep. See Fig. 6. The bimonthly data from XBTs are transferred to INCOIS for download and analysis [13].

Expendable conductivity-temperature-depth (XCTD) is a profiler instrument to capture water temperature and conductivity of the ocean water depth in a large area. It is transmitted to the data buoy which acts as an IoT Edge cloud, where it is recorded for further analysis.

XBT and XCTD (257 / 92) profiles of the Indian Ocean were analyzed in one year. INCOIS is also planning to deploy 900 XBT probes along the major shipping routes of Chennai-Andaman-Calcutta and Bombay-Mauritius. This will help to monitor the upper ocean thermal structure in IOR.

5) Tide gauges

Periodic tidal oscillations are like the breathing pattern of the oceans. Tide gauges (TD) are installed in ports, harbors and some strategic locations to measure the water levels. Tidal predictions are important for navigational purposes. As shown in Fig. 7, TD data analysis helps in estimating the approaching pattern of oceanic disasters like storm surges or tsunamis. Long time series of tide gauge data is used to study sea-level changes associated with global warming [14].

The acoustic TDs measure the time taken by acoustic pulses to reflect vertically from the ocean surface. 1-minute averages data is transmitted every 5 minutes interval through VSAT, GSM, and INSAT from 100s of national and international Tide Gauges.

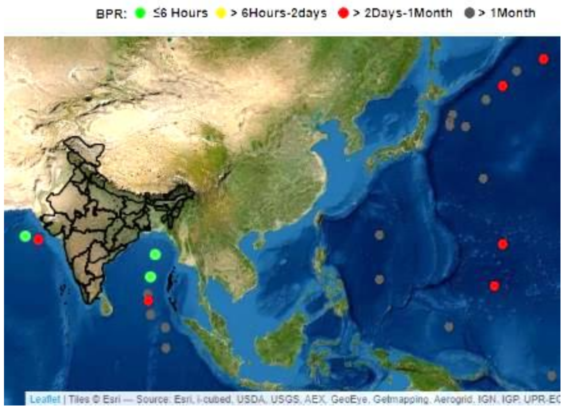

Figure 8 Bottom Pressure Recorders (BPRs) in IoR

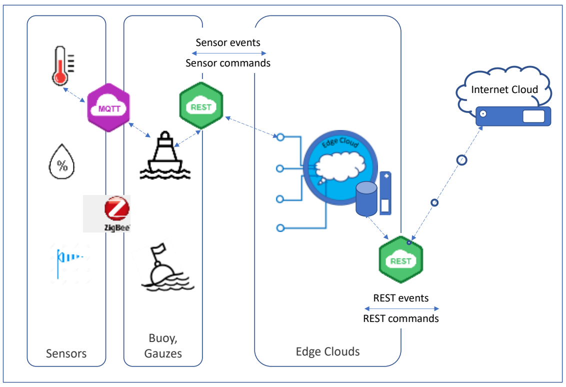

Figure 9 Pictorial representation of the core IoT Edge of the BPR

6) Bottom Pressure Recorders (BPRs)

BPRs is the core IoT edge component of the Tsunami Early Warning System. BPRs identify the sea-level changes in the source region of tsunami genic. This helps in building the propagation of Tsunami waves, speed, and spread in the rest of the open ocean.

As part of the ITEWS, a real-time IoT cloud network of Deep Ocean Assessment and Reporting Tsunamis (DART) has been established by the National Institute of Ocean Technology (NIOT) consisting of 12 BPRs. They transmit real-time data to NIOT Chennai and INCOIS Hyderabad. Arrangement of the BPR is in such a way that they give 30- and 60-minutes interval data of the arriving tsunami wave. This not only helps in differentiating the signals from the tsunami wave versus the seismic Rayleigh signals in the earthquake region but also provides redundancy, enough time for warning and action [15]. As shown in Fig. 9, India has four and two BPRs in the Bay of Bengal and the Arabian Sea, respectively.

The BPR operates in one of two data reporting modes: Normal mode and Tsunami Response Mode. Normal mode is a low power, scheduled transmission mode, in which samples are taken every 15 min and transmitted every 1 hour. Tsunami Response Mode is a triggered event mode. In this mode, samples are taken every 15 seconds and transmitted every 5 minutes [16].

The core IoT Edge of the BPR uses a piezoelectric pressure transducer to make 15 seconds-averaged measurements of the pressure exerted on it by the overlying water column. The Tsunami detection algorithm running at

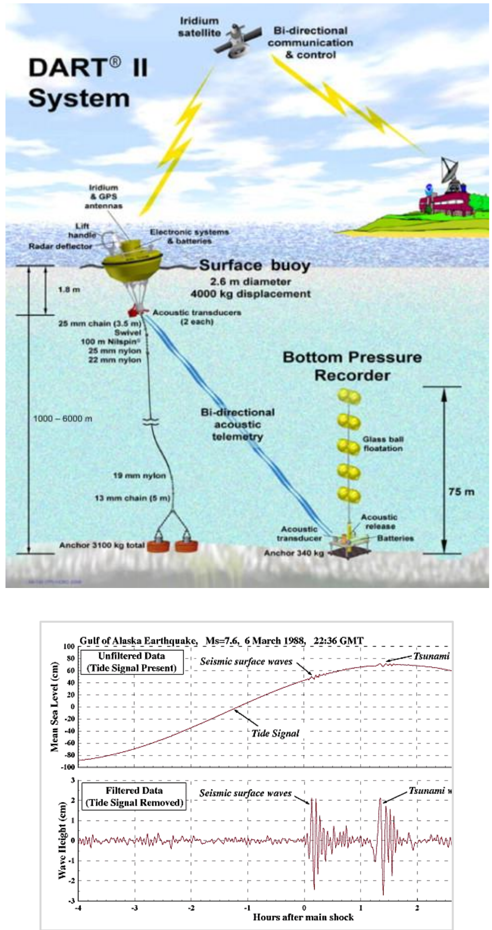

Figure 10 DART II system using BPR. Observations from Gulf of Alaska Earthquake and observations from Tidal signal, Seismic surface waves and Tsunami waves event. Source: DART II System organizations

the edge cloud generates predicted water height values within the tsunami frequency band and compares all new observed samples thereafter with these predicted values.

If two 15-second water level values exceed the predicted values greater than the threshold (e.g., 30 mm), the system switches the mode from Normal mode to Tsunami Response Mode. An acoustic link transmits data from the BPR on the sea floor to the surface data buoy. The data are then relayed via a satellite (e.g. INSAT) communication finally to the ITEWS.

Each BPR system has a two-way communication link. They transmit and receive data from Tsunami Warning Centre. The data center at INCOIS is equipped with state-of-the-art computing hardware for data reception, which includes, INSAT two-way communication hub, data processing & visualization, and dissemination facilities. ITEWS can remotely trigger the tsunami response mode of BPR Edge nodes, at any time. They can also gather BPR health or the tsunami response mode data.

Fig. 8 depicts the results observed from the Gulf of Alaska Earthquake on 6th March 1988. When the tidal signal was removed, a correlation between the seismic surface waves height and Tsunami waves height was observed. This system deployed at 6000m of ocean floor helped detect 67 BPR records, 21 Tsunami records, and 7 Tsunami events [17].

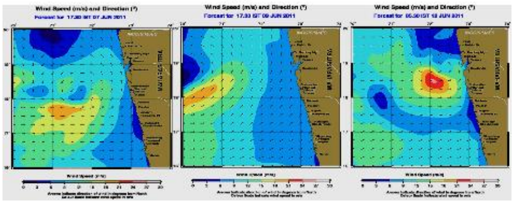

Figure 11 Wind Speed and Direction forecast service images – source mKRISHI® Fisheries

B. *Remote Sensing Satellites observations Cloud system*

The Remote Sensing Satellites Observations Cloud system receives the data from NOAA and Terra and Aqua Satellites.

NOAA-AVHRR is Advanced Very High-Resolution Radiometer, which includes image data products such as sea surface temperature, Cloud classification (Clear, Sun glint, Low, High & Part), Visible bands, (Radiance/Reflectance), fog, NDVI, etc.,

MODIS (TERRA/AQUA) Data products include atmospheric data like Aerosol (Type, Optical Depth), Water vapor (IR & Near IR), Cloud (BT's, Fraction, Face, Optical Thickness, Effective Particle Radius), Fog (Day & Night fog product) and Profiles (Moisture, Temperature, Lifted Index, Water Vapor). It also includes ocean parameters like Chlorophyll-a, Kd-490, POC-Clark, TSM-Clark, Calcite, etc. [18].

It also gets the Ocean color monitor (OCM) data from Oceansat-2

These data products from different satellite passes are stitched together and then analyzed to generate advisory services like the Potential Fishing Zone (PFZ). As shown in Fig.11 it is used to generate the wind speed and direction images too.

III. INTEGRATED INTERNET OF THINGS (IOT) CLOUD

The Architecture of each of the above IoT cloud can be represented by a conceptual Amazon AWS architecture shown in Fig. 12(a) and 12 (b) where each IoT cloud pushes the data through AWS IoT core which will be passed to the REST API / services subscribed to the data. Each IoT edge cloud has two major components – Intelligent Edge Computing and embedded analytics functions such as 'Inference', 'predictions' at each Edge cloud.

1) *Edge Computing*

Computing integrates conventional edge devices and services. It supports various connection within various nodes at the edge and manages the local storage. It performs the required basic, incremental, or anomaly calculations, at this stage the convergence of operational technologies and information technologies occur.

2) *Embedded Analytics*

The embedded analytics functions give the 'Autonomous' state to the edge. It maintains a low amount of history and state of the devices and runs rule-based algorithms to take a localized decision. This is embedded in an AI platform at the edge which can collaborate with the AI platform at the central Cloud. This not only improves the speed in action but also reduces the communication payload, increasing the overall battery and equipment life.

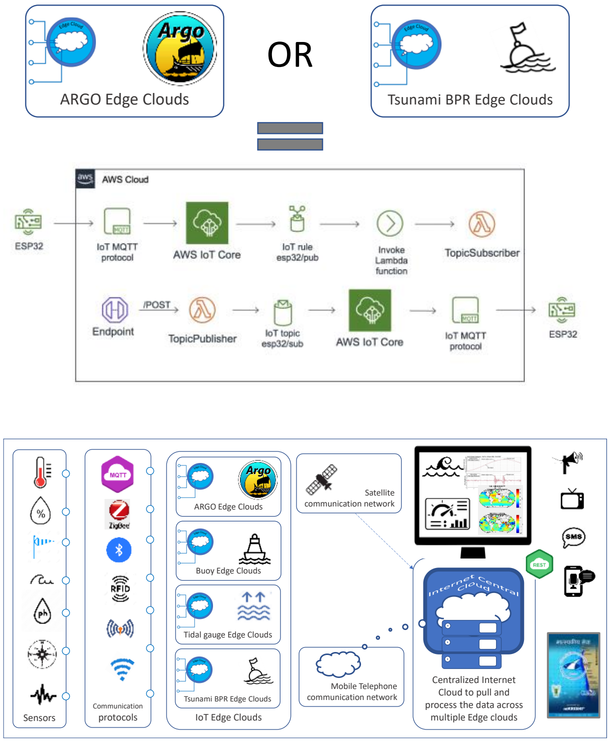

Figure 12 Integrated IoT Cloud – Data flow from IoT Edge to IoT Cloud to Internet Cloud – (a) conceptual using AWS and (b) equivalent ocean observation system (OOS for EWS)

3) *Data Pipelines*

Data received from multiple edge clouds such as the Argo platform, Moored and Drifting Buoy, Current Meter Mooring, and XBT, etc. are assembled into a common data cloud repository. As per the predefined metadata template, this data is processed in a standardized format. Data undergoes the quality control process as per the predefined quality control procedure to generate uniform data sets for further processing.

4) *Data and Insight Publishing*

Processed data is published through the various channels for consumption. They are published as API service, or web applications, or mobile applications and/or available for download as CSV or XLS, or PDF files. Various insights like processed Tidal gauge data and Bottom pressure recorder data is used at TIEWS for Tsunami monitoring. It is also used to generate PFZ and Wind Speed/direction forecasts for the fisheries sector.

5) *Early Warning System (EWS) – Advisory for fishermen*

INCOIS acquires the sea surface temperature, weather, and phytoplankton data from oceanic IoT edge nodes and NOAA satellites. It produces Potential Fishing Zone (PFZ) and Ocean State Forecasts. APIs are used to fetch the data for different coastal states for seven days in advance, refreshed four times a day. This content is made available in the mKRISHI® Fisheries Android application in eight Indian local languages [19]. This helped fisherfolks, their family, and other ecosystem stakeholders to identify the ocean risk zones, occurrence date and time of the hazardous situation, and cyclones in advance (see Fig. 13). This helped fisherfolks to re-plan their journey. This data-driven pre-planning helped reduce the risk exposure and hence saving the lives of many fishers.

Figure 13 Early Warning System – mKRISHI® Fisheries mobile application

IV. CHALLENGES

This approach streamlines the overall communication between the edge and central computing server but is not that easy. Some of the major challenges are:

- Lack of standardization among the IoT device in terms of hardware modules for sensing, storage, computer, and communication.
- Varying technology stacks of communication software modules, protocols, payload type and size, error handling.
- Software API variation, which leads to difficulty in orchestration at the edge cloud level and at the central cloud level
- Distributed workload, which leads to inefficient load balancing and resource allocation among the IoT sensor box or edge components.
- Design of EWS – Since most of the stakeholder had low digital and educational literacy, designing a mobile app service was quite tricky. We had to conduct multiple design thinking interactions with the fisheries stakeholder to arrive at the best suited, simple to understand, and use design for the early warning system applications [20].

V. RESULTS AND BENEFITS

Before Argo, ocean and climate scientists had to rely on sparse temperature or salinity measurements either conducted by commercial and research vessels, or a limited number of stationary moorings. But those would introduce huge spatial biases due to oversampling in heavily traveled shipping lanes

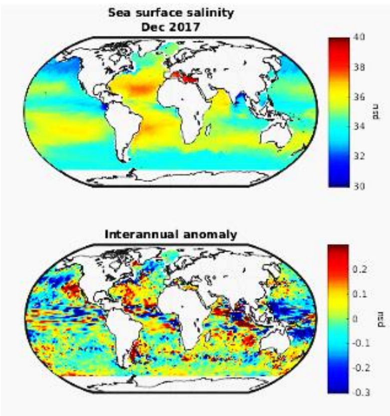

Figure 15 Sea surface salinity – source argo.ucsd.edu/

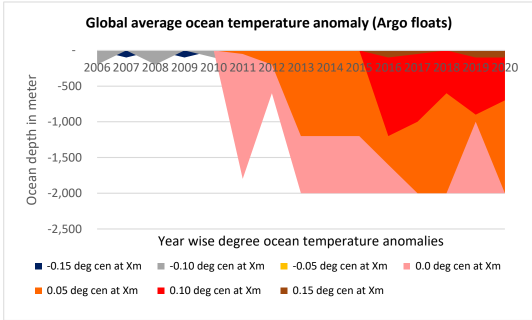

Figure 14 Global average ocean temperature anomaly (Argo floats)

and temporal biases as in high latitudes due to harsh winter conditions ship travel used to be restricted. This global and all-season, coverage is crucial to detect climate change signals, because, within and between major ocean basins, heat is constantly transferred around different areas. And seasonal cycles in some regions can overshadow interannual variability. The Integrated IoT Cloud approach provides a continuous universal information to quantify longer-term changes ocean changes, mainly at two levels.

The upper 2000-meter water column provides a signature of the anthropogenic change in ocean heat content over two decades. This much depth is enough to look beyond the seasonal temperature and salinity cycles impact, into the regions of the ocean that are dominated by decadal warming trends [21].

Fig. 15 shows an average of the sea temperature anomalies, up to 1900 meters in depth. This is based on the data measured by the Internet of Argo floats (IoAF) since 2004. While temperatures in the upper ~600 meters fluctuate with shorter-term climate events like El Niño-Southern Oscillation, deeper waters display a consistent warming trend. This indicates Earth's atmospheric warming.

Warmer air can withhold and carry more moisture. With the continuous increase in the average global temperature, existing patterns of evaporation and precipitation will intensify further. This will mean higher drought risk for the arid regions and flooding in the wet region.

Argo salinity data can be used to quantify changes in the hydrological cycle related to climate change. Fig. 14 shows the monthly Argo salinity data from 2004 onwards. It also has a monthly difference of monthly salinity versus average salinity for that month over decades. It shows a clear salinity increase in salty regions (for example, the Northern Arabian Sea) and a decrease in salinity in fresh areas (for example, the North Bay of Bengal).

Integrated EWS is a tool to save lives and livelihood, both. CMFRI Mumbai Research center conducted a study in 2015 across 13 fisheries co-societies in Raigad, Maharashtra. The study found that the fisherfolks saved approximately 30 percent of high-speed diesel when they planned their trip based on the information from the mKRISHI Fisheries app. It not only helped in saving the cost of the fisheries trip but also reduced the CO_2 emission, as an estimated 1.2 percent of global oil production is consumed for fishing. Early warning systems also helped in safe and secure fishing [22]. In 2016, Min. of External Affairs (Govt. of India) and NITI Ayog recognized mKRISHI® Fisheries as Top 20 Mission-Driven Social Impact Innovations in India.

Deployment of the drifting buoys generates in-situ data, as well as validate the satellite data. This helps augment the ocean observations using satellite and increase the accuracy of the macro analysis from satellite data due to the feedback of the microanalysis by the in-situ buoys. This helps in achieving scalability at a lower cost of deployment.

DART cloud using BPRs helps in early detection, near-source siting, and real-time reporting of the Tsunami. INCOIS system estimates risk in coastal areas, wave height that can hit them, or riskier coastal vulnerable buildings. Using GIS mapping of the vulnerable regions, administrators can generate a simulation of the extent of inundation.

The ITEWS can now detect IOR tsunami-genic-earthquakes within 10 minutes of their occurrence and can disseminate the advisories to the concerned regional authorities. Over the last 14 years, ITEWS has monitored nearly 630 earthquakes of a magnitude of about 6.5 magnitudes [23]. Out of these, 101 occurred in the IOR, leading to Tsunami on 7 occasions. Due to a coordinated effort, warnings were issued in less than 10 min. to 25 IOR countries either through fax, email, SMS.

VI. Conclusion

Ocean has large volume. It can also transfer heat from its surface to its deeper level. Hence it acts as a heat sink for Earth and 90% of the excess heat absorbed by the Earth is stored in the oceans. Integrated IoT EWS helps in the study of the ocean to better understand the spread of climate change and its adversarial impact in an objective manner.

Tsunami early warning is a race against time. Adversity leads to take a systematic and holistic approach, and the early warning system has progressed into a multi-hazard framework encompassing multiple types of IoT cloud edge systems. It generates multiple value-added digital info services such as storm surge, cyclone warnings which benefit the society, especially the coastal population and fisherfolk, saving lives and damage to property. Because of all these, India has become the first country in the Indian Ocean Region to achieve the Tsunami Ready recognition.

Acknowledgment

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References

[1] Dr. Mohammad Abdur Rob, "Natural Disasters in Indian Ocean region and its Impact on SocioEconomy of the Countries", Jan. 12, 2021. [Online]. Available: http://www.ions.global/sites/default/files/7f_0.pdf.

[2] UN Economic and Social Commission for Asia and the Pacific. Committee on Disaster Risk Reduction, 6th session. (2019, August 28-30). *ESCAP/CDR/2019/1, Item 2 of the provisional agenda of Changing geography and intensification of disaster risks in the Asia-Pacific region*. [Online]. Available: https://www.unescap.org/sites/default/files/Summary%20of%20the%20Asia-Pacific%20Disaster%20Report%202019_English.pdf

[3] INCOIS. *Indian Tsunami Early Warning Centre User Guide Version-1*. (2011) Accessed: Jan.16, 2021. [Online]. Available: https://incois.gov.in/documents/tsunami/ITEWC_NTWC_UserGuide-Version1_Final.pdf

[4] Alexander S. Gillis. (2019). internet of things (IoT). IOT Agenda. . Available: (accessed 10 March 2021). https://internetofthingsagenda.techtarget.com/definition/Internet-of-Things-IoT.

[5] *Internet of Things Global Standards Initiative*, Rec. ITU-T Y.2060, International Telecommunications Union, Geneva, Switzerland. 2012.

[6] "What is IoT Cloud." Arm.com. https://www.arm.com/glossary/iot-cloud (accessed Feb. 1, 2021).

[7] Suprit Kumar. (2018). Indian Data Buoy Program and Data Analysis. Discovery and Use of Operational Ocean Data Products and Services, [PowerPoint slides]. https://classroom.oceanteacher.org/pluginfile.php/17974/mod_resource/content/1/L2%20Indian%20data%20buoy%20%20program%20and%20data%20analysis.pdf

[8] "What is Argo?." Agro.edu. https://argo.ucsd.edu/. (accessed 10 March 2021).

[9] "Present Status of Argo Floats in Indian Ocean." https://incois.gov.in/argo/AFAll.jsp (accessed 10 March 2021).

[10] Meindl, Eric A., and Glenn D. Hamilton. Programs of the national data buoy center. Bulletin of the American Meteorological Society 73, no. 7 (1992): 985-994.

[11] Sundar, R., R. Venkatesan, M. Arulmuthiah, N. Vedachalam, and M. A. Atmanand. "Development and performance assessment of a hybrid telemetry system for Indian tsunami buoy system." Underwater Technology 33, no. 2 (2015): 105-113.

[12] Murty, V. S. N., M. S. S. Sarma, A. Suryanarayana, D. Sengupta, A. S. Unnikrishnan, V. Fernando, A. M. Almeida et al. "Indian moorings: Deep-sea current meter moorings in the Eastern Equatorial Indian Ocean." (2006).

[13] Boyer, Tim, V. V. Gopalakrishna, Franco Reseghetti, Amit Naik, V. Suneel, M. Ravichandran, NP Mohammed Ali, MM Mohammed Rafeeq, and R. Anthony Chico. "Investigation of XBT and XCTD Biases in the Arabian Sea and the Bay of Bengal with Implications for Climate Studies." Journal of Atmospheric and Oceanic Technology 28, no. 2 (2011): 266-286.

[14] Faridatunnisa, Maritsa, and Leni Sophia Heliani. "Study of Sea-level Rise Using Tide Gauge Data Year 1996 to 2015 at Semarang and Prigi Stations." In 2018 4th International Conference on Science and Technology (ICST), pp. 1-4. IEEE, 2018.

[15] Ramadass, Gidugu Ananada, Narayanaswamy Vedachalam. "A study of the algorithms for the detection of tsunami using an ocean bottom pressure recorder." Marine Technology Society Journal 48, no. 1 (2014): 76-83.

[16] Srinivasa Kumar, T., Patanjali Kumar, and Shailesh Nayak. "Performance of the Indian tsunami early warning system." The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences 37, no. 8 (2010): 271-274.

[17] "BPR Technology - Bottom Pressure Recorder." https://nctr.pmel.noaa.gov/Review98/Talk/gonzalez_r98_3.html. (accessed 10 March 2021).

[18] Nayak, R. K., S. K. Mishra, Nagamani PV Satyesh Ghetiya, S. B. Choudhury, and M. V. R. Seshasai. "REMOTE SENSING APPLICATION IN SATELLITE OCEANOGRAPHY." *REMOTE SENSING* Vol. 93, no. 2 (2018): 156-165.

[19] Singh, Dineshkumar, Divya Piplani, Sujit Shinde, and Srinivasan Karthik. "mKRISHI fisheries: a case study on early warning system (EWS) for disaster communication and management." In 2016 IEEE International Symposium on Technology and Society (ISTAS), pp. 1

[20] Singh, Dineshkumar, Divya Piplani, Karthik Srinivasan, and Sujit Shinde. "Visual design for blue ocean services: mKRISHI® fisheries." In Proceedings of the 8th Indian Conference on Human Computer Interaction, pp. 96-101. 2016.

[21] "X1 – Argo and the warming ocean." https://argo.ucsd.edu/science/argo-and-climate-change/. (accessed 10 March 2021).

[22] Singh, V. V., and Dinesh Kumar Singh. "mKRISHI® Fisheries-A Blue Ocean Innovation." Marine Fisheries Information Service; Technical and Extension Series 230 (2016): 3-6.

[23] "Tsunami warning system at INCOIS monitored nearly 630 earthquakes of 6.5 magnitude." https://www.thehindubusinessline.com/news/national/tsunami-warning-system-at-incois-monitored-nearly-630-earthquakes-of-65-magnitude/article33417257.ece. (accessed 10 March 2021).

Development of Touch Less Smart Toilets and Sewage Monitoring System Using IoT*

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***Abstract*—As institutional, commercial and public spaces start to re-open across the nation, experts from medical domain have repeatedly cautioned of the possible dangers of sharing confined spaces with others, which has urged renewed queries concerning the safety of our public Toilets, washrooms and restrooms. Durability and convenience were once the two vital considerations in designing washrooms. Today, user wellbeing and health have become equally significant. Harmful viruses and bacteria are majorly aerosols from toilet basins and urinals. The objective of this project is to build up a smart toilet and smart anaerobic sewage tank system to address the problem of airborne bacteria/virus transmission from sewage tank and toilet basins. In the first phase of this project, this device will restrict the disseminate of harmful virus/bacteria by automatically closes the lid, and does auto flush, even before their ejection into the air. In the second phase, ultrasonic sensor monitors the anaerobic sewage tank system to prevent overflow. The proposed system displays the real time liquid sewage level in the LCD monitor and indicates the maintenance team for the need of disposal as the level exceeds certain threshold. In this project design, a servo motor and a battery operated DC geared motor along with a Turbidity, Ultrasonic and Infrared Sensors operates in unison with an Arduino UNO microcontroller to build the smart toilet device. In addition hygiene monitoring, compliance is embedded in the proposed system using Radio Frequency Identification techniques.**

***Index Terms*—IOT , IR sensor, turbidity sensor, UV sensor, RFID reader**

I. Introduction

As the covid-19 cases started increasing exponentially, worldwide focus re-centered on Corona Virus and its prevention mechanism (See Figure:1). COViD-19 mainly disseminate through droplets either from mouth or nose when speaking or coughing. It is also possible to get affected by touching surfaces with virus droplets [1]. COVID-19 raised consciousness among people worldwide, of the need to remain watchful in the confined spaces where the probability of disease spread is extremely high. A public toilet is most unsafe space. The origination of the communicable aerosols out of the toilet basins is the common source of syndrome transmission, alike to sneezing and coughing, but usage of the toilet is unavoidable. Hence, it is significant to determine methods to prevent transporting the virus outside the confined toilet space.

Preventing interaction with the flush button, toilet seat covers effectively lowers the likelihood of catching any type of bacteria/virus. Flushing without closing the toilet lid will lead to virus and bacteria contaminating the whole toilet space [2]. Toilet basins are un-hygienic places that comprise hazardous viruses and bacteria that contaminate humans when pouring water expels out these viruses and bacteria from the toilet basin. J. Barker and M. V. Jones stated that the toilet flushing action will lead to the complete contamination of the whole confined toilet space. Once flushed, the bacterial (Serratia) denseness in the atmosphere can rise from 14 Colony Forming Unit CFU m3 to 1360 CFU m3, this implies that there are 1000 times more viruses and bacteria units aerosolized, which are highly hazardous, that a person can devour. Such viruses and bacteria stick to the various toilet surfaces for more than 50-60 minutes [3]. National institute of health indicates that new coronavirus-Covid-19 may stay on few surfaces like plastic for few days. The coronavirus, in aerosol form can stay active in a confined toilet space for up to three days, which plays a major route for infection transmission [4]. Hence an automatic toilet lid /seat closure is a suitable technique for stopping the disseminate of these viruses and bacteria. The prime objective of the project is to design a secondary device for the toilets to automatically close the toilet seat lid before flushing to reduce the interaction with the contagious toilet surfaces where different kinds of bacteria and viruses often exist.

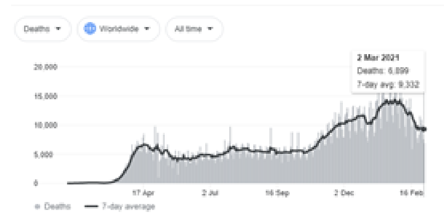

Fig. 1. COVID-19 World Wide-Death Rate-2nd March 2021

The rest of the paper is catalogued as follows, Section 2, presents related work of smart toilet designs. In Section 3 we introduce the proposed smart toilet and sewage monitoring system design using IoT. In Section 4 presents the working model and discussion and Section 5 concludes the work.

II. Related Work

Banait, P. (2019), used array of sensors like gas and UV sensor to detect the water level and smell. Arduino UNO microcontroller is used in this process. The objective of this paper is once dirt is detected, it triggers the fan, water motor and automatic flusher [5]. Begam, S. A. (2019) used sonic, gas, IR sensor and RFID to detect smell and dirt level and signals the monitoring team through LCD display and buzzer [6]. Mithya, V. (2019) used turbidity, gas sensor for determining the dirt, unwanted gas and bacteria in the toilet area. GSM and Wi-Fi module is used for alerting and messaging the maintenance team [7]. Sujeetha R (2019). Developed a system to monitor water quality and detect foul odour using NodeMCU micro-controller / ESP8266, alert system is used for messaging the need for maintenance [8]. Sudha, V. (2018) reviewed modern technologies which are used in public toilets. The objective is to reduce the water consumption, assist visually challenged to use the lavatory and monitor user health using array of sensors [9]. Elavarasi, K. (2018) , the objective is to detect unwanted gases present in the toilet and also the depth of septic tank, using array of sensors and PIC 16F877 . Once the dirt is detected the system sends the message through GSM module . In this paper RFID scanner is also used for monitoring and storing the maintenance log [10] . Katariya, D. (2018), used MQ4 , MQ135 sensor with microcontroller UNO, to detect the Odour, Methane and Ammonia content in the toilet. A robotic arm type of brush is used to automatically clean the toilet basin without human intervention. This appliance is developed for railway toilet management [11]. Muntashar, N. (2018) used array of sensors to detect toilet health and to monitor the water level. GSM module is used for alerting the maintenance team [12]. Sangwan, S. (2017), the objective is to detect the user health by collecting the urine, stool and spit samples. Post processing of these samples are done to determine Kidney stone, Sugar level, Urinary tract infection, Pregnancy, Fecal occult blood, fecal pH / Acidity test and alcohol presence [13]. Hashemi, S. (2015), used array of sensors and controllers to detect unwanted odor and gas. The prime objective is to reduce the water usage in toilets. This project also focus to separate solid and liquid waste [14].TableI shows the review of smart toilet designs in detail.

It is observed from the literature, most of the smart wash-rooms focus mainly on sewage maintenance and disposal, collecting urine and stool samples for health monitoring and minimizing water consumption by auto flushing. Though most of the proposed systems claim smart toilets, their main set back is their appliances does not focus on touch less activities to prevent spread of bacteria and viruses. Most of the medical analysis done based on urine and stool collection in smart toilets, leads to faulty identifications. The main objective of our proposed system is to develop a cost effective battery operated smart toilet system that controls the disseminate of noxious viruses and bacteria by automatically closing the toilet cover/ lid even before flushing the waste. When toilet cover/ lid is automatically closed, noxious bacteria and virus can no more be expelled from toilet basin.

TABLE I
REVIEW OF SMART TOILET DESIGNS

Year	Author	Scope	Function	Controller Used
2019	Banait, P. et.al [5]	Smell detector, Water level detector	once dirt is detected, it triggers the fan, water motor and automatic flusher	Arduino UNO
2019	Begam, S. A. et.al [6]	Unwanted smell and gas detector	detect smell and dirt level and signals the monitoring team through LCD display and buzzer	8051 Microprocessor
2019	Mithya, V. et.al [7]	Dirt, Gas and Bacteria Detector	used turbidity, gas sensor for determining the dirt, unwanted gas and bacteria in the toilet area. GSM and Wi-Fi module is used for alerting and messaging the maintenance team.	Arduino UNO , ESP8266 WiFi Module
2019	Sujeetha R (2019) et.al [8]	Foul Odour and water quality detection	Developed a sytem to monitor water quality and detect foul odour , alert system is used for messaging the need for maintenance	NodeMCU microcontroller / ESP8266,
2018	Sudha, V. et.al [9]	Reduction of water consumption, assist visually challenging people,User health is monitored	reviewed modern technologies which are used in public toilets. The objective is to reduce the water consumption, assist visually challenged to use the lavatory and monitor user health using array of sensors	Arduino UNO
2018	Elavarasi, K. et.al [10]	Unwanted gases and depth detection	to detect unwanted gases present in the toilet and also the depth of septic tank, using array of sensors and PIC 16F877 . Once the dirt is detected the system sends the message through GSM module . In this paper RFID scanner is also used for monitoring and storing the maintenance log .	PIC 16F877
2018	Katariya, D. et.al [11]	Odour,methane,Ammonia Detector	detects the Odour, Methane and Ammonia content in the toilet. A robotic arm type of brush is used to automatically clean the toilet basin without human	Arduino-UNO

TABLE II
REVIEW OF SMART TOILET DESIGNS

Year	Author	Scope	Function	Controller Used
2018	Muntashar, N.et.al [12]	Water Level,odour detector	used array of sensors to detect toilet health and to monitor the water level. GSM module is used for alerting the maintenance team.	Arduino-UNO
2017	Sangwan, S. et.al [13]	Urine:Kidney stone,Sugar level,urinary tract infection,Pregnancy. Stool: Fecal occult blood,Fecal pH / Acidity test. Spit:Alcohol presence	health maintenance technology through which the user can identify any health condition	Arduino-UNO
2015	Hashemi, S. et.al [14]	detect unwanted odour and gas	reduce the water usage in toilets. This project also focus to separate solid and liquid waste	Arduino

III. PROPOSED SMART TOILET AND SEWAGE MONITORING SYSTEM DESIGN USING IOT.

The proposed work has two major phases. The first phase includes automatic closure of toilet seat lid and automatic flushing based on smell detection sensor inputs. This is with help of servo motor and battery operated DC motor along with a turbidity, Ultrasonic and Infrared Sensors operates in unison with an Arduino UNO microcontroller. In addition based on the signal received from the turbidity, gas sensor a decision is made and toilet status is displayed in the LCD monitor. RFID scanner is used by the maintenance team to update the maintenance status.

Anaerobic sewage tank 'system are a type of onsite sewage facility (under-ground sewage chamber), they are majorly used in rural areas which are not linked to a proper sewerage system. Once the sewage tank is full of solid waste, sewage back-ups in toilets basin, this will lead to airborne diseases. Hence, it is essential to pump the sludge into transport containers. In second phase of our system Ultrasonic sensors monitors the anaerobic sewage tank 'system to prevent overflow. The proposed system displays the real time liquid sewage level in the LCD monitor and indicates the maintenance team for the need of disposal as the level exceeds certain threshold. The proposed system architecture is shown in the figure 2.

Hardware Interface

- Ardunio Uno R3 -2 qty
- Gas sensor Mq3
- Gas sensor Mq2
- LCD with L2C Module
- Ultrasonic sensor

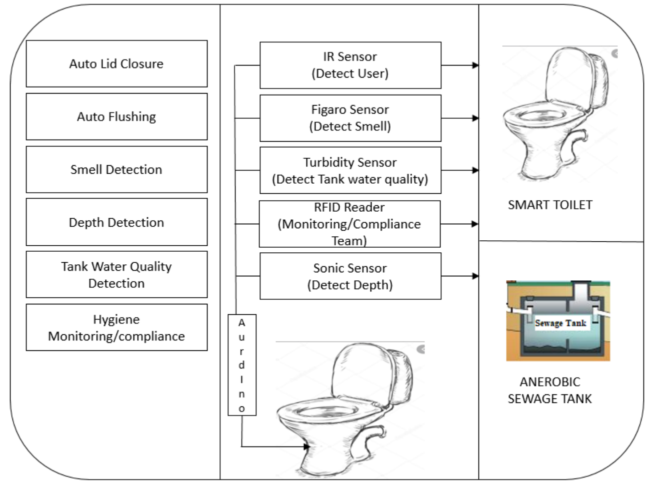

Fig. 2. System Architecture

- Motor driver
- IR sensors
- Servo pro sg90
- Bo Motor
- RFID with reader and writer
- Micro DC 3 to 9v Submersible water pump
- Power supply Units
- Buzzer
- LED indicator

Software Interface

- Arduino IDE 1.6.13
- Catia V5

A. WORKING MODEL

The gas sensor is placed below the rim of the Toilet basin, to detect undesirable gases present in the confined toilet space. If the sensor detects the foul smell, it activates the motor and closes the lid. Once the lid is closed, touch sensor get pressed, which initiates the motor for automatic flushing. The gravity aurdino turbidity sensor detects quality of water by determining the intensities of turbidity. This sensor is deployed in the flush water tank to determine the quality of water and to check bacterial presence. If the turbidity level rises, it generates a signal and alerts the toilet maintenance team and displays Service Required message in the LCD Monitor connected to the door(See Figure:3).

As the user enters the washroom, he/she reads the LCD display connected to the door, if it displays Ready to Use message , user enters the toilet and put the hand over IR sensor to activate the motor, once the motor gets activated, it closes the toilet lid and automatic flushing is done. Once the toilet basin is clean, IR sensor is used to open the lid and the toilet seat cover. If foul smell is detected continuously it alerts the toilet maintenance team. The maintenance monitoring team worker will be provided with Radio Frequency Identification (RFID) tag, with identification code. The RFID reader is fixed to the door and manually aligned over the RFID Tag earlier

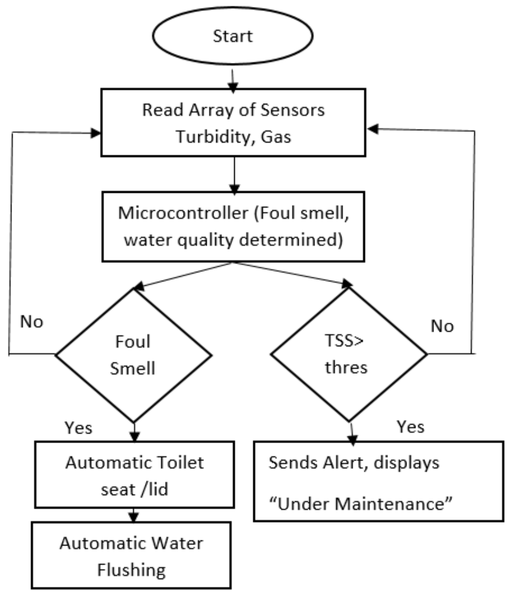

Fig. 3. Phase:1.1 Flow Chart

to the cleaning process. The RFID reader scans the tag and updates a database with details such as toilet ID, cleaning time, cleaning process status so on. The data updated in the database will help the concerned authorities to monitor and ensure timely cleanliness of public toilets and cleaning activities of the sanitary workers. (See Figure:4).

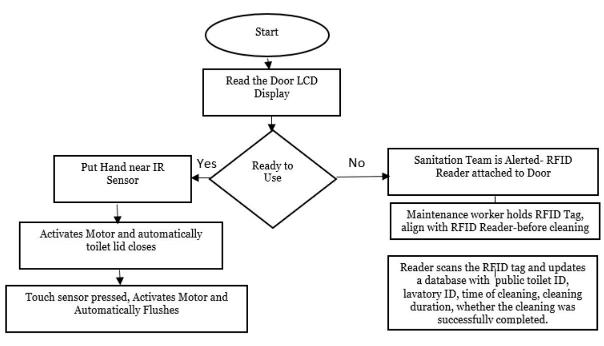

Fig. 4. Phase:1.2 Flow Chart

Anaerobic sewage tank is deeply buried and covered, the sewage liquid level could not be easily monitored. Traditional techniques like floating ball liquid sewage level determination requires to soak the floating ball in sewage liquid, the major setback is the floating ball gets strained over time and leads to malfunctioning. In our proposed system Ultrasonic sensor is fixed below the lower part of the tank cover plate. MAX-485 is a low slew rate and low power transceiver, ported with Ultrasonic sensor for signal reception and transmission to microcontroller. The microcontroller output is connected to liquid crystal display, which displays real time liquid sewage level, if the level exceed the threshold alert signal is sent through buzzer.(See Figure:5).

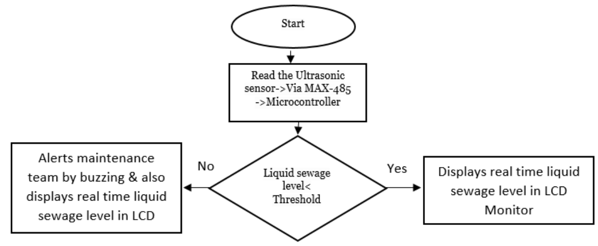

Fig. 5. Phase:2 Flow Chart

IV. Results and Discussion

Figure6 shows the prototype of our proposed smart toilet system. Two arduino UNO boards are used in our system.One for controlling automatic toilet lid closure and flushing and other controller board for sewage tank monitoring. Before user entering the toilet, a LCD monitor fixed to the door will display the status of the toilet(See Figure 7 and 8).If toilet needs service, maintenance team is alerted, **Cleaning in progress** status is displayed in the LCD monitor (See Figure 9 , this service will prevents other user to use the dirty washroom. If the washroom status is **ready to use**, user enters the toilet, a battery operated system controls the spread of noxius by automatically closing the toilet cover/ lid even before flushing the waste. When the toilet cover/lid is closed, noxious viruses can not ejected from the toilet basin (See Figure 10 and 11.

Fig. 6. Prototype of Proposed Smart Toilet

V. Conclusion

As the planet continues to curl into confusion due to Coronavirus, there is a dire need to stop the transmission of this pandemic in the common public spaces. The project mainly focus to build a smart toilet system that will intend to provide the impact on decreasing the disseminate of noxious

Fig. 7. LCD Monitor Displaying Status of Smart Toilet

Fig. 8. LCD Monitor Displaying Status of Smart Toilet

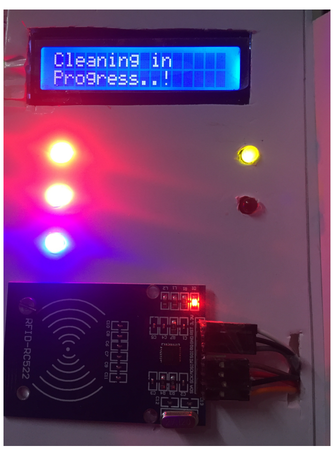

Fig. 9. LCD Monitor Displaying Status of Smart Toilet

viruses and bacteria. This is achieved using small-scale, cost-effective electrical components like servo motor , battery operated DC geared motor, array of sensors operates in unison with an Arduino UNO microcontroller. In addition Hygiene monitoring, compliance is embedded in the proposed system using Radio Frequency Identification techniques. In future we would like to embed Ultraviolet lights into the system design

Fig. 10. Automatic Lid Closure

Fig. 11. Automatic Lid Opening

to ruin the viruses and bacteria that dwell in the toilet basin.

References

[1] WHO. (17 April). Q&A on coronaviruses (COVID-19). Available: https://www.who.int/news-room/q-a-detail/q-a-coronaviruses.

[2] C. P. Gerba, C. Wallis and J. L. Melnick, Microbiological hazards of household toilets: droplet production and the fate of residual organisms, Journal of Applied Microbiology, vol. 30, (2), pp. 229-237, 1975.

[3] J. Barker and M. V. Jones, The potential spread of infection caused by aerosol contamination of surfaces after flushing a domestic toilet, Journal of Applied Microbiology, vol. 99, (2), pp. 339-347, 2005.

[4] Anonymous (-03-23T12:39:29-04:00). Study suggests new coronavirus may remain on surfaces for days. Available: https://www.nih.gov/news-events/nih-research-matters/study-suggests-new-coronavirus-may-remain-surfaces-days.

[5] Pinki Banait, Sarika Kore, Arman Shaikh, Rameshwar Marbate, Divya Tayde, Sonali Katre, Prof. Amol Mahajan: Automatic Washroom Cleaning System, International Journal of Scientific Research in Computer Science, Engineering and Information Technology 2019, Volume 2, Issue 5.

[6] Shaik A Johny Begam, A.Siva Prabhu, S.Vijay Simha, T.Siva Prasad, Y.Gnana Teja: Design Of Smart Washroom System For Clean And Green Environment, International Journal of Research in Advent Technology, Special Issue, March 2019, E-ISSN: 2321-9637.

[7] Mithya V, Divya Prabha.N, Sisma Samlein S, Madhumitha M: Smart Toilets using Turbidity Sensor, International Journal of Innovative Technology and Exploring Engineering (IJITEE), Volume-8 Issue-5S March, 2019, ISSN: 2278-3075.

[8] R. Sujeetha, Abhinav D, Rithik R, Abishek S : Toilet Management System Using IOT, International Journal of Scientific & Technology Research , Volume 8 - Issue 12, December 2019 Edition
[9] V. Sudha, N. Jeba, R. Akiladevi: A Survey on the Modern Technologies used in Public Toilets, International Journal of Recent Technology and Engineering (IJRTE), ISSN: 2277-3878, Volume-7 Issue-4S, November 2018.
[10] K.Elavarasi, E.Elakiya, Mrs.R.P.Kaaviya priya: Implementation of Smart Toilet (Swachh Shithouse) Using IOT Embedded Sensor Devices, International Journal of Advanced Research Trends in Engineering and Technology (IJARTET), Vol. 5, Special Issue 9, March 2018.
[11] Dharmesh Katariya, Pratik Parik, Akshay Pincha, Gauri Lodha, Anita Borse: Smart Toilet, International Journal of Electrical, Electronics and Data Communication, ISSN(p): 2320-2084, ISSN(e): 2321-2950, Volume-6, Issue-5, May-2018.
[12] Nafeesa Muntashar, Sahana KN, Saniya Shilledar: Smart Urinal Mech-Automatic Flush, JETIR June 2018, Volume 5, Issue 6.
[13] Sandeep Sangwan, Nikhil Chugh, Pradyumn Kumar Tiwari: Smart Toilet An IoT Solution, International Journal of Advance Research in Science and Engineering, Volume No.06, Issue No. 11, November 2017.
[14] Hashemi, S.:Innovative Toilet Technologies for Smart and Green Cities. 8th conference of the International Forum on Urbanism, 2015

IoT fueled AI system for Food Wastage Reduction and Efficient Redistribution of Excess Food

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***Abstract*—Real-time data monitoring aided with Internet of Things (IoT) and analysis of the data fueled by Artificial Intelligence (AI) will play a key role in predicting food consumption pattern and effective redistribution of excess food. This paper proposes a centralized real-time IoT-enriched system, supplemented by past data to predict the real-time food supply and demand in a region. Data will be obtained from the digitized food directory. The data obtained would be, the type of food ordered, the type of day it was ordered, other influential factors and the edge computed data from the sensors which would give the people count. These past data will be analyzed and fed to a model that can predict quantity of food that will be needed every day at a particular place. Data can also be used to estimate the average amount of food that can go as waste every day and come up with adequate logistics to transfer this surplus food to places in need of food without it going stale.**

***Index Terms*—AI, IoT, Data processing, Food distribution, ML, Deep Learning, Food supply chain, Food Wastage.**

I. Introduction

According to the Food and Agriculture Organization (FAO) report entitled 'The State of Food Security and Nutrition in the World 2020' almost 690 million people worldwide (8.9% of the world's population) are estimated to have been undernourished in 2019 [1]. That said, the global volume of edible food waste is estimated at 1.3 billion tonnes [2]. This waste is not food waste alone, the equivalent carbon footprint is 3.3 billion tonnes, the water needed to generate this amount of food is 250 cubic km, that is 3 times the volume of Lake Geneva and about 28% of the total agricultural land available is used to cultivate this waste food. There are five stages in the food supply chain (FSC), they are agricultural harvest, post-harvest handling and storage, production processing and packaging, distribution and consumption. Food is wasted in all of these stages in different ways. Worldwide, food waste impacts sustainability and efficiency of food and nutrition programs.

On one hand, the surplus food is getting wasted while on the other hand millions of people are hungry. How can technology help in this context? How can technology be applied to overcome this situation? Can a system be devised to distribute this surplus food which can be used to feed the needy? This system would help in reducing the food wasted, thus contributing to the sustainable development of the world and at the same time, would feed the hungry. This paper suggests such a novel system aided with technology. Existing ideas that use technology for reducing the food wastage are first highlighted and then an efficient model is suggested which if implemented on a large scale would help to effectively reduce the food wastage and will aid in redistribution of the excess food to the needy.

II. Technology in food waste reduction

Over the years, innovations such as Machine Learning (ML), AI and Data Science have seen quantum strides that have developed into something amazing. They have been deployed to help people make the right decisions. These intelligent systems have marked their presence in a variety of other industries around the world and their implementations in all fields are growing rapidly. Food industry is one of the new markets where AI and ML are being used. There are many food products in the supermarkets that go to waste every day, mainly because of weak demand forecasting. ML will play a crucial role in this scenario and reduce the amount of food waste. ML will create a better demand forecast using previous data on how much food goes to waste, how much a product sells etc. It will allow supermarket owners to order products at an acceptable level, not more or not less. Intelligent and creative processes will certainly enhance demand preparedness in the supply chain. IoT technology is trying to deliver solutions that enhance the supply chain by using a wide range of sensors, some with very high precision measurements and ML algorithms for Big Data analysis. One of the companies operating in this direction is Centaur Analytics, which began in Volos, Greece in 2014. They aim to provide a system that will upgrade the quality of the post-harvest stage of the supply chain [3].

There are a few innovative AI restaurant analytic firms. These companies help a restaurant to manage the raw food material to be purchased on a weekly basis and also predicts the consumer inflow pattern. Thus, efficiently and technically managing the food resource. One such company is Tenzo [4]. They predict the future food demand with the power of ML and AI to order the right amount of food needed by taking into account data from a range of factors - including account sale, weather, social media reviews etc. Weighing in these factors, the software predicts the footfall in a particular place at a particular time and eliminate the food waste. Real-time data and machine learning are providing appealing solutions to the restaurants. One can see a fast paced adoption of AI and ML technologies in the food industries.

AI and IoT solutions are already being deployed in the Food Industry with positive outcomes. These proven technologies could be combined so that food wastage and world hunger could be tackled.

III. Proposed Model

This paper proposes an IoT fueled AI system for food wastage reduction and efficient redistribution of excess food. This system is divided into 4 stages, Stage 1 consists of the places where the excess food would be present like restaurants and marriage halls. These places would be equipped with an array of sensors to collect data that will be transferred to a central server via IoT. The server will also have data from sensors located at places where food is in need (stage 4) such shelter homes, old age homes, orphanages etc. The supply and demand will be dynamic and depends on various factors but they won't be completely random. The AI algorithm in the Stage 3 will come into play here, the system will be trained and modeled initially as per some collected data. This AI system will predict the amount of food that will be left over in a city on an average day and in real-time monitor the amount of food that may go unused and deploy an efficient logistics to distribute the surplus food to the food deficient places. The AI system can further notify these places about the amount of food that may arrive there as donations, they can prepare additional amount of food, if need be. Fig. 1 shows the proposed system's block diagram with all the 4 stages. The functionality and constituents of the four stages are elaborated in the following sections.

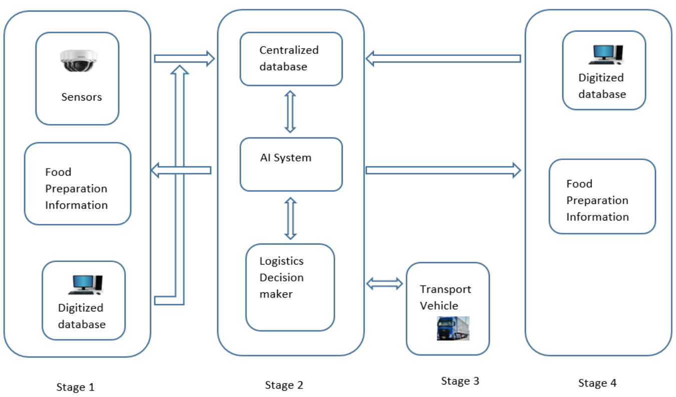

Fig. 1: Constituents of the proposed model

A. Stage 1 :- Places with surplus food

Any place where there is a risk of surplus food being available, such as restaurants, wedding/function halls and other social gathering venues. If these locations deploy this model, they have dual advantages.

- One is that, this system based on past records and other variables, will forecast and report footfall to these locations on a given day. This data would help these places to prepare food for only those many people.
- Second is to make use of the extra food, that remains due to some unforeseen reasons. The excess food will be properly collected and redistributed before the food goes stale.

Since the predictions can sway to some extend, a real-time analysis of the footfall and amount of food remaining need to be obtained, once the AI system(Stage 2) has this data the real -time feedback mechanism in the system will notify these places if more food needs to be prepared or not. Stage 1 consists of three sections, they are

1) Sensors:

- CCTV camera data scaled with edge computing.
  This data gives the people count and would be transmitted to the central server on real-time basis through an IoT device.
- Smart Containers which can determine how much food was prepared and how much food is remaining. This is, again a real-time data and it would be send to the central server. The sufficient volume of food which needs to be prepared is determined and measured.

2) Digitized Database:

- All the details and records of the place, if restaurants then billings, if banquet halls then directory containing future bookings etc. would be in this digitized database. This digitized database would also contain the location details, the day of the week, special locations etc.
- These data are transferred to the IoT device which in turn sends it to server.

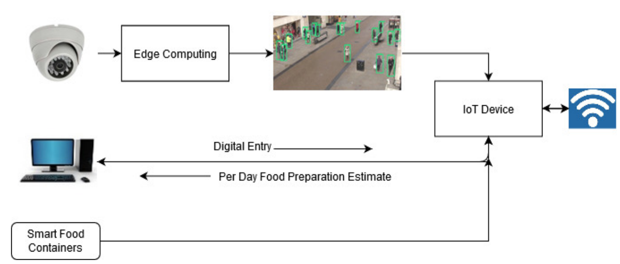

Fig. 2: Constituents of stage 1

3) Food estimated Data :

- This is an input from the second stage of the proposed model. The AI system in the server will predict the amount of food needed for a particular day and conveys it to the place via the IoT device.

Clubbing all the information from all the sections of Stage 1 the AI system running in the server would provide the information about the amount of food which needs to be prepared on a particular day. If the optimum amount of food is prepared, food wastage would be low. The AI system with the real-time input data would be able to predict if any food

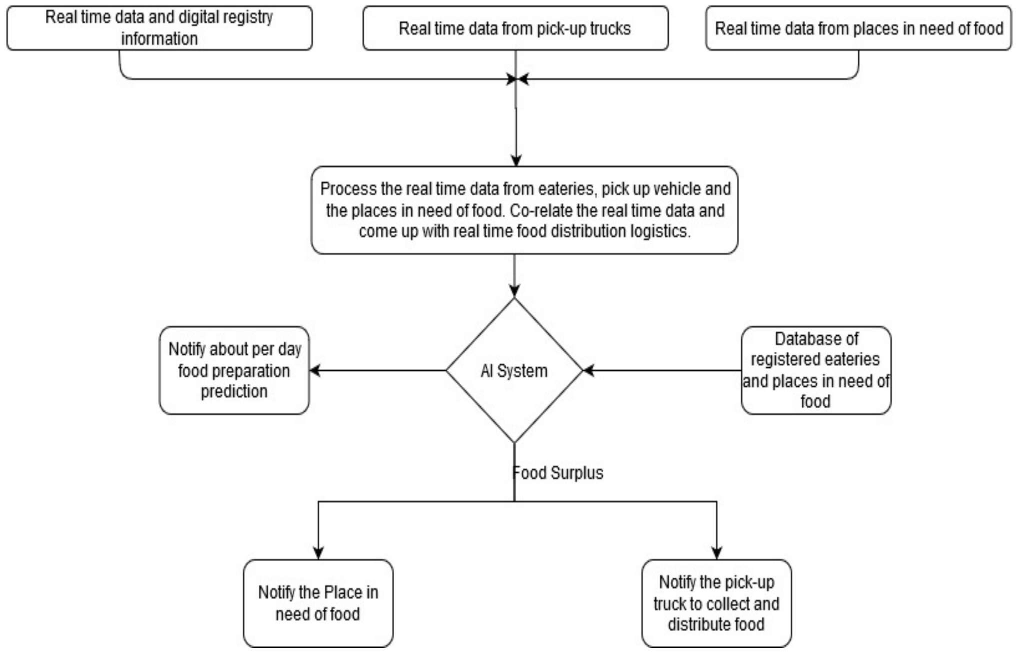

Fig. 3: Overall generic algorithm

can go as waste.
In case of food shortage, the AI system will alert the place in real-time about the need to make more food in order to meet the demand and by what quantity it has to be prepared. It would take into consideration the amount of time that would be needed to prepare the food on time. If the system detects any extra amount of food then the AI would initiate the process to collect that excess food and deliver it to the places in need of food before it goes stale. Fig. 2 shows the constituents of Stage 1 and the data flow.

B. Stage 2 :- The AI system in Server

The central node of this proposed model is the server. This will host the centralized database which would be the brain and memory of this system and the AI algorithms would be running on it. Along with these, the Stage 2 consists of another important section which is termed as Logistic decision maker. Following are the three sections of Stage 2,

1) Centralized database: The database will act as the history keeper so that the AI system can learn from it. Following are the features of the centralized database.

- City-wise database
  Previous data of each eatery, event hall etc. These are transmitted from the Stage 1 and is compressed and stored here. This data is used to train and improve the AI system.
- The data includes, date and day of the week, amount of food needed on a particular day, importance of the day and future bookings.
- Each place will have its own database, also the places where additional food is required will have another database. The places in need of food would send the required data daily.

2) AI system: The brain of this model is the AI system. Based on the previous data in the database and the real-time data obtained from various locations, the AI system can determine the food demand and in real-time it would service the food shortage via efficient redistribution of the surplus food. The AI system also informs the Stage 1 about the amount of food that needs to be prepared on a particular day. In other words, it makes the decisions and conveys it to Stage 1 and Stage 3. Also the system should be able to handle the data in the centralized database. One can't have infinite memory space to store all the values, therefore AI must decide which data is relevant and which previous data can be ignored and deleted [5]–[7]. The proposed model AI system would also be very complex and the overall system would be implemented by clubbing various known AI models together.

3) Logistics Decision Maker : This section plays a pivotal role in making the logistics for the effective redistribution of the food. Food, being a perishable item, if not transported properly and efficiently would go stale. This section uses the data from the AI system to efficiently lay down the routes that can be taken by the vehicles to reach the destination as quickly as possible.

- AI will be predicting the food usage at a particular place on a particular day, the real-time data from these places will convey the amount of food which will be leftover daily.
- The above data along with input from places which need food is fed to the Logistics Decision Maker.
- Shortest way by which the excess food can be redistributed to places in need is identified.
- Real-time data from the transporting vehicles, this helps in keeping the system updated about the traffic situations

and manages the other resources efficiently on a real-time basis.

The overall algorithm the AI model uses is shown in the fig. 3.

C. Stage 3 :- Transport Vehicles

A smart refrigerated transport vehicle will be a part of this proposed model as shown in fig 4. Following are the features

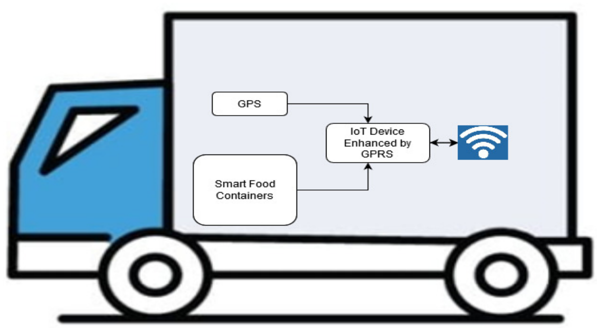

Fig. 4: Smart refrigerated pick-up Truck

of this smart refrigerated transport vehicle:-

- Transmit the real-time location of the vehicle.
  The vehicle would be fitted with GPS and GPRS technologies that will transmit its location to the Logistics Decision Maker in Stage 2. This helps in effective routing of the vehicle.
- Real-time food health information is conveyed to the server.
  The food would be placed in another type of smart containers, which will send data to the IoT module fitted inside the vehicle, which in turn will transmit the data to the server.
- Optimum route to be taken by the vehicle is obtained from the server's Logistics Decision maker, which sends the information depending upon the real-time location of data being transmitted from this vehicle.

D. Stage 4 :- Places in need of food

The final stage represents the places in need of food like orphanages, old age homes, low income colonies etc. While preparing food at these places the additional food which can come from different places (redistributed food from Stage 1) could be taken into account. The AI system gets data from Stage 4 to determine the approximate number of people who needs to be fed on a particular day in a particular place. The data from Stage 1 would aid the AI system to know what amount of food needs to be redistributed and pass it to Stage 4, resulting in preparation of only that much amount of food, again reducing the wastage of food. Constituents of this stage are :-

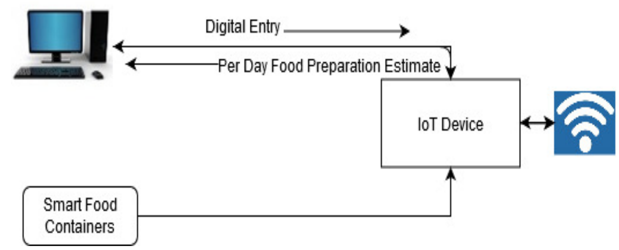

Fig. 5: Constituents of Stage 4

1) Digitized Database: Similar to the section in Stage 1 but the data collected would be slightly different. This data gives the information about the number of people who will need food on a particular day. This digital data is send to the server to be saved and the AI model uses this data to train itself.

- All the details and records of the place, like the number of people, who are present, food consumed in a day etc.
- Real-time data like the amount of food left in the smart container and the number of people left to have food is send to the server. The smart container used in this stage is the same as that used in Stage 1. These data are transferred to server on real-time basis.

2) Food estimated data : Similar to the section in Stage 1.

- The AI system in the server will predict the amount of food that needs to prepared on a particular day at each location. Remaining food will arrive in transport vehicles. Its timing and quantity will be notified.
- The information would be updated and notified on real-time basis. Based on the real-time data the AI system gets from a location and other factors which can have considerable effect on the amount of food that can reach at a particular place, after processing these and running that through its neural model, the AI system sends back the food estimation data.

Fig. 5 shows the constituents of Stage 4 and the data flow.

The system will become more efficient by continuously learning using the data it gets over time. The ultimate aim of the AI system is not to meet the food requirement at a particular place where it is needed but to reduce the food which is prepared and to effectively redistribute the excess food, if any. This in effect reduces the wastage of food and at the same time feeds the hungry.

IV. Conclusion

Approximately 1/3 of the agricultural produce ends up in landfills which is not only the wastage of food but the wastage of energy and other resources like water, agricultural land etc. used to cultivate, transport and prepare the wasted food. A considerable amount of food is wasted after the food reaches the consumer and this excess food can be used to feed the needy. In this paper an innovative system aided with IoT and AI technologies is proposed to tackle the problem. An architectural overview of the proposed system is presented. How the system could be realized using AI and the type of sensors needed for the realization is also suggested. The proposed self-learning algorithm, on implementation, will gradually reduce the food wastage over time. With the efficient redistribution of excess food, the problem of malnutrition could be solved. When the food wastage reduces, the food prices too would go down which would result in access to healthy and nutritious food for the underprivileged.

REFERENCES

[1] FAO, “The state of Food Security and Nutrition in the World” FAO, 2020. [Online]. Available: http://www.fao.org/publications/sofi/2020/en/. [Accessed: 04-Apr-2021].

[2] FAO, ”Food Wastage: Key Facts And Figures.” FAO, 2020 [online] Available at: http://www.fao.org/news/story/en/item/196402/icode/. [Accessed: 04-Apr-2021].

[3] Centaur Analytics. [Online]. Available: https://centaur.ag/. [Accessed: 04-Apr-2021].

[4] “Restaurant management and sales forecasting app,” Tenzo. [Online]. Available: https://www.gotenzo.com/. [Accessed: 04-Apr-2021].

[5] J. Xu, L. Ma, W. Zhang, Q. Yang, X. Li and S. Liu, ”An Improved Hybrid CNN-SVM based Method for Bearing Fault Diagnosis Under Noisy Environment,” 2019 *IChinese Control And Decision Conference (CCDC)*, San Francisco, CA, 2018, pp. 125-129, doi: 10.1109/EDGE.2018.00025

[6] A. Bostan, C. Ekin, G. Şengül, M. Karakaya and G. Tirkeş, ”Deep Learning and Current Trends in Machine Learning,” 2018 *3rd International Conference on Computer Science and Engineering (UBMK)*, Sarajevo, 2018, pp. 467-470, doi: 10.1109/UBMK.2018.8566365.

[7] M. A. Abbas, ”Improving deep learning performance using random forest HTM cortical learning algorithm,” 2018 *First International Workshop on Deep and Representation Learning (IWDRL)*, Cairo, 2018, pp. 13-18, doi: 10.1109/IWDRL.2018.8358209.

Data Reduction Strategy using Neural Adaptation Phenomenon in Internet of Things

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***Abstract*—Internet of Things (IoT) have got significant popularity among the researchers' community as they have been applied in numerous application domains. Most of the IoT applications are implemented with the help of wireless sensor networks (WSNs). These WSNs use different sensor nodes with small battery power supply. Hence the energy of sensor node is considered as one of the primary constraints of WSN. In most WSNs applications, the sensed data which is generated from same location sensor nodes are identical or time-series/periodical data. This redundant data transmission leads more energy consumption. To reduce this energy consumption, a Data Reduction strategy using Neural Adaptation Phenomenon (DR-NAP) has been introduced to decrease the communication energy in routing data to the BS. Neural adaptation phenomenon has been utilized for designing a simple data reduction scheme to reduce the amount of data transmitted. By this way the sensor node energy is saved and the network lifetime is enhanced. The proposed approach has been implanted in the existing Gravitational Search Algorithm (GSA) based clustered routing for WSN. The sensed data is transmitted to CH and BS using DR-NAP. Real sensor data from Intel Berkeley Research lab has been used for conducting the experiments. The experiment results show 47.82% and 51.96% of improvement in network lifetime when compared with GSA based clustered routing and Clustering Scheme Using Canada Geese Migration Principle (CS-CGMP) for routing, respectively.**

***Index Terms*—Wireless Sensor Networks, Internet of Things, Neural Adaptation, Energy Efficient Routing, WSN, Data Reduction, IoT**

I. Introduction

Currently, Internet of Things (IoT) is growing technology along with the current scenarios such as wild-forest monitoring, medical research and healthcare, environmental monitoring, disaster relief, structural health monitoring, military, industry monitoring, etc. [1]–[3]. Most of the IoT applications are implemented with the help of wireless sensor networks (WSNs) [4], which are a collection of wireless sensing devices equipped with sensor nodes which are densely set-up to monitor the environment parameters such as humidity, pressure, temperature, vibration, acoustic sound, motion, pollutants, wind speed, wind direction, etc.

In WSN, energy efficiency is one of the challenging factor, which influences the design of network. There are numerous ways and means for attaining energy conservation in WSN. Energy-efficient routing, sleep/wakeup systems, battery replacement, radio optimization, and data reduction are the key methods suggested to tackle energy conservation [5].

Routing is an an important activity for communicating the sensed data to the Base station (BS) that consumes maximum energy. Hence routing protocols must focus on improving energy efficiency. Sensor nodes near by the BS are burdened since they need to forward lot of packets to BS and hence their energy exhausts soon in multi-hop communication. Various energy-saving mechanisms such as cluster architectures, optimal relay node placement, sink mobility, energy as a routing metric during setting up the path, and multipath routing can be adopted for efficient routing [6]. Another approach for addressing energy efficiency in WSN are energy harvesting and wireless charging technique to recharge the batteries of sensor nodes without human consultation [7]. In addition, another alternative solution to energy efficiency is Data Reduction, where reducing the amount of similar data to be communicated to the BS. Because data transmission is expensive in terms of energy to be spent.

The major contributions of the proposed research work are:

- Data redundancy reduction and transmission technique to reduce energy consumption
- Adoption of Neural Adaptation Phenomenon for data reduction in order to achieve energy efficiency
- Integration of proposed approach with GSA based clustered routing
- Network lifetime enhancement through reduced data communication.

Paper is prepared as follows: Section II describes Related work. Section III provides basics of Neural adaption phenomenon. Section IV describes the proposed data reduction techniques using nueral adaption phenomenon approach. The results of the experiments conducted are compared with the GSA based approach and CS-CGMP based approach in Section V. Finally, the conclusion is presented in Section VI.

II. Related Work

In cluster-based architecture, the network area is divided into a smaller section; each section is referred to as clusters. Each cluster posses a chief, known as Cluster Head (CH). WSN Cluster-based architecture contributes in energy efficiency, scalability, reducing route-finding delay, and loop-free routing [8]. Various research works have been performed on energy-efficient cluster-based routing. The famous cluster-based routing strategies are LEACH (Low-Energy Adaptive Clustering Hierarchy) [9], DEEC (Distributed Energy-Efficient Clustering algorithm), HEED (Hybrid Energy-Efficient Distributed Clustering) [10] [11], etc.

In the literature, many load balanced cluster-based routing approaches [12]–[15] have been proposed for efficient routing. These approaches improve the network lifetime by achieving load balance among the CHs.

Cluster-based routing for WSN achieves energy efficiency; they still need improvement since energy conservation is vital for enhanced life of the network. To minimize the energy consumption of sensor nodes, several prediction strategies have been investigated [16]–[18]. These prediction strategies are performed based on the observation of the sensed data and sensor nodes are capable of performing computations for training and using predictors in a distributed manner. The representatives of the existing prediction strategies and data reductions methods are reviewed in this section.

MPEG encoding based prediction model [16] was proposed by Goel et al. to monitor the environment. This approach has taken the lessons from the MPEG encoding process for designing the prediction model. The prediction-model was sent to the sensor nodes after it was built. Only when the sensor nodes' sensed data differs from the reading given by the prediction model, or when the reading reaches a pre-defined threshold, do the sensor nodes send it to the monitoring devices. This phenomenon is called as PREdiction-based MONitoring (PREMON) paradigm. This paradigm avoids the unnecessary data transmissions from the sensor nodes by predicting the readings at the monitoring entity. However, extra computation has to be performed to determine the prediction model.

McConnell et al. [17] proposed a prediction strategy which is performed based on the targeted data. The sensor nodes transmit only the target data instead of sending all the sensed data. [18] proposed data-driven processing based on Spatio-temporal suppression strategy on continuous data but not continuous reporting of data. The authors adopted the models for optimized data collection. Ken [19] was suggested by Chu et al. as a robust approximation technique. To minimise data communication from sensor nodes to BS, this method used replicated dynamic probabilistic models.

Data compression methods for IoT sensor nodes have been presented using the Two-Tier Data Reduction (TTDR) technique [20]. The temporal correlation in the sensed data is used in this technique; Delta Encoding and Run-Length Encoding(RLE) has been utilized for data compression. At the gateway tier, hierarchical clustering is used to group data sets from sensor nodes based on the Minimum Description Length (MDL) concept. The MDL theory compresses the data set pairs into a single group. As a result, the scale of the data sets is kept to a minimum.

A clustering-based data collection framework with a prediction scheme has been presented by Jiang et al. [21]. In this framework, a prediction scheme has been combined into data collection by adaptively enabling/disabling the prediction scheme. The adaptive scheme is adopted for controlling the prediction, and to investigate output tradeoff between between lowering communication costs and limiting prediction costs. In addition, for node-to-node propagation of aggregates, sleep/awake scheduling has been used; this framework makes use of an effective cluster-to-cluster propagation.

Jarwan et al. proposed a two-tier data reduction framework with Dual Prediction (DP) and Data Compression (DC) schemes [22]; spatio-temporal correlation is the basis for these schemes. To save energy and bandwidth, this framework reduces the number of data transfers. The DP scheme has been used to reduce transmissions between member nodes and CHs; the DC scheme has been used to reduce transmissions between sink nodes and CHs. However, Neural Network (NN) implementation of this framework is tedious in WSN because of the simple processing capability of sensor nodes.

Sayed et al. have introduced Distributed Data Predictive Model (DDPM) for decreasing the energy depletion of sensor nodes and thus enhancing the network lifetime [23]. For forecasting communication shortcomings, this strategy is based on a distributive clustering model. For removing unwanted reflections and transmitted signals with noise, a Recursive Least Squares (RLS) adaptive filter merged with a Finite Impulse Response (FIR) filter has been used; they seek to reduce the size of the data to be transmitted for energy efficiency.

In WSN, a prediction strategy based on the Hierarchical Least-Mean-Square (HLMS) adaptive filter [24] has been developed for data reduction. This filter was used by both the sensor nodes and the sink nodes to forecast measured values; as a result, sensor nodes could send sensor readings that vary by a certain amount from the prediction. The number of data sent by each node has been minimised in order to save energy.

A crucial issue in the conventional clustered routing is the redundant transmission of periodically sensed data which are alike for subsequent rounds of data transmission phase. Because transmission of identical data to the CH/BS is an energy-consuming process, it is considered a vital issue. Furthermore, the above-mentioned approaches involved the undue amount of computational overhead for performing the predictions and need to fix the error threshold correctly for efficient data prediction. To overcome the aforementioned limitations, a Data Reduction using Neural Adaptation Phenomenon (DR-NAP) dependent routing approach is proposed.

A. Neural Adaptation Phenomenon

Generally, a change in the habitat is the stimulus; the reaction of the organism to it is the response. Neural adaptation or sensory adaptation is defined as the receptivity of the sensory system is gradually decreasing to a constant stimulus. It is realized as a common phenomenon of dissolving neural activities concerning repeated or prolonged stimulation. It is a ubiquitous phenomenon and a dynamic process. It has been noticed in many neurons, periphery, and central nervous system ($https://psychologenie.com/understanding-sensory-adaptation-with-examples$).

Every phase of the stimulus, for example, a replay of pure accent of constant intensity or the deflection of a whisker by a fixed amplitude, causes any neuron responsive to the applied stimulus to respond with some simple response. A spiking neuron (non-adapting neuron) usually maintains a specific firing rate [25]. The adapting neuron lowers its response activity to a steady-state value.

Neural Adaptation are of two types: 1. Rapid Adaptation and 2. Slow Adaptation. Rapid adaptation evolves within a millisecond to seconds in the human body; it happens in the auditory system in the range of milliseconds and it evolves in many hundred milliseconds to seconds in the visual system. Slow Adaptation evolves in seconds to minutes, hours or days in the human body

This particular neural adaptation mechanism is related to data reduction in WSN sensor nodes. In most of the WSN applications, sensor nodes sense the same/similar data for a subsequent number of rounds. When the sensor node senses a data, it can immediately respond to its CH by transmitting the data. If the sensed value in the current round is the same as the sensed value in the previous rounds, it is not necessary to transmit data to the CH, instead sensor node may transmit a bit to indicate current value is equal to previous value. Otherwise, the sensor node transmits the currently sensed data to the CH. In this way, the number of data transmissions between the sensor node to CH can be reduced when the lifetime of the WSN is significant for running the system without any human intervention. Hence this intention inspired us to adopt a neural adaptation phenomenon for data reduction in the routing of WSN.

III. Proposed Approach

The proposed approach used cluster communication for collecting the data from different sensor based IoT devices. Clustering & communication process consists of two phases:

1) Clustering Phase - This phase includes partitioning the network field into clusters, choosing a precise number of CHs, and binding the sensor nodes to an appropriate CH.
2) Data Transmission Phase - This phase includes communicating data to the CH with the aid of neural adaptation phenomenon and later forwarding the data from CH to BS.

A. Clustering Phase

The network field is divided into two layers: the border layer and inner layer. In the proposed approach, ten percent of the network area in the boundary is considered as border layer; the remaining area is referred to as an inner layer. Ten percent of the network area denotes ten percent in the height and width of the area. As the boundary nodes are far away from the BS, their data communication distance is more and hence the boundary nodes exhaust energy soon. Accordingly, the sensor nodes in the border layer are not considered for the cluster head selection. The CHs are selected from the sensor nodes in the inner layer; the sensor nodes in the border layer can communicate the data through the nearest CHs in the inner layer. The inner layer is sub-divided into squared zones. The node density of a zone is measured as the total number of nodes which are alive in a zone. The clustering phase is repeated for every stipulated number of rounds.

1) Selection of CH: CHs are very important for cluster based communication in WSN. CH selection phase is performed as in CS-CGMP based routing strategy [13]. The number of CHs will be elected with the help of node density in a network as well as in zone. The node density of the zone will decide the number of CHs.

Computing number of CHs: The required number of CHs for every zone is computed using Equation 5. It is determined based on the node density of the zones.

$$Num\_CH_{Z_i} = round\Big(\frac{Node\_Density_{Z_i}}{AVG\_NODE\_DENSITY}\Big) \tag{5}$$

where $Node\_Density_{Z_i}$ denotes number of nodes in i^{th} zone, $AVG\_NODE\_DENSITY$ is average number of nodes present in entire network by considering all the zones and is calculated using $(\frac{Total\_Number\_of\_Nodes}{Number\_of\_zones})$. Node which is having more energy compared to other nodes and considering the overall communication and transmissions distances with all other sensor node and with BS will be considered for selection of a CH.

2) Cluster Set-up Phase: In this phase, GSA-based clustering approach [13] has been utilized for the balanced binding of sensor nodes in the inner layer to the CHs after selecting the required CHs. BS determines the best binding of a sensor node to CH based on residual energy of CH, energy to be spent for its member nodes for aggregation by CH, and sensor node to CH distance. The sensor nodes in the border layer are associated with the nearby CHs. After finding the optimal binding of sensor nodes to the appropriate CHs, BS sends a short message to all sensor nodes. The message for the member sensor node consists of an assigned CH_ID. Further, the message for the CHs consists of a list of member sensor nodes and its forwarding CH.

B. Data Transmission Phase - Neural Adaptation Phenomenon

The data transmission phase includes two sub-phases:

1) Member sensor nodes to CH Communication
2) CH to BS Communication.

Each sensor node sense the data and it can store value. Second time onwards it will sense and compare with stored value, if they are same then transmit flag value is set to 0. Instead of transmitting sensed value, sensor node will transmit the flag, which indicates previous value.

1) Member sensor nodes to CH Communication: In this phase, the neural adaptation phenomenon has been utilized to enhance the network lifetime by reducing the number of data transmissions. After clusters are formed, the member sensor nodes can send the sensed data to respective CH during its allotted slot. Sensor nodes may sense the same/similar data for subsequent rounds in periodical data transmission. If sensed value matches with the previous value then sensed data is not transmitted instead a flag will transmitted to indicate same as previous value or no change in data compared to previous value. Otherwise, sensed data will be transferred from sensor node to the CH. When CH receive a flag bit then it takes the previously received data as the current value. Hence, the number of data transmissions between the sensor node to CH has been reduced. Then the CHs will aggregate the data which receives from sensor nodes and then forwards to the BS.

2) CH to BS Communication: When a CH receive data from its member sensor nodes for every round of data transmission, it will store the received value as previous value. When a CH receives a flag (which indicates same as previous sensed value), it will take previous value as current value.

When CH has not received any data, $Nodata\_Count_i$ is incremented. If $Nodata\_Count$ is greater than $Nodata\_Thresh$, the member node is declared as dead node. If the $Alike\_Flag$ is set, CH takes the previous value as the the current value. If no flags are set, the two previous values are same then CH takes the previous value as current value. Then $Alike\_Flag$ is set; otherwise it is considered as sequence. Then current value is calculated from the two previous values; $Sequence\_Flag$ is set. Similar procedure is applied for all the member nodes. Finally, using multi-hop communication, CH aggregate and communicate the data to BS. CHs will transmit its aggregated data to the BS through intermediate CH, which is identified with the help of residual energy and distance to to BS .

IV. Simulation Results and Discussion

The simulation experiments of the proposed approach were conducted to validate the performance of data reduction strategy DR-NAP; it has been incorporated and implemented with GSA-based Clustering Routing Strategy (GSA-CRS) [13] and Clustering-Scheme using Canada Geese Migration Principle (CS-CGMP) [26]. The results of the proposed approaches were considered and compared with no data reduction strategy techniques.

WSN scenario as shown in Fig. 1 is used by Intel Berkeley Research Lab ($http://db.csail.mit.edu/labdata/labdata.html$) and generated the data as shown in Fig. 2 has been considered for simulation. In this scenario, 54 sensor nodes were deployed on $44m \times 35m$ network field with BS placed at the center. For

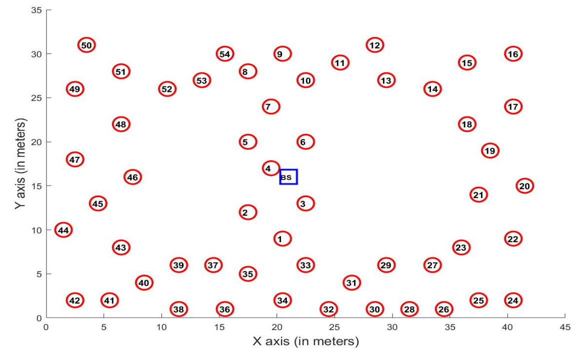

Fig. 1: WSN Scenario - Intel Berkeley Research Lab

the simulation, sensor readings of Intel Berkeley Research lab between $February\ 28^{th}$ and $April\ 10^{th}$, 2004 was used. Mica2Dot sensor nodes collected temperature, humidity, voltage, and light values , along with topology information for every 31 seconds.

A. Result Analysis

In this section, the performance is compared between GSA-CRS and CS-CGMP approaches with/without DR-NAP is presented. To verify the performance, lifetime and remaining energy of network are considered in this paper. Fig. 3 and Fig. 4 depicts the performance comparison of GSA-CRS and CS-CGMP approaches with/without data reduction.

Network lifetime: In DR-NAP, the number of data communications have been reduced and hence reduces the communication cost. Further, the network lifetime of GSA-CRS with DR-NAP is improved by 47.82% when compared with GSA approach without DR-NAP. The network lifetime of CS-CGMP approach with DR-NAP improved by 51.96% when compared with CS-CGMP approach without DR-NAP. Fig. 3 shows the network lifetime of proposed approaches namely GSA-CRS, CS-CGMP with and without Data reduction for temperature data.

Average Residual energy of Node: Average residual energy of every node in the network over the rounds of 2300 is show in Fig. 4. The proposed approaches GSA-CRS with DR-NAP, CS-CGMP with DR-NAP have improved their energy level on average, by 50.75% and 40.87% more than GSA-CRS and CS-CGMP without DR-NAP respectively. The number of data packet transmission is reduced which leads in reduction of energy consumption and residual energy usage.

V. Conclusion

A neural adaptation phenomenon based data reduction technique for Internet of Things and Wireless Sensor Networks has been proposed in this paper. The DR-NAP strategy has been implanted in GSA based clustered routing for reducing the number of data transmissions between sensors to CHs and BS. Member sensor nodes will communicate the sensed data to the CHs based on the recently sensed values. If the recently sensed readings are identical or in sequence, sensor nodes

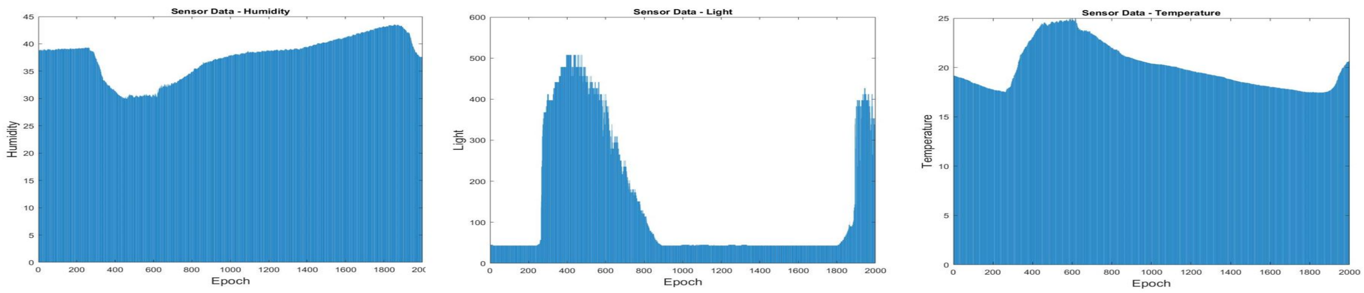

Fig. 2: Sample of Intel Berkeley Research Lab's sensed data ($http://db.csail.mit.edu/labdata/labdata.html$)

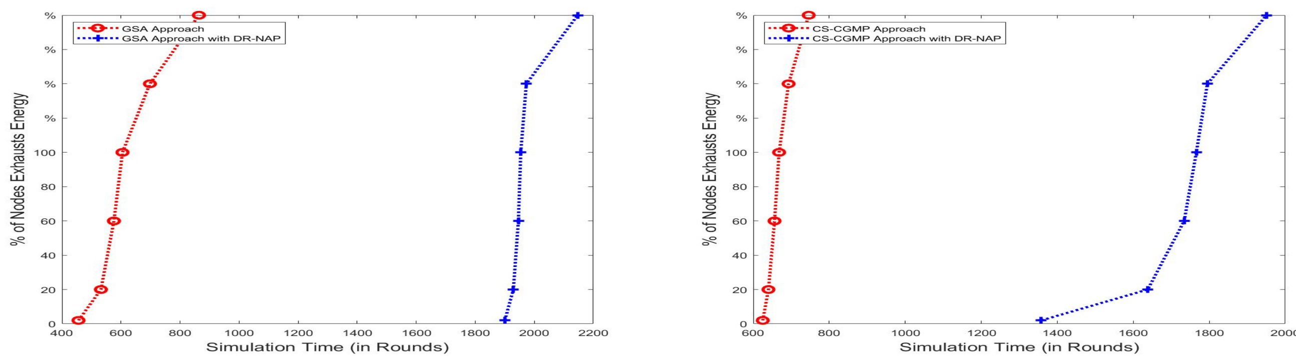

Fig. 3: Comparison of Network lifetime for GSA-CRS, CS-CGMP approaches with and without Data reduction

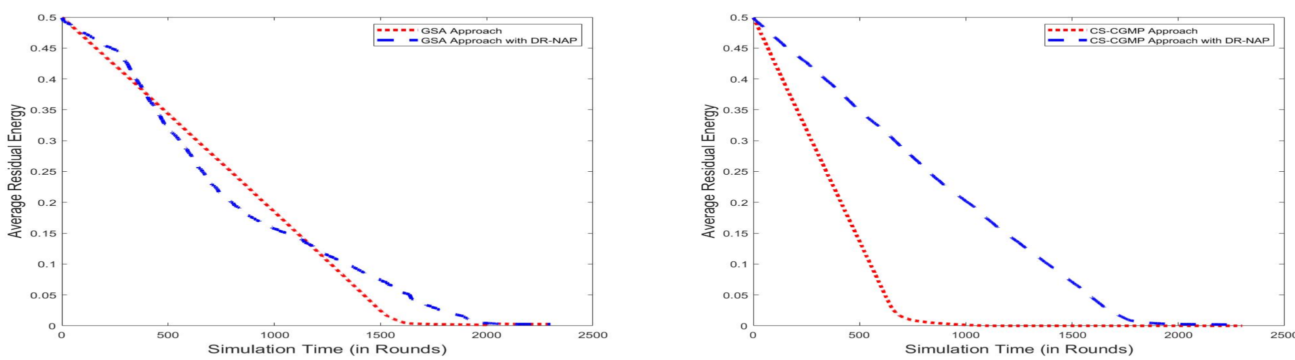

Fig. 4: Comparison of Average Residual Energy for GSA-CRS, CS-CGMP approaches with and without Data reduction

need not transmit, instead it may send an indicator signal bit 1 stating that current recorded value is equal with previous round value; otherwise, the sensed valued are transmitted. Hence, the total energy consumption has been decreased in individual sensor nodes. As per experiments conducted, it was noticed that the performance parameters such as network lifetime and average residual energy have been improved. The efficacy of GSA-CRS with DR-NAP has been enhanced by 47.82% in network lifetime when compared with GSA-CRS without DR-NAP; the CS-CGMP with DR-NAP has enhanced its network lifetime by 51.96% against CS-CGMP without DR-NAP. In future research works, the proposed data reduction strategy can be extended for handling multimedia data like image, video, audio, etc. in Wireless Multimedia Sensor Networks (WMSN) and IoT.

REFERENCES

[1] Ian F Akyildiz, Weilian Su, Yogesh Sankarasubramaniam, and Erdal Cayirci. Wireless sensor networks: a survey. *Computer networks*, 38(4):393–422, 2002.

[2] Jennifer Yick, Biswanath Mukherjee, and Dipak Ghosal. Wireless sensor network survey. *Computer networks*, 52(12):2292–2330, 2008.

[3] Koppala Guravaiah and R Leela Velusamy. Prototype of home monitoring device using internet of things and river formation dynamics-based multi-hop routing protocol (rfdhm). *IEEE Transactions on Consumer Electronics*, 65(3):329–338, 2019.

[4] Koppala Guravaiah, Arumugam Kavitha, and Rengaraj Leela Velusamy. Data collection protocols in wireless sensor networks. In *Wireless Sensor Networks-Design, Deployment and Applications*. IntechOpen, 2020.

[5] Tifenn Rault, Abdelmadjid Bouabdallah, and Yacine Challal. Energy efficiency in wireless sensor networks: A top-down survey. *Computer Networks*, 67:104–122, 2014.

[6] Jamal N Al-Karaki and Ahmed E Kamal. Routing techniques in wireless sensor networks: a survey. *IEEE wireless communications*, 11(6):6–28, 2004.
[7] Ke Li, Hao Luan, and Chien-Chung Shen. Qi-ferry: Energy-constrained wireless charging in wireless sensor networks. In *2012 IEEE Wireless Communications and Networking Conference (WCNC)*, pages 2515–2520. IEEE, 2012.
[8] M Mehdi Afsar and Mohammad-H Tayarani-N. Clustering in sensor networks: A literature survey. *Journal of Network and Computer Applications*, 46:198–226, 2014.
[9] Wendi B Heinzelman, Anantha P Chandrakasan, and Hari Balakrishnan. An application-specific protocol architecture for wireless microsensor networks. *Transactions on Wireless Communications*, 1(4):660–670, 2002.
[10] Ossama Younis and Sonia Fahmy. HEED: a hybrid, energy-efficient, distributed clustering approach for ad hoc sensor networks. *Transactions on Mobile Computing*, 3(4):366–379, 2004.
[11] Li Qing, Qingxin Zhu, and Mingwen Wang. Design of a distributed energy-efficient clustering algorithm for heterogeneous wireless sensor networks. *Computer communications*, 29(12):2230–2237, 2006.
[12] A Kavitha and R Leela Velusamy. Simulated annealing and genetic algorithm-based hybrid approach for energy-aware clustered routing in large-range multi-sink wireless sensor networks. *International Journal of Ad Hoc and Ubiquitous Computing*, 35(2):96–116, 2020.
[13] A Kavitha, Koppala Guravaiah, and R Leela Velusamy. A cluster-based routing strategy using gravitational search algorithm for wsn. *Journal of Computing Science and Engineering*, 14(1):26–39, 2020.
[14] Haidar Safa, Mathieu Moussa, and Hassan Artail. An energy efficient genetic algorithm based approach for sensor-to-sink binding in multi-sink wireless sensor networks. *Wireless networks*, 20(2):177–196, 2014.
[15] Koppala Guravaiah and R Leela Velusamy. Beach: Balanced energy and adaptive cluster head selection algorithm for wireless sensor networks. *Adhoc & Sensor Wireless Networks*, 42, 2018.
[16] Samir Goel and Tomasz Imielinski. Prediction-based monitoring in sensor networks: taking lessons from mpeg. *ACM SIGCOMM Computer Communication Review*, 31(5):82–98, 2001.
[17] Sabine M McConnell and David B Skillicorn. A distributed approach for prediction in sensor networks. In *Proceedings of 1st international workshop on data mining in sensor networks as part of the SIAM International Conference on data mining*, pages 28–37. SIAM Press Newport Beach, CA, 2005.
[18] Adam Silberstein, Gregory Filpus, Kamesh Munagala, and Jun Yang. Data-driven processing in sensor networks. In *CIDR*, pages 10–21, 2007.
[19] David Chu, Amol Deshpande, Joseph M Hellerstein, and Wei Hong. Approximate data collection in sensor networks using probabilistic models. In *22nd International Conference on Data Engineering (ICDE'06)*, pages 48–48. IEEE, 2006.
[20] A. K. M. Al-Qurabat, C. Abou Jaoude, and A. K. Idrees. Two tier data reduction technique for reducing data transmission in iot sensors. In *2019 15th International Wireless Communications Mobile Computing Conference (IWCMC)*, pages 168–173, 2019.
[21] H. Jiang, S. Jin, and C. Wang. Prediction or not? an energy-efficient framework for clustering-based data collection in wireless sensor networks. *IEEE Transactions on Parallel and Distributed Systems*, 22(6):1064–1071, 2011.
[22] Abdallah Jarwan, Ayman Sabbah, and Mohamed Ibnkahla. Data transmission reduction schemes in wsns for efficient iot systems. *IEEE Journal on Selected Areas in Communications*, 37(6):1307–1324, 2019.
[23] Walaa M El-Sayed, Hazem M El-Bakry, and Salah M El-Sayed. Integrated data reduction model in wireless sensor networks. *Applied Computing and Informatics*, 2019.
[24] Liansheng Tan and Mou Wu. Data reduction in wireless sensor networks: A hierarchical lms prediction approach. *IEEE Sensors Journal*, 16(6):1708–1715, 2015.
[25] Jan Benda. Neural adaptation. *Current Biology*, 31(3):R110–R116, 2021.
[26] A Kavitha, Koppala Guravaiah, and R Leela Velusamy. Cs-cgmp: Clustering scheme using canada geese migration principle for routing in wireless sensor networks. *Wireless Personal Communications*, pages 1–22, 2020.

IoT based Smart Medicine Reminder kit

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Abstract

Patients across the globe have varying requirements and schedules for the intake of their medicines. This usually results in patients missing their dosage or taking their medicines at the wrong time. The IoT based smart medicine kit reminds patients to take the dose and keeps track of their schedule. Additionally, the kit consists of health data capturing sensors such as glucose sensor, pulse oximeter sensor and temperature sensor. We can operate the Smart Medicine Reminder Kit from a mobile application. We feed the time as to when the patient should consume the medicine. The user gets notified through mobile notification, LED glow and a Buzzer alarm embedded in the smart medicine reminder kit alerts when a patient is supposed to take medicine. Predefined users other than the patient can also get notified about the status of the medicine intake and medicine quantity through mobile application. The load sensor senses and notifies a nearby pharmacist. Such a system would be beneficial when there is a Pandemic like COVID-19 or an epidemic like Ebola, as the patient would get minimum physical assistance. We can use the device in hospitals and nursing homes on a large scale.

1. Introduction

IoT takes connectivity to the next level by connecting numerous devices to the web, working with man to machine and machine to machine interactions. IoT ecosystems are not limited to a particular field but have business applications in home automation, healthcare, factory line automation, medical, retail, vehicle automation and more.

IoT technology lets us produce real-time solutions in a global environment. Mainly, it provides us wireless solutions that can be utilised in indoor and outdoor conditions to monitor the environment and track objects distantly.

Perhaps the most appealing application for IoT in Healthcare, giving us a chance to various clinical applications, such as remote health monitoring, work-out plans, illness care and elderly care. The diverse implementations of the frameworks and products related to the Internet of Things (IoT) are transforming the medical services field. Patients and suppliers both stay to benefit from IoT. A few employments of medical services in IoT are portable (mobile) health applications of wearable gadgets that grant patients access to their health information.

In [2], A.P.Sankar et al. surveyed 45 people (including 17 clinicians). This survey revealed that more than thirty-three per cent of patients assumed that it is better to skip the dosage than take medicine later than the prescribed dosage time. Many clinicians disagreed with this assumption. This opinion makes the need for a Smart Medicine reminder kit stronger on a daily basis. Missed or delayed dosage of medicines and sorting of the medicines are regarded as our problem statement here. Many aged and people with complex medicine schedule face difficulty in managing their intake. Using the Smart Medicine Kit to solve this problem will help manage medicines and dose intake.

The Smart Medicine reminder kit that we propose reminds the medicine intake with a notification on the mobile phone and LED and Buzzer in the IoT Device. The kit reminds the patient and assures that dosage has been taken by notifying concerned personnel related to the patient and even notifies when the patient misses the reminder. It can also be used to collect data of the patient to analyse his health, concerned with the time of medicine intake by premeditating the consequences of missing a particular dosage. In paper, [5], has used an IoT based intelligent box to monitor health. Temperature sensor, Pulse Oximeter sensor and glucose sensor are included in this box to monitor health along with providing medicine reminder. Paper [12], and [16] has briefed about how a smart medicine reminder device can be beneficial to blind people. A wearable can also be included in the device to make the system useful for deaf patients.

Additionally, a system like this would be beneficial during Pandemics and Epidemics. The proposed system would be handy for remote monitoring and timely medicine intake for COVID-19 diseased home-quarantined patients as there would be none to assist them physically.

2. Related Work

In paper[1] by Alen John Thomas et al. have efficiently used Raspberry pi, and Magnetic Reed switches operated by Stepper motors. They have made their model such that the medicine box is opened when the reminder occurs. A user may or may not come to take medicine. Exposing medicines to air might contaminate them or may lead to misuse by children unintentionally.

In paper [10] written by Abdul Minaam et al., they have used modules like pill dispensing, pill refilling, et cetera. The module for pill refilling is complex and could use more power to dispense a pill. Instead, we can include an LED screen to display the number of pills to be taken from the medicine box along with its name and save the data to mobile application through Bluetooth/WiFi module.

ARM 7 is used in the paper [3] written by Karishma K et al. and in the paper [6] by mrunali et al. In our model, we are using an Arduino, which can be interfaced with many more components and also be used to store and record data in the cloud.

DR. P. H. Zope et al. in paper [4] and papers[7], [13], [18], [22] have made a system with an LCD interface to display the data like time,compartment and medicine name which are related to the medicine intake. Additionally, this model can be made more usable by utilising a mobile notification for medicine intake reminder using a mobile application. Whereas, model in paper [8] has used an SD card for data input to the medicine kit, we use a mobile application.

In a similar use case by Cornell University students [11], the device provides an edge in avoiding the confusion of mixing up medicines by maintaining separate compartments but creates a problem of finding a ceiling for the number of compartments to provide as it varies from patient to patient.

Paper [9] written by Goncalo et al. talks about how even the smallest sensor data can be used in healthcare systems to enhance it.

In [20], authors propose a Non-invasive glucose sensing IoT system that makes use of an Opto-physiological glucose sensor, which uses a photo-diode and accelerometer to measure blood glucose levels. This sensor can be embedded in the medicine reminder kit to collect glucose levels without pricking the user's finger.

Kumar et al. in [24] stated a non-invasive method for glucose sensing that uses smart contact lenses that take the tears in a person's eye and measure the glucose levels.

IEEE has introduced IEEE 11073 standard, which caters to health and fitness devices. For example, in [21], medication dispensers, activity monitors, glucose level monitors, et cetera have been used to collect medical data that can be analysed later for providing health-related suggestions to the user.

In [14], the authors Jayesh Patil and Sameer Khairmode built the system such that pill intake time for particular patients is initially set in the system and can be changed by the patient to his requirement and the alarm buzzes at that specific time. An LCD screen is added to show the timing and make the system user friendly. After consuming the medicine, the system will update the pill number. Also, to check the pill count, if the quantity of box pills goes low, the order for a particular pill is sent by the system automatically to the medical store via SMS.

Authors of paper [23] aid us in understanding and reassuring us how Mobile health systems from an IoT perspective can be feasible in terms of data acquisition and security. They also suggest that mobile health devices will reduce the cost of healthcare and ”can benefit patients in quick diagnosis, remote monitoring and home rehabilitation”.

3. Proposed Model

The prescribed medicine dosage time is required to be set by the user through his mobile application, at which the device should remind the user for medicine intake. The user will get a notification at that time on his mobile notifying him to consume medicine. Apart from the user, any concerned/predefined user can also see if the medicine was consumed or not (See figure 1). At the time of the medicine intake, an LED will blink, and a Buzzer embedded in our IoT Device will ring along with a display of the number of pills to take in the LCD. When the user takes medicine, he can press a button to stop the Light and the Buzzer. Alternatively, we propose to embed weight and light sensors on the device to acknowledge the intake by confirming the difference in weight of the compartment when the medicine is taken and as the light sensor is exposed when the box is opened.

3.1. Block Diagram of the Proposed System

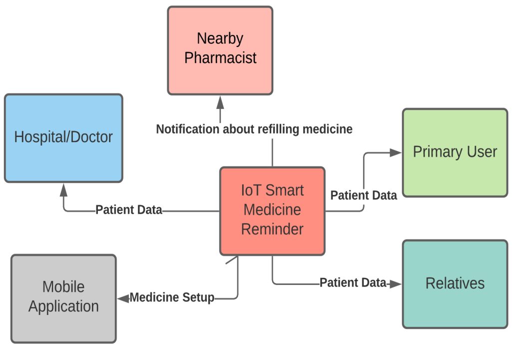

Figure 1. Block Diagram of the proposed system

The data collected from the smart medicine reminder kit, preferably using a mobile application as cited in papers [15] and [17] can be used for tracking the time at which the medicine is being taken, patient monitoring, analysing data from time to time to send reports of improvement or trends of ill-health by comparing with existing data sets. In this case to complete the system, IoT and Cloud can be integrated as cited in [19] and [25] (See figure 2).

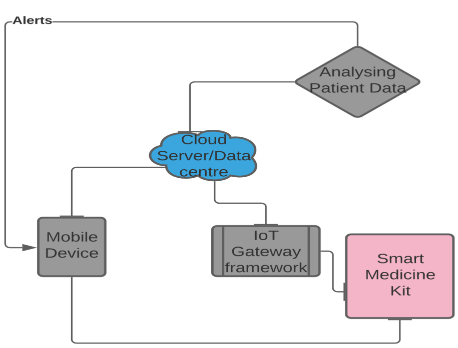

Figure 2. Flow of Patient/User data

3.2. IoT system Involvement

The IoT Devices' LED glows, and Buzzer rings for a certain amount of time, or we can set a button to control it. The IoT device also sends a notification to our mobile device when it is time for medicine intake(See figure 3).

3.3. Mobile Device Involvement

After the medicine intake time is set, the phone reminds the user to take medicine with a notification. The led glows on the corresponding compartment, and buzzer alarms on the IoT device when it is time for medicine intake. We also

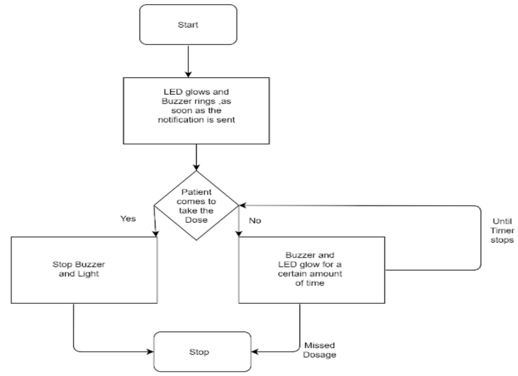

Figure 3. Workflow of our IoT Device Involved

record and keep a log of data stored in the mobile application for future use(See figure 4).

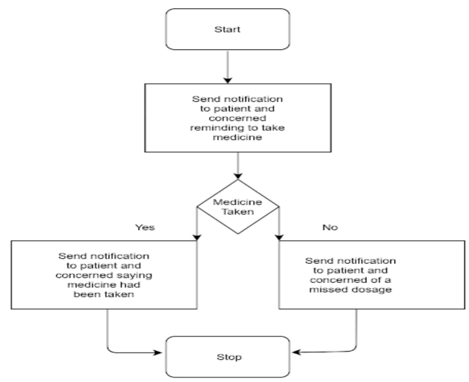

Figure 4. WorkFlow of our Mobile Device

4. Implementation

A set of hardware components is required to implement the proposed model. These are few essential components:(See figure 5):

- Arduino Uno Board
- LEDs
- Buzzer
- RTC DS3231 module
- Wifi ESP8266 Module
- Weight Sensor
- Light Sensor LDR
- Temperature Sensor LM35
- Glucose sensors
- Pulse Oximeter sensors

4.1. Hardware tools Required

1. Arduino Uno uses an 8-bit microcontroller ATmega328P, and it has a 32KB flash memory. Arduino Uno board makes interfacing easier as it can be connected to all other components. It also has an internal EEPROM that stores real-time data in it, and we do not lose the data stored in EPROM when the Arduino loses power. A set of instructions can be sent to the microcontroller by programming in Arduino Uno IDE.

2. The LCD screen is connected to Arduino Uno through some control pins, address and data bus. It displays what setting the system has been set to through the buttons. It displays time by communicating with RTC via Arduino Uno.

3. RTC module has I2C interfacing with Arduino Uno, and it keeps a time counter in real-time.

4. Led Blinks and the Buzzer rings as the reminder for time to take medicine.

5. Temperature sensor LM35, Pulse Oximeter Sensor and glucose sensor are used to collect patient data when he visits the medicine reminder kit. This data is sent to the cloud for further processing or analysing.

6. The weight sensor is to compute the difference in weight of the medicine compartment before and after the intake, enabling us to know the status of the intake and the logs of the box detail. It can also send notifications for refilling to a pharmacist when the weight goes below a threshold value.

7. Light Sensor is to know when and which compartments have been opened. It can be used to notify the user if a compartment is not close properly.

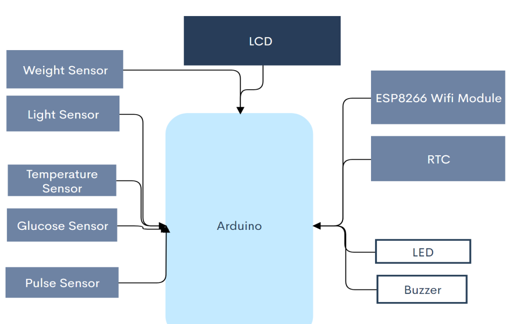

Figure 5. Block Diagram Of the sensors connected to Arduino

5. Experimental Results

We have simulated a basic version of the smart medicine reminder kit using Proteus Pro 7.

5.1. Software tools Required

We have written code in Arduino IDE for simulating a basic model. We use Proteus Professional 8, a software application utilised essentially for electronic circuit designs, to build the schematics for assembling printed circuit boards. We have written code in Arduino IDE for simulating a basic model.Arduino IDE is used to write and upload the code to the board.

5.2. Working of the Simulated system

Real-world connections can also be made in the same manner. The same code can be loaded, and the systems' behaviour will be the same. The simulated version is not very smart compared to the proposed model as it does include real-time sensing and processing of data. The circuit of the simulated system is given in figure 6.

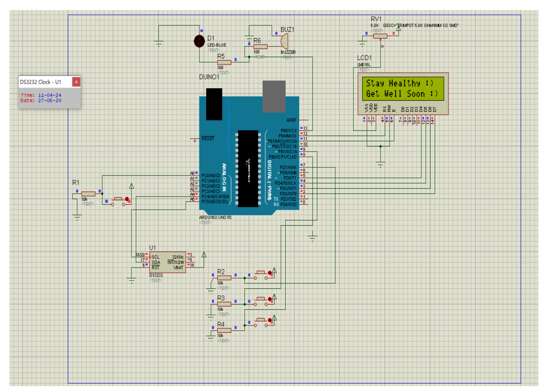

Figure 6. simulation Circuit

5.3. Flow chart of the Simulated Circuit

The flow chart depicts the workflow of the simulated circuit. The LCD screen keeps showing different screens until there is an input from the button. The time is set in the code, and when it is the time of medicine intake, the led blinks and buzzer rings until the stop button is pushed(See figure 7).

5.4. Basic Prototype of the smart medicine reminder kit

We are using Pulse Oximeter and temperature sensor, and their data is being transmitted to Thingspeak(cloud) via ESP8266 WiFi Module. This data can also be exported to hospitals and doctors. It can also be used for research and further analysis. On the other hand, the Bluetooth module is used to serve as a reminder from the app. For the prototype, we manually controlled the operation of LED and

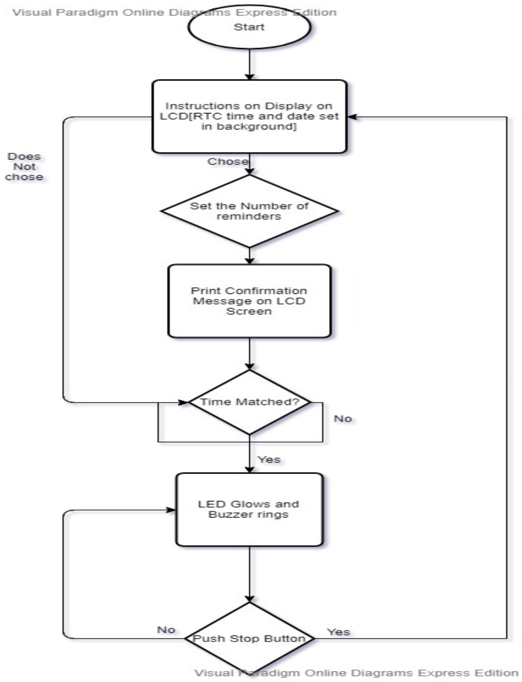

Figure 7. Flowchart of simulated circuit

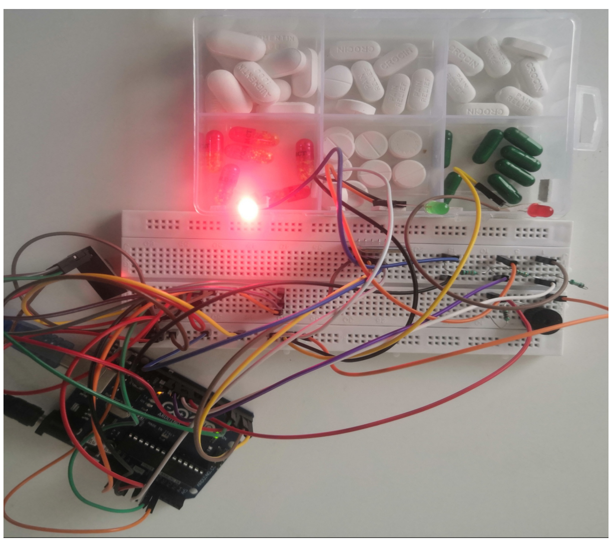

Figure 8. Basic Prototype of the Smart medicine reminder kit

buzzer due to the absence of the RTC DS3231 timer module. LED glows in the compartment of which the medicine is to be taken. The glow of LED in compartment one can be observed(Figure 8), indicating that the medicine in compartment one should be taken. Buzzer also rings as long as one of the lights is on, which acts as an additional reminder.

6. Conclusion

An IoT based Smart Medicine Reminder kit will be helpful for older people, people with a long prescription list, people who are unable to read the medicine description and can be used for tracking dose and not missing a dosage. Further, the multi-user feature can be useful for old age homes and hospitals by increasing the number of compartments. It will keep the patients' close ones informed about medicine intake, which is a necessary aspect of this model. Further, our model has new features of using a weight and a light sensor in the IoT device for notifying about refill and box open/close status. We aim to monitor and analyse the collected data at the data centre to come up with useful insights that may be helpful for doctors, patients and concerned relatives. The IoT-based smart medicine reminder kit will address the widely persisting issue of missed dosage by regular and occasional medicine consumers and provides several additional features to utilise the obtained information from the Smart Medicine Reminder kit.

References

[**1**] A smart medikit using IoT technology,Thomas, Alen John and Radhakrishnan, Abhishek and Geroge, Arun and Joy, Geo and Krishna, Gayathri R, International Journal.Toronto,Ont.volume 8, number 3, 2019

[2] 'What is a missed dose?'Implications for construct validity and patient adherence , Sankar, AP and Nevedal, DC and Neufeld, Stewart and Luborsky, MR, AIDS care,Taylor Francis, volume 19, 2007.

[3] Nyapathi, N.U., Pendlimarri, B., Karishma, K. and Kavya, C., 2016. Smart Medicine Box using ARM 7 Micro controller. International Research Journal of Engineering and Technology.

[4] DR. P. H. Zope, Nidhi Solanki Smart pill box health care system.International Research Journal of Engineering and Technology (IRJET),3, 2018

[5] Hailma, J. Josephine Hope. "An IoT based intelligent medicine box." (2015).

[6] Mrunali Digambar Patil, Intelligent medicine box.International Research Journal of Engineering and Technology (IRJET), 2017.

[7] Yash Sharma and Vijayrajsinh Zala Parth Vyas Sanjay Bhati,Harshid Soni. Smart medicine reminder box.International Journal of Science Technology Engineering, 3, 2017.

[8] Nilesh Singhal Harsh Shah Prof. Prashant Uapdhyay Viral Shah, Ji-gar Shah. Smart medicine box.Imperial Journal of InterdisciplinaryResearch(IJIR), 2, 2016.

[9] Gon calo J. F. Carnaz1and Vitor. An overview of iot and healthcare.2019.

[10] Minaam, Diaa Salama Abdul, and Mohamed Abd-Elfattah. ”Smart drugs: Improving healthcare using smart pill box for medicine reminder and monitoring system.” Future Computing and Informatics Journal 3.2 (2018): 443-456.

[11] Smart Medicine Box , ECE 4760 Digital Sys Design-Microcontroller, Mingyuan Huang (mh2239), Jie Zhang (jz652), Cornell University.

[12] Shailaja, M., K. Lokeshwaran, and S. Sheik Faritha Begum. ”Smart medication pill box for blind people with pulse sensor.” Int. J. Recent Technol. Eng 8 (2019): 388-395.

[13] MediSmart: Better health with IoT based med box, Raut Vaibhavi,Tanaya Patil,praparna moharana,shantanu ghanekar,swati A.Joshi; International Journal of Advance Research, Ideas and Innovations in Technology ISSN: 2454-132X (Volume 5, Issue 3)

[14] The Autonomous Pill Dispenser with Alarm and Mobile Notifications Jayesh Patil, Sameer Khairmode, Rishikesh Lokhande ,Omkar Shinde Computer Department, PVG’s College of Engineering and Technology Pune International Journal for Research in Applied Science Engineering Technology (IJRASET) ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887 Volume 7 Issue IV, Apr 2019

[15] Veena Saraf, Husna Tajwar, Android Application Design for Automatic Tablet Dispenser, INTERNATIONAL JOURNAL OF ENGINEERING RESEARCH TECHNOLOGY (IJERT) Volume 09, Issue 07 (July 2020)

[16] Iot Based Medication Monitoring System for Independently Living Patient, S. Kiruthiga, B. Arunthadhi, R. Deepthy varma, V. R. Divya Shree, International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-9 Issue-3, February, 2020

[17] Scan Med: A Healthcare Application using QR Code, Unde Gorakh Shankar ,Ranjeet Kumar,Khan Abdullah Z,Asst.Prof Dagadkhair Pooja,Department of Computer Engineering, G.H Raisoni college of engineering and management, Ahmednagar, India 2018 IJCRT — Volume 6, Issue 2 April 2018 — ISSN: 2320-2882

[18] REVIEW ON SECURE BIOMEDICAL USING IOT , JETIR May 2019, Volume 6, Issue 5 (ISSN-2349-5162)Sapna R Tayde, Pra sanna M Walchale, Sachin A Vyawharea CSE Department, Sanmati Engineering College, Washim, India.

[19] Junaid Latief Shah, Heena Farooq Bhat, Asif Iqbal Khan, Chapter 6 - Integration of Cloud and IoT for smart e-healthcare, Editor(s): Valentina E. Balas, Souvik Pal, Healthcare Paradigms in the Internet of Things Ecosystem, Academic Press, 2021, Pages 101-136, ISBN 9780128196649,https://doi.org/10.1016/B978-0-12-819664-9.00006-5.

[20] 5.R. S. H. Istepanian, S. Hu, N. Y. Philip, A. Sungoor, ”The potential of Internet of m-health Things m-IoT for non-invasive glucose level sensing”, IEEE Annual International Connference in Engineering Medicine Biology Society (EMBC), pp. 5264-5266, September 2011.

[21] IoT Architecture and System Design for Healthcare Systems Niharika Kumar Department of Computer Science and Engineering BNMIT Bangalore, India 2017.

[22] Review Paper for Smart Medicine Kit, Anjana Bhardwaj, Upasana Sharama, Ranjeeta Yadav (ABES Engineering College, Department of Electronics Communication Engineering, Ghaziabad, U.P, IOSR Journal of Engineering, ISSN (e): 2250-3021, ISSN (p): 2278-8719, Vol. 08, Issue 7, 2018.

[23] S. H. Almotiri, M. A. Khan and M. A. Alghamdi, ”Mobile Health (m-Health) System in the Context of IoT,” 2016 IEEE 4th International Conference on Future Internet of Things and Cloud Workshops (FiCloudW), 2016, pp. 39-42, doi: 10.1109/W-FiCloud.2016.24.

[24] Kumar, P. M., Lokesh, S., Varatharajan, R., Chandra Babu, G., Parthasarathy, P. (2018).Cloud and IoT based disease prediction and diagnosis system for healthcare using Fuzzy neural classifier. Future Generation Computer Systems, 86, 527–534.

[25] Prabal Verma, Sandeep K. Sood, ”Cloud-centric IoT based disease diagnosis healthcare framework”, J, Parallel Distrib. Comput., 2018.

IoT, Fog and Cloud Computing Based Virtual Patient Monitoring and Telemedicine

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Abstract **- The paper focuses on a combination of emergency response and health system capacity-building efforts consistent with the COVID-19 containment plan that was recently developed by the Ministry of Health and Family Welfare (MOHFW), Government of India with support from the World Health Organization (WHO) and partners. It utilizes existing healthcare devices as nodes in an IoT network for large-scale patient monitoring as well as remote healthcare (Telemedicine). The system combines network-enabled devices with a mobile application acting as the fog node. The final data is stored in the cloud where long-term analytics and symptom-based diagnostics take place. These data and relevant analytics are made available to the medical personnel who can make the final diagnosis. The system finds relevance in both maintaining a medical presence in ill-equipped and remote locations as well as round-the-clock monitoring of elderly patients at home or in assisted living centers. So, we propose a continuous checking and control instrument to screen the patient's condition and store his/her information in a server utilizing Wi-Fi-based wireless communication.[2]**

Keywords – Internet of Things, Fog computing, Cloud Computing, 5G networks, Health Monitoring

I. INTRODUCTION

According to statistics from the Medical Council of India, our nation has a doctor to patient ratio of 1:1445, considering an average availability of 80% of the total doctor populace. With an approximate 9.27 lakh active allopathic doctors serving a population of 1.3 billion with a growth rate of 1%, there is a dire need for manpower in the Indian healthcare sector. Internet of Things (IoT) is a new revolution of the internet and is an adaptive growing research area in multiple domains, including healthcare. With the increasing accuracy and affordability of wearable sensors and smartphones, remote health care monitoring has evolved at a rapid pace.[4] IoT health monitoring also helps to monitor and control the spread of any contagious disease as well as to get a proper diagnosis of the patient, even if the medical personnel are at a different geographical location. This situation, therefore, provides a perfect opportunity for the introduction of virtual patient monitoring solutions (VPMS). The injection of technology will greatly benefit this sector, allowing more efficient use of human resources and ready availability. The situation is further benefitted by the growing internet penetration in rural areas. With the increased implementation of IT and management, data is now playing a vital role in disease diagnostics, drug administration, and healthcare management [16]. The developments in wireless sensor networks (WSN), body area networks (BAN), cloud computing, and big data technologies further simplify the implementation of the Internet of Things (IoT) in the healthcare industry. [17]

This paper aims to demonstrate an IoT-enabled system on high-speed 5G networks that allow doctors to check a patient's health parameters and monitor their progress remotely. It builds on the techniques first demonstrated by Shaw [6] as well as the INTEGRIS TeleRehab program [8]. It also incorporates a few under-development wearable technologies being developed by the IoT research cell of the University of Calcutta. Communication can be established through secure video conferencing channels while a network of internet-enabled devices and sensors continuously monitor the patient's vitals. For individuals requiring round-the-clock monitoring, these sensor networks can be autonomously run under the commands of a local centralized system acting as the fog device that continually backs up sensor data to the cloud. The system can ensure that the patient's vitals remain within predetermined levels, and generate alerts if any anomalies are detected. This concept can also find implementation in other applications such as elderly care in urban and peri-urban backgrounds, where we have the added benefit of relatively less interrupted cellular data services (4G+ speeds).

II. LITERATURE REVIEW

Virtual or remote patient monitoring has already been implemented in several developed nations across the globe. [1]. The concept of Telehealth has existed ideologically since the early twentieth century with radio and later television being a source of communication. Telehealth capacities were built into the spacesuits of the Apollo astronauts to monitor their health parameters and address any issues.[7] Modern telehealth combines the domain of IoT along with existing communication systems for comprehensive monitoring, early detection, and long-distance care system.[3] A modern evolution of this domain is the virtual patient monitoring systems (VPMS). In developing nations like India, VPMS provides a suitable solution for medical support in remote areas as well as providing round-the-clock care to patients institutionalized for prolonged durations.[12]

In his publication [6], Shaw elaborates on the development of Telehealth in the modern era and how in over 30,000 Trans-telephonic exercise monitoring sessions of patients with cardiopulmonary diseases, no circulatory arrests were documented despite the inclusion of high-risk cardiac conditions. Wakefield's evaluation of video and telephonic communication for monitoring patients with high-risk heart conditions showed a noticed delay in time to readmission as well as a massive increase in general data about symptoms pertaining to cardiovascular conditions.

In their publication [8], the team has highlighted the feasibility of using a real-time pulse oximeter and ECG data from the patient exercising on a motorized treadmill at a remote site. The researchers concluded that advanced aged patients with the aforementioned conditions can safely be monitored via telerehabilitation systems. The INTEGRIS TeleRehab program, based out of Oklahoma since the late 1990s has shown significant success in telehealth systems through a high-speed T-1 communication line and a Polycom system. Their success led to expansion into the domains of occupational and speech therapy.

The significant success of telehealth over the years combined with the beleaguered national health system of India facing an acute shortage of medical personnel causing over-extension of these valuable resources presents an ideal situation for implementing such a system.[10][11] Also, the recent SARS Cov2 outbreak [15] that has affected numerous countries around the globe and caused significant economic damage is a classic example of how the modernization of our health care systems has been ignored for too long. Remote Patient Monitoring arrangement allows observation of patients outside of customary clinical settings (e.g., at home or isolation centers), which expands access to quality health services and significantly reduces expenses. With benefits to both rural and urban sectors, this is the logical step forward for more efficient utilization of our nation's limited health resources.[13] With a primary focus of monitoring patients with cardio-pulmonary conditions, the system may be further extended and established to support a wider array of medical conditions as well as general vigilance of individuals who require constant monitoring such as the elderly and the differently-abled.[5]

III. PROPOSED METHODOLOGY

The data collection process will revolve around 4 primary parameters to be monitored along with the patient's inputs on a daily questionnaire. Here, the intention is to build an independent sensor hub for monitoring user vitals and alerting if necessary. The final communication with a medical professional takes place through a live teleconferencing solution, choosing one of the many readily available solutions. The sensor hubs (FOG devices) are individually connected to the cloud where the bulk of data processing and analysis takes place. The analyzed data is readily available to medical professionals for their opinion through a simple and vivid online dashboard. Fig. 2 demonstrates our data acquisition (DAQ) module.

At the simplest level, the system accepts e-prescriptions from authorized medical personnel. It then updates the patient's current daily medical roster (if any) and appropriately generates alerts at the designated time. This aims to prevent missing doses, which is especially prevalent in the case of elderly patients

Fig. 1. E-Prescription concept.

The parameters being considered for this study include blood pressure, body temperature, oxygen saturation in the blood (SpO2), real-time heart rate readings as well as blood glucose levels. The blood pressure readings are to be taken at regular intervals through a connected Sphygmomanometer that transfers its readings to the local fog device after measurement. The data is then stored in the cloud and analyzed based on previous data for the patient. Any risk markers such as recurring high blood pressure or hypertension can be flagged and reported accordingly to the doctor's patient dashboard.

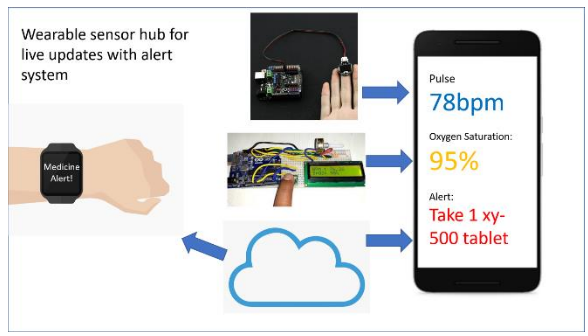

Fig. 2. Data Acquisition Module

The temperature sensor is connected to the digital pin of the microcontroller board. Based on the data in Table 1, we determine if the temperature lies within the normal range. Using the data, the controller converts it into its corresponding value in degree Celsius (°C) using the equation:

temperature (°C) = [raw value*5/4095- (400/1000)] *(19.5/1000)

Oxygen saturation is monitored through a similarly connected pulse oximeter (Fig.3). The device detects the patient's blood oxygen level and communicates it to the fog. These readings are especially necessary for patients facing chronic obstructive pulmonary diseases and other respiratory hindrances. Sudden drops in oxygen levels will generate high-level alerts and the nearest caregiver can be instructed to administer respiratory aid. Table 2 highlights the optimum oxygen saturation levels.

Fig. 3. Oxygen Saturation level monitoring

The patient’s pulse is calculated in two primary ways as shown in Fig 3 and Fig 4. Wearable technology with embedded passive heart rate sensors is used for real-time pulse readings. Additionally, secondary and tertiary readings are collected through the blood pressure and oxygen saturation sensors, since both operate in close contact with the patient. A combination of these readings will minimize any possibly erroneous data that crops up, reducing the chance of false alerts. Table 3 highlights just this.

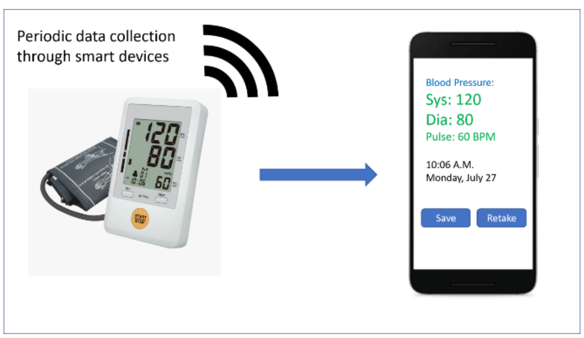

Fig. 4. Blood Pressure Monitoring

Finally, we also aim to monitor a patient's blood glucose through a similar, internet-enabled glucometer (Fig. 5) that can transmit data to the fog node. While much research is being conducted in the field of non-invasive glucometers, the lack of affordable and proven technologies will require us to currently rely on the readings of the standard blood-based invasive glucometers. This will be substituted for a non-invasive system as soon as a compatible, accurate, and economical product is available[14]. The values of Table 4 are some basic benchmarks we consider.

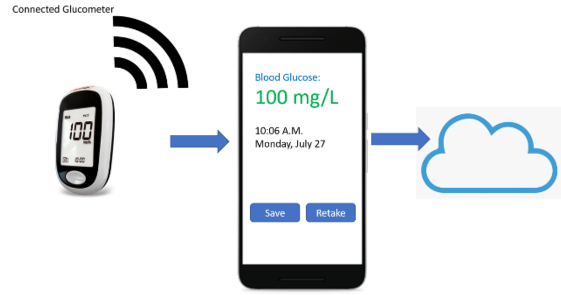

Fig. 5. Glucometer data collection

With these sensors appropriately deployed, the next point of action is the fog node. It can be a compact, low-power server based on Raspberry Pi or a more powerful server for large patient hubs as well as a controller application running on a sufficiently powerful smartphone. The benefits of sensor fusion are visible in Table 5 where we combine oxygen saturation and body temperature for some common diagnostics. Besides doubling as a local server, the smartphone will also provide a means for showing health alerts and limited analytics data to the patient or their local caregiver. The full dataset and its analysis will be visible to the designated doctor, allowing virtual patient monitoring. The smartphone application will also provide the patient with daily questionnaires (Fig. 6) aimed at identifying any new symptoms or conditions that might require medical intervention. These questionnaires will need to be filled up daily and stored in the cloud for the patient’s symptom analysis and the doctor’s reference.

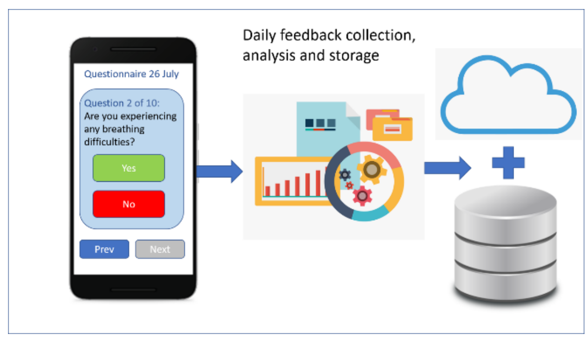

Fig. 6. Proposed questionnaire system

The final system has a structure like Fig. 7

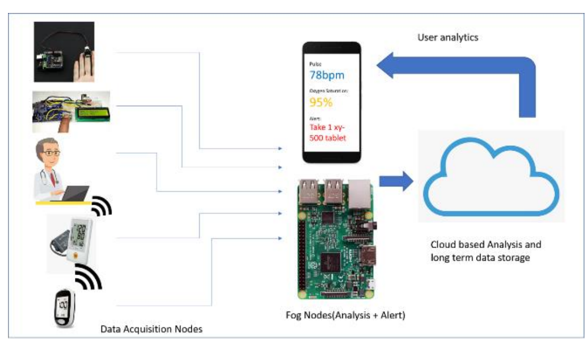

Fig. 7. Composite system

A. *Alert Generation Criteria:*

TABLE I. BODY TEMPERATURES

Body Temperature (°C)	State
36.0 – 37.5	Normal
>37.5	High
<36.0	Low

TABLE II. BLOOD OXYGEN SATURATION CLASSIFICATION

Reading(% SpO_2)	State
95% - 100%	Normal
90% - 95%	Low
<90%	Very Low

TABLE III. PULSE RATE CLASSIFICATION

Pulse Rate (BPM)	State
60 BPM – 100	Normal
>100	High
<60	Low

TABLE IV. BLOOD GLUCOSE METRICS

Fasting Blood Sugar Levels	Post Meal Blood Sugar Levels	State
70-100 mg/dl	70-140 mg/dl	Normal
101-125 mg/dl	141-200 mg/dl	Prediabetes (Low)
>=125 mg/dl	>=200 mg/dl	Diabetes (High)

TABLE V. POSSIBLE DIAGNOSIS

Pulse Rate with SpO_2 (from Oximeter)	Body Temperature		
	Low	*Normal*	*High*
Very Low	Emergency Checkup	Respiratory Distress	Emergency Checkup
Low	Hypothermia	Mild breathing trouble	Fever
Normal	Health Checkup	Healthy	Fever

[a] **Red** indicates high-risk alert

Orange indicates moderate risk warning

B. *Risk and Mitigation Plan*

- There has to be a proper and continuous internet connection, otherwise, the data would not be updated timely. So, stable connectivity is essential.
- As common with any solution that requires data transmission between devices and servers, there is a risk of unauthorized access to the secure networks. This may be mitigated by implementing encryption algorithms to convert our data into appropriate ciphertext.

IV. Possible Use Cases

As mentioned before, the domain of Telehealth and Telemedicine has been in use since the 1960s. In the ongoing SARS Cov2 (Covid-19) Pandemic, its relevance and usefulness have once again come to the forefront of the medical community. Many government health organizations, including the Indian Health Ministry, are openly advocating telemedicine as a quick and efficient method of treating the massive population. It also reduces risks of contamination in case of pathogens as highly contagious as the SARS Cov2. Therefore, it is only fair to assume that this medium of virtual healthcare will remain relevant in a post-pandemic world.

Apart from healthcare and monitoring patients with highly infectious diseases, the system can make modern and high-quality healthcare accessible in remote locations of India. Doctor consultations can be carried out virtually through teleconferencing while the aforementioned sensor networks can effectively monitor the patient's vitals and flag any inconsistencies. Machine learning-based models can also be used to assist the diagnosis by efficiently relating the patient's symptoms and current health parameters with relevant online repositories and make suggestions to the medical personnel. This can allow currently overstretched medical resources to be utilized more effectively and efficiently.

Another possible use case could be the domain of geriatric care, where the system could be adapted for round-the-clock monitoring of elderly patients with minor editing. In this case, a new functionality of a local caregiver can be added which will alert the patient’s local attendant in case of any anomaly. The wearable alert and monitoring device can also be adapted with multi-axis gyro-sensors to detect and predict falls, alerting the local caregiver if any of the parameters cross predefined thresholds. Significant research has already been carried out in the domain of fall prediction [9].

V. Conclusion:

The Internet of Things (IoT) increases interoperability, machine-machine communication, and data sharing that makes healthcare service delivery more efficient and effective. It facilitates that the individual's health parameter data is secure within the cloud, hospital stays reduced for traditional examinations, and most importantly, health parameters can be monitored and disease diagnosed by specialists remotely. This project is an ideal example of implementing technological assistance in the Indian healthcare domain with potential for expansion in other developing nations. It will also highlight and remedy previously unanticipated challenges and issues that may arise in moving a real-time connected system into locations with limited connectivity.

VI. Future Scope:

The future scope for this project includes more dense networks of sensors, simultaneous monitoring of patients through interconnected hubs as well as comparative studies with patients in different geographic locations. Also, the potential for the development of new, minimally invasive medical devices as a corollary (Non-invasive glucometers, Non-contact sphygmomanometer) is not to be ignored. Finally, the system aims to mitigate the challenges brought forward in highly contagious outbreaks similar to the ongoing SARS Cov2 pandemic.

VII. References/Citations:

[1] Woodbridge, Diane & Evangelista, Lorraine & Chen, Chien-An & Han, Kyungsik & Kang, Jinha & Tu, Michael & Chen, Victor & Nahapetian, Ani & Sarrafzadeh, Majid. (2010). An automated vital sign monitoring system for congestive heart failure patients. IHI'10 - Proceedings of the 1st ACM International Health Informatics Symposium. 108-117. 10.1145/1882992.1883010.

[2] Wang, Xuyu & Yang, Chao & Mao, Shiwen. (2020). On CSI-Based Vital Sign Monitoring Using Commodity WiFi. ACM Transactions on Computing for Healthcare. 1. 1-27. 10.1145/3377165.

[3] https://www.ericsson.com/en/blog/2018/10/5g-and-iot-improving-lives-of-the-older-adults

[4] Haghi, Mostafa & Thurow, Kerstin & Stoll, Regina. (2017). Wearable Devices in Medical Internet of Things: Scientific Research and Commercially Available Devices. Healthcare Informatics Research. 23. 4-15. 10.4258/hir.2017.23.1.4.

[5] Pinto, Sandro & Cabral, Jorge & Gomes, Tiago. (2017). We-Care: An IoT-based Health Care system for Elderly People. 10.1109/ICIT.2017.7915565. 2017 IEEE International Conference on Industrial Technology (ICIT) At: Toronto, ON, Canada

[6] Shaw, Donald K. “Overview of telehealth and its application to cardiopulmonary physical therapy.” Cardiopulmonary physical therapy journal vol. 20,2 (2009): 13-8.

[7] Wakefield BJ, Holman JE, Ray A, Scherubel M, Burns TL, Kienzle MG, Rosenthal GE. Outcomes of a home telehealth intervention for patients with heart failure. J Telemed Telecare. 2009;15(1):46-50. doi: 10.1258/jtt.2008.080701. PMID: 19139220.

[8] Marshall, S & Shaw, Donald & Honles, Grace & Sparks, Kenneth. (2008). Interdisciplinary approach to the rehabilitation of an 18-year-old patient with bronchopulmonary dysplasia, using telerehabilitation technology. Respiratory care. 53. 346-50.

[9] Pang I, Okubo Y, Sturnieks D, Lord SR, Brodie MA. Detection of Near Falls Using Wearable Devices: A Systematic Review. J Geriatr Phys Ther. 2019;42(1):48-56. doi:10.1519/JPT.0000000000000181

[10] https://www.nih.gov/news-events/news-releases/worlds-older-population-grows-dramatically

[11] https://www.business-standard.com/article/pti-stories/doctor-patient-ratio-in-india-less-than-who-prescribed-norm-of-1-1000-govt-119111901421_1.html

[12] https://e360.yale.edu/features/why-india-is-making-progress-in-slowing-its-population-growth

[13] https://plushcare.com/blog/how-does-a-virtual-doctor-visit-work/

[14] https://www.pharmaceutical-journal.com/news-and-analysis/features/non-invasive-glucose-monitoring-for-diabetes-five-strategies-under-development/20203666.article?firstPass=false

[15] Shubham Banka, Isha Madan, and S.S. Saranya, Smart Healthcare Monitoring using IoT. International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 15, pp. 11984-11989, 2018.

[16] Yamin, M. IT applications in healthcare management: a survey. Int. j. inf. tecnol. 10, 503–509 (2018). https://doi.org/10.1007/s41870-018-0203-3

[17] Baloch, Z., Shaikh, F.K. & Unar, M.A. A context-aware data fusion approach for health-IoT. Int. j. inf. tecnol. 10, 241–245 (2018). https://doi.org/10.1007/s41870-018-0116-1

FRAMEWORK for Roadside Litter Identification and Face Recognition using Convolutional Neural Networks

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Abstract— Conventional street cleaning methods involve lots of human resources. Using face detection and image processing techniques, the identification of people who litter on the roadside is made possible. By fixing cameras in crowded places such as bus stands and markets, the proposed system utilizes a deep neural network algorithm called Convolutional Neural Network (CNN), especially Mask Region Convolutional Neural Network (Mask R-CNN). The proposed schema makes use of this deep learning algorithm to analyze the photographs of the streets and detects the litter (if any) in them. Further, in the presence of litter, the schema identifies the person throwing the litter. In-built library files of Python are involved in this process for generating and comparing the face encodings. Reducing operational costs and assisting with better monitoring of the streets can improve the system efficiency tremendously.

Keywords— Cleanliness, Face Recognition, litter detection, MASK - RCNN, Neural Networks

I. INTRODUCTION

Littering is a common occurrence all around the world. Some may even refer to it as chronic. People cannot help but litter everywhere, be it on roads, railway tracks, floors, water bodies, etc. Swachh Bharat Abhiyan – A Government of India mission to make people more responsible towards their surroundings and motivating them to take charge of the cleanliness around them. However, the closest thing to punishment enforced by the government is imposing a fine of rupees five hundred to whoever litters of one's free will according to Section 278 of The Indian Penal Code. Currently, the process of litter detection on streets is not automated and it demands human intervention at almost every level which makes it even more time-consuming. Most of the tasks involved in street cleaning i.e., litter detection and classification can be automated using deep learning techniques. In this paper, an automated workflow is proposed to achieve these tasks. Our proposed framework aims at improving the environment of a city by using object detection and face recognition techniques. By doing so strict laws and measures can be enforced effectively, to make the citizens more responsible towards their environment.

II. LITERATURE SURVEY

In paper [1], the mobile processing component of the proposed framework is considered. The main goal of this component is to process the captured pictures and determine if they are worthy for deeper processing. Further object detection and classification are performed on the captured images. Performing object detection using CNN is one of the alternatives. Optimized variants of CNN such as Region Convolutional Neural Network (R-CNN) [2], [3] have been produced due to the advancements in the field of deep learning. However, the training model which uses R-CNN is expensive in terms of space and time and performs slow object detection [4]. A more enhanced implementation is Fast R-CNN [4], which has significant performance improvements. It delivers at near real-time rates for object recognition using deep neural networks with multiple layers of convolutional and max-pooling layers. Selective search is used to generate predictions and it involves a great deal of time. To overcome this, Faster R-CNN replaces the selective search method with a region proposal network which makes the algorithm much faster [5]. However, pixel-to-pixel alignment between network inputs and outputs cannot be performed by Faster RCNN. To execute coarse spatial quantization for feature extraction, it utilizes the Region of Interest (RoI) Pool. An easy, quantization-free layer known as RoI Align, conserves the exact spatial locations. It is used in Mask R-CNN [6]. Mask R-CNN is theoretically simple. A class label and a bounding-box offset are the results of Faster RCNN. In addition to this, a third branch that outputs the object mask (a binary mask that indicates the pixels at where the object is in the bounding box) is added. The extraction of the spatial layout of an object is carried out using Mask RCNN.

III. PROPOSED METHODOLOGY

With the aid of the above-mentioned literature, the proposed schema is designed and depicted in Fig. 1. The proposed schema automates the task of litter detection by using deep learning algorithms applied on images of streets captured through a camera. A pi camera captures the images at every 20s and feeds them into the processing component that has the primary goal to process the captured pictures and determine their worth for in-depth processing. This result is fed into the Object Detection Block (ODB) that uses the Convolutional Neural Network (CNN), especially the Mask RCNN. The ODB is responsible to differentiate the litter and non-litter objects successfully.

2000 region proposals for the input image are achieved with the help of an individual network with a selective search algorithm [10]. RoI Align layer which is not quantized is utilized to reshape the predicted region proposals. Each region proposal image is deformed into a fixed size of 224x224. These region proposal images are then passed to the trained CNN to obtain a 4096-dimensional feature vector against all the 2000 region proposals, resulting in a 2000x4096 dimensional matrix.

Each region proposal is classified using SVM (Support Vector Machines) [7] for each class. The SVM weights(4096-dimensional) are built into a matrix and it is multiplied with the feature matrix for all the N classes. This results in a matrix that assigns a score to each class to which a region proposal belongs. The class with the maximum score isprovided with a request. Hence, all the 2000 region proposals or bounding boxes in the image are provided with a class label. Out of those many bounding boxes, many of them would be redundant. Hence, the overlapping bounding boxes need to be removed and are accomplished using a Non- maximum suppression algorithm [9].

Using the scores, the system distinguishes between litter and non-litter. For litter, the control is transferred to the face detection block. The inbuilt functions of Python generate and compare the face encodings [12]. The algorithm considers the specific essential measurements of the face such as the color, the size, the eyes slant and the gap between eyebrows, etc. The combined features define the face encoding and are used to identify the specific image (face). Further, the images are compressed and stored in the cloud. The final output displays an image with the bounding box over the trash and the person who threw litter along with labels.

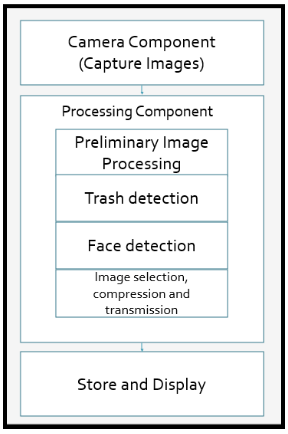

Fig. 1. The proposed system

IV. IMPLEMENTATION

The proposed algorithm is implemented using Python script language. The processing component is made up of several program files and is shown in Fig. 2. The function of each program is narrated below.

- Main Program that consists of trash detection and face detection instructions.
- Mask RCNN folder that consists of python files of the base configuration class and the main mask RCNN model implementation. It also contains common utility functions and classes, display, and visualize functions.
- The training set provided in the trash folder includes all the annotations of JSON files. VGG image annotator [11] was utilized for image annotation.
- A separate folder is made use to record all the images captured by the raspberry pi camera module.
- To train the network, weights are exploited.
- A set of known images are stored in a distinct folder.

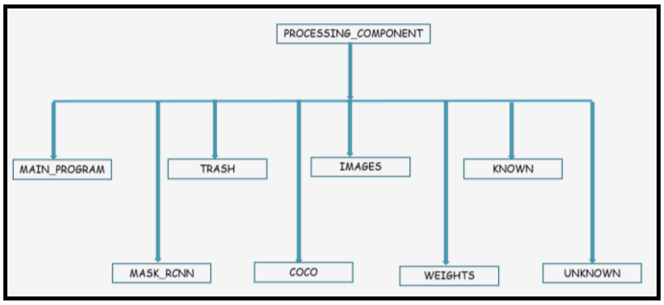

Fig. 2. Processing Component

A. *Main Program*

As shown in Fig. 3, all the necessary library files such as Pycocotools, Kaggle, Mrcnn, TensorFlow (1.14.0), Keras, NumPy, Scipy, (2.2.0), Face_recognition, Pillow, TensorFlow, Skimage, h5py, Ipython, Cv2, Matplotlib, and Python are initially installed.

B. *Trash detection and Face recognition*

All the required weights along with the configuration functions of MASK-RCNN are imported. The number of GPU to work on the processing of the image is set, in addition to the number of the image processed per GPU. The configuration details of the MASK_ RCNN are displayed. The device is set to load the neural network on. The model is inspected in training or inferences mode. The validation dataset is loaded and a model is created in inference mode. On creating, all the trained weights are loaded. Further, the images from the directory (wherein the images are stored) are obtained once it is captured by Raspberry Pi every 20 seconds. Object detection on the images is performed and the results are displayed. If the scores of the result are greater than the threshold, then the images processed by the trash detection block are stored in a folder called unknown.

With the help of functions in face recognition, the encodings from the face present in the image are generated. Similarly, encodings for the set of known images are generated. Comparison between the encodings is carried out until a match is found. Eventually, the output is shown with labels and scores. The flowchart illustrating the flow of the face detection process is shown in Fig. 4. The hardware diagram is demonstrated in Fig. 5. The connections to the Raspberry Pi model [8] are depicted in Fig. 6.

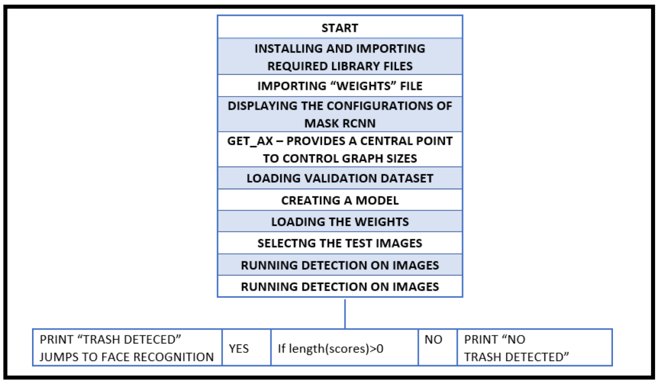

Fig. 3. The Flow of the Main Program

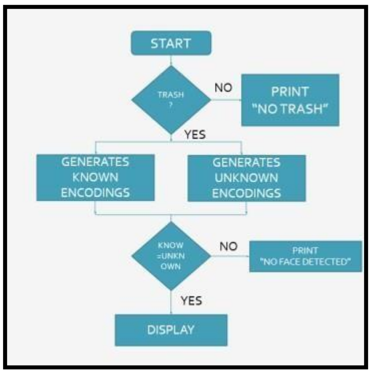

Fig. 4. Flowchart of Face Detection

Fig. 5. The Raspberry pi 4 with camera module

Fig. 6. Connections in raspberry pi 4

V. RESULTS ANALYSIS

The results generated by the system are shown in Fig. 7, 8, 9, 10, 11, and 12. The dimensions of the image to be processed and the dimensions of the image after pre-processing are displayed in the results. In addition to the scores, the message (TRASH DETECTED or NO TRASH DETECTED) is shown as an output. There are four possible illustrations: With trash in the presence of the person, with no trash but in the presence of a person, with trash along with no person, with no trash along with no person. Here, Fig 7,9, 11 represent the outputs with trash in the presence of a face. A bounding box around the face of the person who threw the trash besides their name is also displayed. In addition to this, the processed image is visible on the screen comprising of the bounding box, labels, and binary mask over the trash along with the labels. In case of no trash with no face, the image captured is displayed as shown in Fig. 8 and 10. Additionally, Fig. 12 exhibits a result with no trash but in the presence of a person.

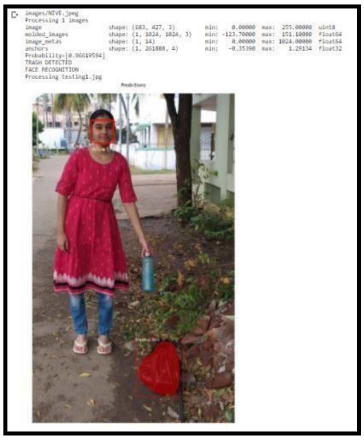

Fig. 7. Output with trash

Fig. 8. Output with no trash

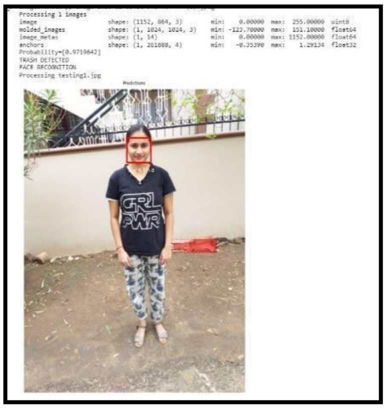

Fig. 9. Output with trash and face detected

Fig. 10. Output with no trash

Fig. 11. Output with trash and face detected

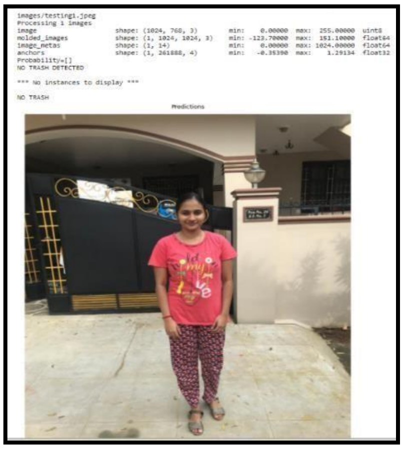

Fig. 12. Output with no trash

VI. CONCLUSION

Cleanliness plays a vital role at all stages of life. If strict rules are enforced, it will be helpful to create a clean city without taking a toll on our health. With the help of cameras affixed in public places like bus stands, markets, etc. along with this system will assist us to identify violators in optimum time with minimum use of manual resources. This system can be further extended by sending an alert message to the individual who litters and penalizes them monetarily. Also, an e-challan or memo could be issued.

REFERENCES

[1] Chandni Ramchandani, Rakshith Koravadi Hatwar, ParteekMakkar, Yanki Shah, Pooja Yelure, MagdaliniEirinaki, “A deep learning framework for smart street cleaning” in *2017 IEEE Third International Conference on Big Data Computing Service and Applications.* [Online]. Available: https://ieeexplore.ieee.org/document/7944927/

[2] A. Alzu’bi, A. Amira, and N. Ramzan, “Compact root bilinear CNN for content-based image retrieval,” Aug 2016, pp. 41–45.

[3] S. Ren, K. He, R. Girshick, and J. Sun, “Faster R-CNN: Towards real-time object detection with region proposal networks,” in Advances in neural information processing systems, 2015, pp. 91–99.

[4] R. Girshick, “Fast R-CNN,” in *Proceedings of the IEEE International Conference on Computer Vision*, 2015, pp. 1440–1448.

[5] Lokanath M, Sai Kumar K, and Sanath Keerthi E, “ Accurate object classification and detection by faster RCNN,” in *IOP Conference Series Materials Science and Engineering, November 2017.* [Online]. Available: https://www.researchgate.net/publication/321478922_Accurate_object_classification_and_detection_by_faster-RCNN

[6] Kaiming He, Georgia Gkioxari, Piotr Dollár, Ross Girshick, “Mask RCNN” arXiv:1703.06870,2017.[Online].Available:https://arxiv.org/abs/1703.06870

[7] “Support Vector Machines”. [Online]. Available: https://scikit-learn.org/stable/modules/svm.html

[8] “Raspberry Pi 4 Model B Datasheet, “June 2019. [Online]. Available: https://www.raspberrypi.org/documentation/hardware/raspberrypi/bcm2711/rpi_DATA_2711_1p0_preliminary.pdf

[9] Jan Hosang, Rodrigo Benenson, Bernt Schiele “Learning Non-Maximum Suppression Algorithm,” arXiv:1705.02950 May 2017. [Online]. Available: https://arxiv.org/abs/1705.02950

[10] “Selective search for Object Detection,” September 18, 2017. [Online]. Available:https://www.learnopencv.com/selective-search-for-object-detection-cpp-python/

[11] “Getting Started with VGG Image Annotator for Object Detection Tutorial,” September 25, 2020. [Online]. Available: https://blog.roboflow.com/vgg-image-annotator/

[12]” Recognizing Face using the “face_recognition” library,” March 9, 2020. [Online]. Availabe:https://medium.com/analytics-vidhya/recognising-face-using-the-face-recognition-library-afdb6d86bcf0

Design and Implementation of Custom Built Quarantine Service Mobile Robot Using Deep Learning and ROS

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***Abstract*— An autonomously navigated custom-built quarantine service robot is a vehicle with sensing ability of its environment and is moving safely in static and dynamic environments. The indoor environment under consideration for robot installation is isolation wards. The robot also serves applications such as patient inspection, greeting the patient using name, logging the name to document for attendance purpose, food delivery, medicine delivery, etc. Also, there are many integrated features like automatic room sanitation, non-contact hand sanitizer, touch less drinking water dispenser, dedicated telemedicine chat application etc. A ROS hybrid algorithm, using the combination of DWA and TEB Path Planners is used for the dynamic path planning of the service robot. The proposed hybrid algorithm used for simulation and hardware implementation has less execution time as that of DWA and TEB path planners. With obstacles, DWA planner and TEB planner takes 55 and 47 seconds respectively for navigating to a fixed goal. The proposed system has an efficient path planning with an execution time of 43 seconds for navigating to the fixed goal. The tuned hyper parameters provides an optimized path plan to the goal. The objective is to deliver services to patients in quarantine by avoiding maximum human contact.**

Keywords*— *ROS, Mobile Robot , Autonomous Navigation , SLAM , DWA , TEB , AMCL , Quarantine Service Robot, Face Recognition

Introduction

A lot of people in India are currently under quarantine since the world is fighting against many highly infectious communicable diseases like COVID -19. The existing hospital robots like Hospital Robot Teams[1], Helpmate[2], etc. mainly concentrated on the path planning and task distribution algorithms. The proposed quarantine service robot can autonomously navigate using ROS - Hybrid Algorithm with execution time far better than existing algorithms. The ROS-Navigation algorithm parameters are tuned to provide the best performance in path planning and navigation. The robot is cost-effective and can serve multiple applications. In isolation wards, the daily attendance is taken manually by a human. But in the presence of highly communicable diseases, it is necessary to minimize human contact. This warrants a multipurpose robotic solution.

Several works on the implementation of hospital robots for various applications are found in the literature. Team Co-operative Robot[1] in hospitality is a concept for Real-time task scheduling and allocation or distribution for a team of hospital robots. VisBug algorithm for hospital transport is used in Helpmate[2]. Single/ multiple lines following mobile robots are implemented in Tray carrying hospital robots[3]. Implementation of a face recognition neural network is given in [4] which was used for integration with ROS for daily attendance application. For telemedicine application, referred [5] which is an implementation of WebRTC for video conferencing. An appropriate task allocation algorithm for multiple robots has been explained in a Hospital Logistics Robot [6]. Implementation of Mask detection network[7] is integrated to ROS Architecture for better intelligence of Covid Robot. The study[9] explains multiple path planning algorithms for a team of robots in a hospital environment. Inspection Robots[10] make queries to the obstacle's avoidance strategies table, and safely avoid obstacles. There are multiple path planning algorithms for a team of robots in a hospital environment is explained in [11]. [12] explains different path planning techniques for coverage path planning. ORB-SLAM Technique is explained in [13]. Robots in [14] and [15] use ROS Architecture for its mapping and navigation. The robot proposed serves the purpose of food/ medicine delivery, non-contact hand sanitation, automatic room sanitation, telemedicine, daily attendance, sound instruction, etc.

Design and Fabrication Of Model

A. Robot Design

The proposed Quarantine Service Robot is a two-wheeled, low-cost robot that gives position and speed feedback to the ROS environment for proper mapping and navigation. The design is created using CAD software and exported as URDF for ROS simulation and hardware implementation. The 3D model created using CAD software is given in Fig.1.

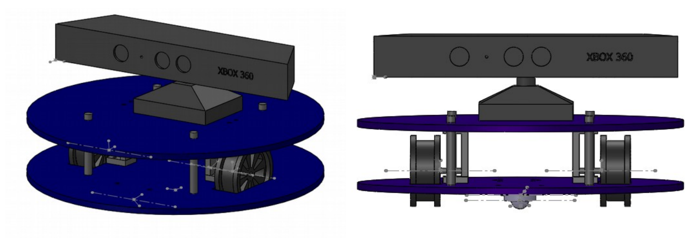

Fig. 1. Different views of 3D model of mobile robot

A rack for holding food/medicines is shown in Fig.2 and a tripod for holding tablet for the online doctor consultation is also integrated into the system. Both are detachable.

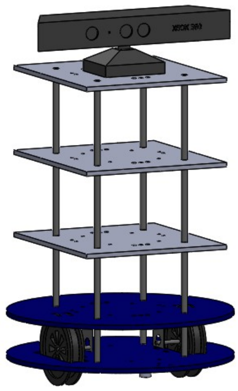

Fig. 2. Modified structure for food/medicine delivery.

B. Fabrication

Used CAD software drawing for laser cutting of acrylic sheet and assembled components properly as per the design shown in Fig. 3. DC motor with position encoder is used for the wheel control. Feedback data from the Inertial Measurement Unit(IMU) and position encoders are used for setting odometry, joint states, and transformation function.

Fig. 3. Hardware Model

This feedback data is required for proper localization and navigation of the service robot. The Kinect camera is used for getting the depth information for navigation. Camera sensor data is used for large distance mapping. IMU data used for short distance mapping. Combination of both provides better mapping and localization. The raspberry pi equipped with the system acts as slave and a remote computer acts as master. The non-contact hand sanitizer, spray sanitizer for room sanitation mode, tripod for fixing tablet for telemedicine chat functionality and racks are the detachable parts of the quarantine robot system. This is attached to the system as per requirement. For multiple task at same time, all parts can be attached.

C. Component Selection

- DC geared motors with position encoder: SGP30-60K
- IMU : MPU6050
- Microsoft Kinect Sensor
- Arduino Mega 2560 Board
- Raspberry Pi 3 Model B
- Servomotors : MG995

SYSTEM DESIGN

A. Overall Architecture

Fig. 4. shows the architecture of the overall setup. ROS installed Raspberry Pi is the brain of the mobile robot setup implemented. Raspberry Pi is connected remotely to the desktop system through an ssh connection. Arduino connected to Raspberry Pi takes data from the Inertial Measurement Unit and position encoders and uses this data for proper Odometry.

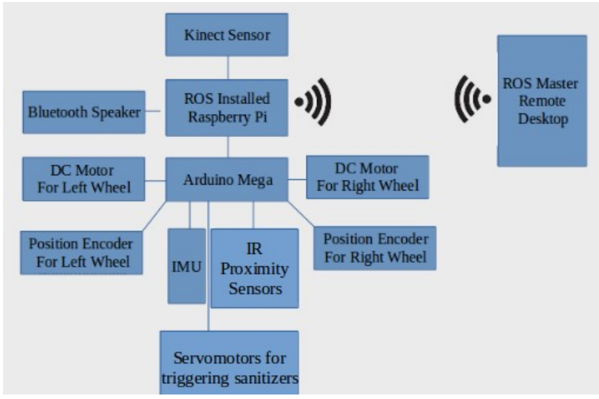

Fig. 4. Architecture of Overall Setup

The Raspberry Pi publishes Kinect Sensor data, Transformation Function, Odometry, and the Joint States to ROS Master. Localization of the robot in the Visualization tool Rviz uses feedback from IMU and position encoders. Data from IMU and Wheel encoders are mixed using EKF filter and the filtered odometry is used for mapping and navigation.

B. ROS – Mobile Robot Hardware Interface

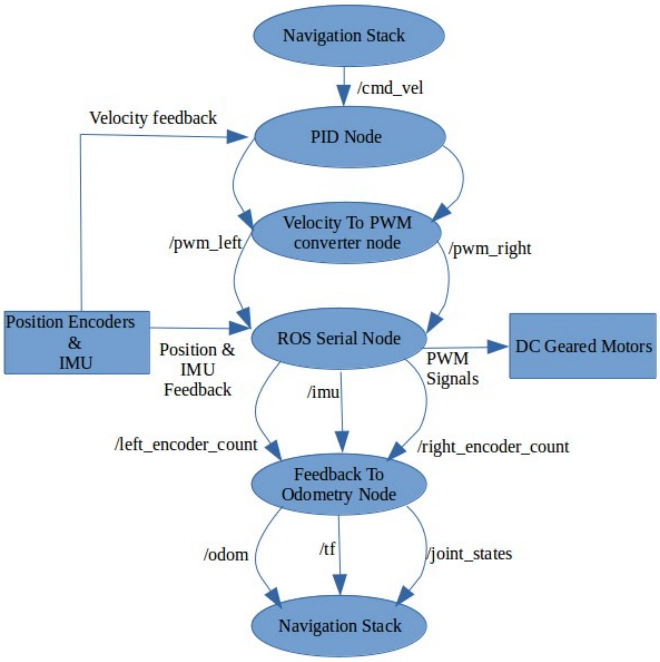

Fig. 5 . ROS – Mobile Robot Hardware Interface Architecture

Fig.5 shows the hardware interface of ROS and the mobile robot. The navigation stack provides the desired velocity to reach the goal position safely. It also estimates velocity at every instant and publishes it as a ROS topic named /cmd_vel. Navigation Stack has built-in navigation algorithms. The tuning of parameters is very crucial while working with the navigation stack. The PID Rospy Node controls the speed of the mobile robot. Then PID node calculates error by taking the difference between the desired velocity extracted from /cmd_vel topic and feedback velocity estimated from position encoders pulse count. The selection of K_P, K_I, and K_D values is essential in speed control.

The ROS – Hardware Interface is done through ROS Serial Communication. ROS Serial Node reads and writes to Digital I/O pins and publishes feedback data as ROS topics. This node also subscribes to the PWM values needed to control the motor. Navigation Stack computes the PWM data from the desired velocity published in the topic named /cmd_vel. Similarly, the ROS Serial node publishes topics that are used by other nodes for processing the feedback data and use for localization, mapping, and navigation.

C. Navigation Stack

The depth information from Kinect Sensor and inertial sensors data are used for navigation. Through the Openni ROS package, we can launch and receive the camera data as a topic. Through the Openni ROS package, we can launch and receive the camera data as a topic. The laser data that is converted from a depth image is used for mapping and navigation. The localization of the robot in the saved map makes use of the AMCL node. AMCL Node subscribes to the ROS topic named /map for preparing the global static map of the environment.

For local obstacle avoidance, it subscribes laser data topic named /scan. Initial pose and transformation function helps in localization. The /amcl_pose topic is used to identify the current position of the robot regarding the static map. Move base node controls navigation to the goal point. This node subscribes to the Goal topic and publishes the desired velocity to the PID controller. The motor control velocity is determined from the desired velocity and feedback velocity.

D. Daily Inspection Of Patients

The Deep learning Network will be trained using a dataset containing images of patients. Fig. 6. shows the flow diagram for the daily attendance system in isolation wards. ROS Node programmed for face recognition[4] and mask detection[7] subscribes to Kinect camera image topic and processes it.

If the mask is detected, the robot will instruct the patient to remove the mask for marking the daily attendance. Then it detects the face and identifies the name of the person in the camera frame. The name of the detected person in the frame will be added to the database for daily attendance. The robot will greet the person using the name.

Training of the network is done using the face pictures of persons in quarantine. So that the network will be able to identify the person, update the name to the database, and greet the person using the name. Then the robot will instruct the patient to wear a mask before leaving. This program logic is based on the consideration that patient is in COVID -19 isolation ward. For any other disease, can make slight changes in the program logic easily. ROS- Deep learning interface system is very flexible.

E. Non – Contact Hand Sanitizer

Fig. 7. shows a detachable non-contact hand sanitizer equipped with the service robot. When the patient brings his hand near the bottle, the IR proximity sensor senses the obstacle. Based on the signal from the IR proximity sensor, the low voltage DC Water Pump dispenses sanitizer liquid through the tube. A nozzle will be provided at end of the tube to control the flow.

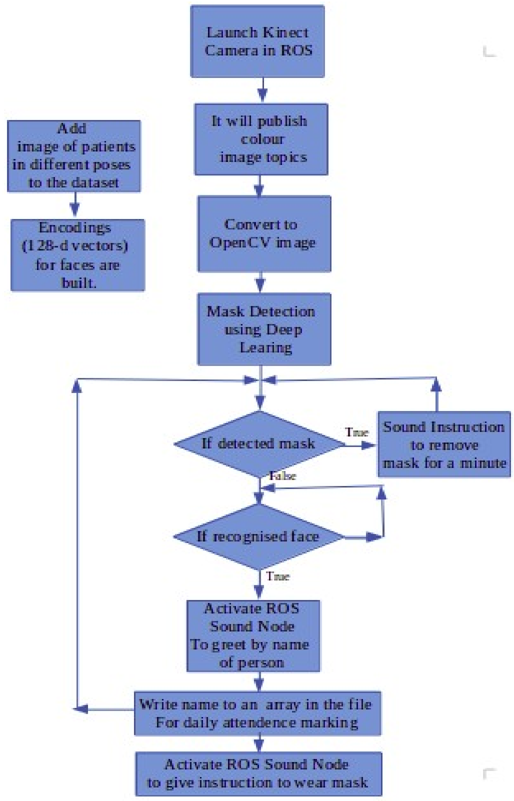

Fig. 6. Robot Inspection of patients, greeting and logging

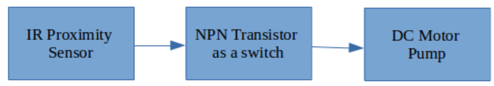

Fig.7 . Automatic Hand Sanitizer Dispenser System

F. Room Sanitation Mode System Design

Room sanitation mode is another feature of the quarantine service robot. A rospy program for the random movements throughout the room is implemented for this purpose. The spray sanitizer attached to the service robot is triggered mechanically during the cleaning mode. The robot wanders around the room randomly without colliding obstacles and sprays sanitation liquid continuously. Thus the entire room can be sanitized in a short time.

G. Telemedicine using quarantine service robot

Dedicated Video Conferencing Application is developed for Telemedicine. The doctor can sit in his room and select the patient to consult. The mobile robot will go to an individual room based on the amcl_pose set in the program. The patient can sanitize his hands using a Non-contact sanitizer attached and accept the request for a video call. After online doctor consultation, he can drop the call. During the doctor rounds time, the robot will go to individual rooms as per selection by the doctor and will be able to consult patients remotely. The doctor can decide whether the mobile robot should move to the room of another patient or return to the home location. This is the idea behind telemedicine using this robot.

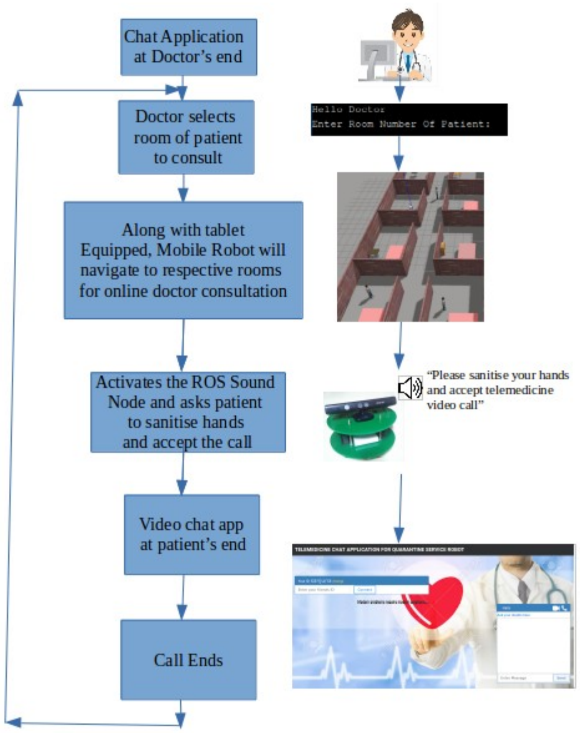

Fig. 8. Algorithm of Indirect Doctor Consultation System

H. Food and Medicine Delivery

The Fig.9. shows the flowchart for food and medicine delivery. The service robot navigates to the specified room using the hybrid ROS-Algorithm. Then instructs patient to take the materials. After delivery, the robot will go back to the home location.

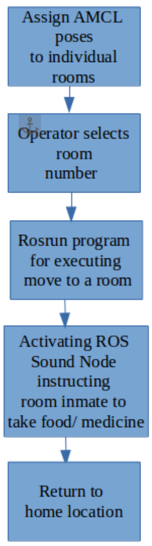

Fig.9. System description of Food and Medicine Delivery

SIMULATION

A. System Integration

This project has significance in the current scenario and will help to reduce the spread of diseases by minimizing social contact with the infected and suspected cases. The quarantine service robot proposed and implemented in this research work will help to do services by avoiding surface contact. The robot will be able to do the services needed by infected people in isolation wards without the need for human presence. The robot will also recognize the face of the patient and update the status in the patient attendance register. This data is significant in the current situation since many disease suspected persons try to escape from isolation wards. This feature can avoid daily manual inspection by a human. The quarantine service robot can navigate safely through its environments and reach the given room number and deliver services like food, medicine, etc. The robot will give light and sound command indication for the delivery trays assigned to respective rooms when it reaches the destination room. Non-contact hand sanitizer is attached to the mobile robot system so that the patients can use sanitize hands without hand touch. The robot takes care of room sanitation also. In sanitation mode, the disinfectant spray is triggered and thus serves the purpose. The user can stop the facility when required. Greeting a person by identifying the name of the patient is also given as a feature.

Dataset of the trained deep learning network contains face images of suspected cases or patients. After the successful encoding of the images in the dataset, the network will be able to recognize the face of the patient/suspect case. This system is useful for the daily inspection of patients for attendance. This research suggests the combination of two ROS navigation algorithms for better path planning. This algorithm decreases planning time and distance traveled through an optimized path planning algorithm. Generated a map of the isolation ward using the SLAM algorithm. The operator controls the remote robot and assigns the tasks to the robot through another ROS-installed master system. The robot navigates to respective rooms as per instruction from the operator. The service robot can navigate through dynamic environments and deliver services needed by the patient. The subsystems of system integration are as follows.

B. Mapping Gazebo Environment

Mapping can be accomplished in two ways. A program for random movements around the simulation world can perform the automatic mapping of a closed environment. The teleoperation node can perform the manual mapping of the environment. The depth information of the image converted to laser scan data named /scan used for navigation. Fig. 10. shows the custom Isolation Ward created in Gazebo. Fig. 11 shows the Gmapping technique. The Gmapping Node subscribes to the converted laser topic. The laser topic is the information regarding obstacles in the local cost map. The map server publishes the ROS topic named /map. Once mapped, the robot can navigate to any goal point freely. Fig. 12 shows a 3D Mapping Technique called Octomapping. It provides three-dimensional information about its surroundings. Gmapping is selected for the service robot.

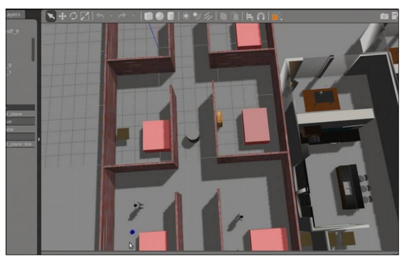

Fig. 10. Isolation Ward Created in Gazebo For Simulation

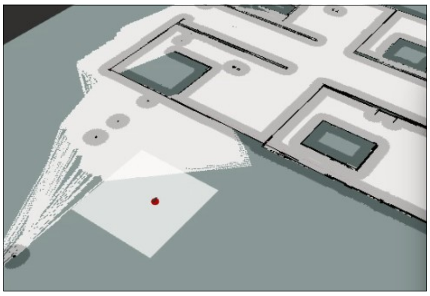

Fig. 11. Mapping of simulation world

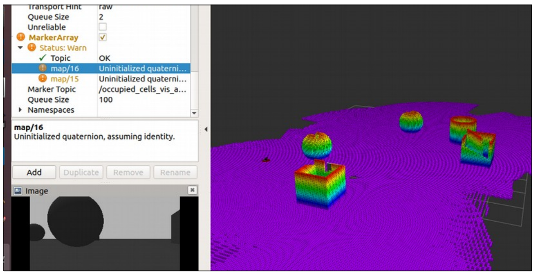

Fig. 12. Octomapping for 3D Map

C. Navigation in Gazebo

Navigation of the robot in the simulation environment is done using AMCL and move base nodes. AMCL helps in localization and move base node controls navigation. Fig. 14 shows navigation in the Gazebo world. Move base node receives a goal position and sends appropriate command velocities to drive the differential driven quarantine service mobile robot. The path to reach the goal position is planned through the combination of DWA Path Planner and TEB Local Path Planner. The path is indicated by the green line. The hyperparameters of these path planners are tuned in such a way that the robot should be able to plan an optimum path towards a goal location. So the hybrid tuned algorithm plans an optimum path that can avoid dynamic random obstacles also. TEB Path Planning algorithm and DWA Local Path planner are combined to give an optimum path plan having dynamic obstacle avoidance for the robot to move to the goal. A static map is provided to the AMCL node for collision avoidance and planning.

D. Simulation in application perspective

In the simulation world, the robot localizes itself using AMCL and finds the shortest path to the room by using path planners. ROS Sound Node should be launched for enabling the instruction feature of the robot. There are five features the robot can accomplish. The robot will perform the task assigned after reaching the goal. The Fig. 13. shows the simulation of the inspection task. The robot finds the shortest path to the specified room number, instructs to remove the mask if the mask detector deep learning module detects the mask, then recognizes the face of the patient using a trained neural network. Then the robot will greet the patient using his/her name and log the attendance to the database.

HARDWARE IMPLEMENTATION

A. System Dynamics

Dynamics for extraction of command velocity topic from Navigation stack and given as motor control signals are given below.

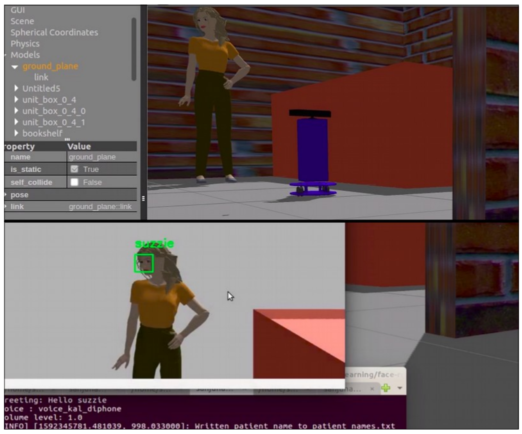

Fig. 13. Face recognition and logging to database in simulation environment

Fig. 14. Navigation using the hybrid algorithm proposed.

For a Differential Driven Robot, linear velocity v is the linear x value obtained from the topic. Angular velocity ω is the angular z value obtained from the topic. Desired right wheel velocity in terms of linear and angular velocities of the vehicle is

$$\omega_r = (v/r) + ((D * \omega)/(2*r)) \quad (1)$$

Desired left wheel velocity in terms of linear and angular velocities of the vehicle

$$\omega_l = (v/r) - ((D * \omega)/(2*r)) \quad (2)$$

where

r – wheel radius
D - distance between wheels

From the ticks from Position encoders, feedback velocity of left and right DC motor wheels is calculated.

For implementing PID Controller, we need to find the error of each motor

$$e = \omega - \omega_{fb} \quad (3)$$

$$\omega_{control} = (K_p * e) + (K_i * \int e) + (K_d * \dot{e}) \quad (4)$$

where

e - Error
ω - Desired wheel velocity

ω_{fb} - Feedback velocity
$\omega_{control}$ - Control velocity
$\dot{e}$ – *Derivative of error*
$\int e$ – *Integral of error*

The feedback topics are generated from the position encoder and the inertial measurement unit.

B. Real-World Mapping Process

Fig. 15 shows the mapping process of the real world. Mapping parameters like minimum_score, transform_publish_period is tuned for better mapping of the real environment where the quarantine service robot is installed. The Map server performs mapping using the gmapping node and successfully saves the map.

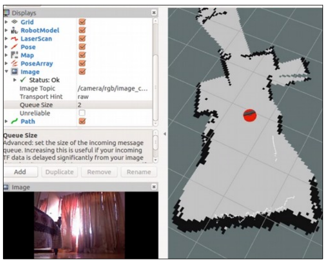

Fig. 15. Mapping Of Real Environment

C. Navigation in Real World

A combined algorithm for navigation using TEB path planner and DWA Path Planner helps in optimized path planning and navigation. Navigation makes use of depth image converted laser data obtained from the Kinect camera.

D. Inspection for Daily Attendance

For the integration of Deep Learning with ROS, subscribe to Camera Topic, convert to CV image, and write as an image file. Fig. 16 shows the mask detection and face recognition output frame. The deep learning network which is trained to detect masks instruct the patient to remove the mask during attendance marking time. The neural classifier network is trained using 2 categories of images. Categories are ‘No mask’ and ´With Mask´[7]. The facial landmarks are also considered for mask detection. The training using thousands of images helps the classifier to classify to mask/no mask category for the real-time input.

When the patient removes the mask as per the instruction from the robot, the trained network recognizes the face of patients in the isolation ward by reading each frame from the saved image file. Face recognition neural network is trained using the dataset of patients in the quarantine center along with their names. Face recognition module[4] is used for the same. Delay caused by saving and reading from image files affected the overall performance of the system. ROS - Deep Learning bridge program is developed to overcome this delay. The program is coded in such a way that it uses text to speech conversion features of ROS and greets the patient when the person is recognized for the first time. The name of the person is updated to the daily attendance database.

E. Non- Contact Hand Sanitizer

IR Proximity Sensor fixed on one side of the hand sanitizer for the detection of hand senses hand. If an obstacle is detected, it triggers a signal to the NPN transistor which acts as a switch. This activates the DC Water Pump and the sanitation liquid is dispensed without human contact. Diseases like COVID 19 spread through surfaces also. This system helps to avoid surface contact and reduce spread.

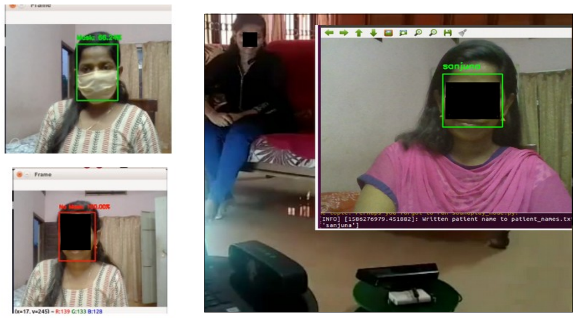

Fig. 16. Mask detection and Face Recognition for daily attendance

F. Room Sanitation Mode

The robot can be switched to room sanitation mode. In this mode, DC Motor triggers sanitation spray, and the robot moves randomly throughout the room. The room will be sanitized. The Fig. 17 shows detachable equipments designed for non-contact hand sanitation and automatic room sanitation.

Fig. 17. Non-contact Hand Sanitizer & Room Sanitation Spray

G. Telemedicine service equipped on the service robot

For telemedicine, developed a simple video chat service that works on a local network. Fig.18 shows the concept of telemedicine using a service robot. The user interface of the system is designed using HTML, CSS, and Javascript. Doctors can consult patients in quarantine through video conferences. Real-time communication is based on WebRTC[5]. A locally hosted PeerJS server that establishes a stable and secure connection between clients. Non-Contact Digital Infrared Forehead Thermometer can be equipped with a mobile base for fever detection.

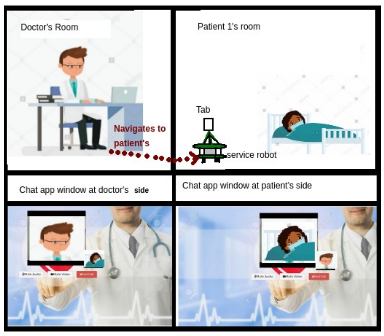

Fig.18. Telemedicine facility integrated on the service robot

A pulse sensor can also be integrated with the service robot to monitor the heartbeat rate. The temperature of the forehead and pulse rate can be sent to the doctor who is consulting the patient remotely through video conference.

EXPERIMENTAL RESULTS

Fig. 19 shows the velocity profile of the mobile robot developed. The X-axis of the graph denotes time. The Y-axis of the graph denotes velocity at the individual axis. Robot motion is smooth on sudden brakes and sudden acceleration. The linear velocity slowly increases and decreases as per the velocity commands from the navigation stack. This is the plot when mobile robots start moving after rest state.

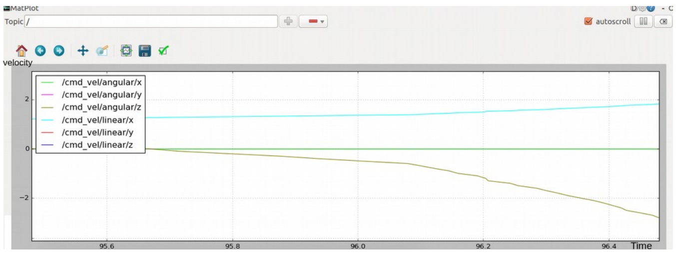

Fig.19. Velocity profile of the robot

For dynamic path planning, a hybrid ROS Navigation Algorithm combining DWA Path Planner and TEB path planning algorithm is used. The cost of traversing through the grid cells is computed and uses this value function to determine linear and angular velocities to send to the robot. DWA Algorithm samples the control space of the robot to dx, dy, and dtheta. It picks up the highest-scoring trajectory in such a way by avoiding illegal trajectories prone to collision. The algorithm will send the appropriate velocity to follow the path. The behavior of the ROS Planner can be tuned using the ROS parameters of the navigation stack. Forward Simulation Parameters sim_time is adjusted for better performance. Low values will provide simple arcs, and high values will provide long curves. So sim_time is set as 2 for the system designed. The inflation radius is set to 0.2m so that the robot can move close to walls for sanitation purposes. DWA planner[8] plans very slowly and is not much stable. Max/min velocity and acceleration are also modified. It will be able to find an optimal path considering time and distance. Using the DWA algorithm, the mobile robot avoids slowly moving dynamic obstacles.

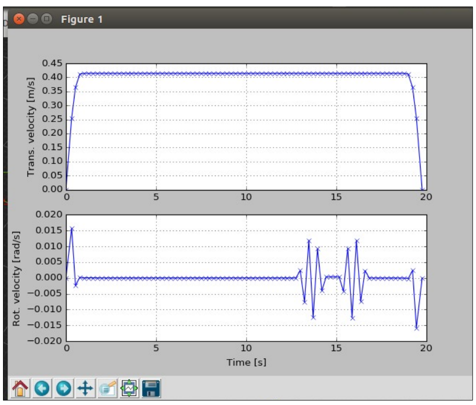

Fig. 20. Translational and Rotational Velocity profile using modified TEB Path Planner

Considering the distance from obstacles, execution time, and runtime kinodynamic constraints, Timed Elastic Band locally optimizes the robot's trajectory. Modified parameters to improve the performance of the path planner. TEB algorithm[6] plans better in the case of fast-moving obstacles. Fig. 20 shows Translational and Rotational Velocity using modified TEB Path Planner. When the robot starts moving towards the goal, translational velocity suddenly increases from zero to a constant velocity. Translational velocity is constant during the motion. The moving obstacles block the preplanned path at the 13th second. The robot changes its orientation at this point to avoid a collision. It continuously tries to find a better path considering the future motion of moving obstacles. At the 17th second, the robot can move in a particular orientation to the goal without much variations in rotational velocity. Instead of reducing translational velocity, the robot moves continuously at a constant speed and changes the direction of movement in case of any obstacle in the preplanned path. The robot will move in the updated path towards the goal. The translational velocity starts decreasing smoothly from the 19th second and becomes zero on the robot stop pose. The rotational velocity also becomes zero on the robot stop pose. When the penalty_epsilon parameter is 1.0, the robot becomes stuck at narrow passages. So value is reduced for better response. Update rate of the local cost map is increased for reducing execution time. TEB Path Planner gives a time-optimal solution. This algorithm can optimize multiple trajectories in different topologies. Initially, a path is planned and is transformed into a timed elastic band. At each loop, the path planner dynamically deletes previous values and inserts new configurations for adjustments on the remaining trajectory to be planned.

Fig. 21 shows a comparison of execution time between DWA, TEB, and hybrid path planners. The proposed hybrid path planner has better path planning and less execution time comparing to DWA and TEB Algorithm. Without any dynamic obstacles, the DWA planner and TEB planner took 44 and 38 seconds respectively for navigating to a fixed goal. The proposed system has an efficient path planning with an execution time of 34 seconds for navigating to the fixed goal. With obstacles, the DWA planner and TEB planner took 55 and 47 seconds respectively for navigating to a fixed goal. The proposed system has an execution time of 43 seconds for navigating to the fixed goal. Fig. 22 shows the new path planned by the robot when a dynamic obstacle is introduced in its way.

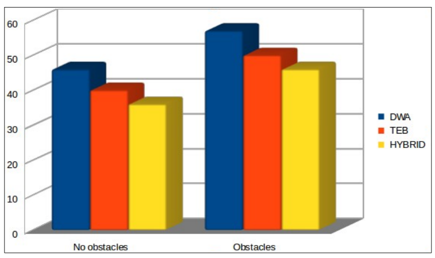

Fig. 21. Comparison of execution time between DWA, TEB and Hybrid Algorithm.

Using this navigation algorithm, robot will be able to navigate to different rooms given by the remote operator and thus deliver services to patients in quarantine by avoiding maximum human contact.

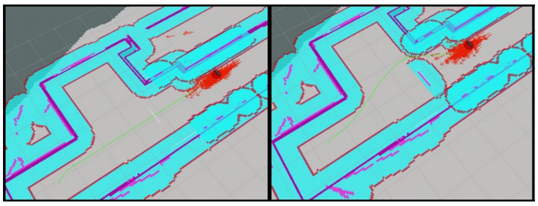

Fig. 22. Dynamic Obstacle Avoidance through Hybrid Algorithm

CONCLUSIONS

This paper proposes a quarantine service robot that can serve multiple purposes. The modified hybrid path planning algorithm takes less execution time comparing to the existing algorithms. Without any dynamic obstacles, the DWA planner and TEB planner takes an execution time of 44 and 38 seconds respectively for navigating to a fixed goal. Better performance is achieved by the proposed hybrid algorithm with an execution time of 34 seconds for navigating to the fixed goal. In a dynamic obstacle environment, the DWA planner and TEB planner showed 55 and 47 seconds respectively for navigating to a fixed goal. The proposed system has an execution time of 43 seconds for navigating to the fixed goal**.** Daily attendance marking system using trained neural networks integrated with ROS helps for an intelligent robotic inspection. The proposed system has a user interface for selecting different modes, to give delivery locations, etc. which are done using roslibjs which makes the system more users friendly.

This research can be extended by having multiple robots in the same hospital, all controlled by a center ROS Master system. Also can incorporate features like Cliff Detection, spot cleaning, Trash Can Localization, etc. in the future. ROS - deep learning integration is providing a wide range of scope for future applications. Currently, robots can detect the face only when the face is not covered. This is an expected area for future work. The five services provided by this low-cost service robot can reduce contact between health workers and the suspect cases to a greater extend. The system provides a cost-effective robotic solution to reduce the spread of communicable diseases and helps to automate hospital services.

REFERENCES

1. Simon Thiel , Dagmar Häbe , Micha Block, “Co-operative robot teams in a hospital environment” , IEEE International Conference on Intelligent Computing and Intelligent Systems 2009
2. J. Evans ,B. Krishnamurthy, B. Barrows,T. Skewis , V. Lumelsky, ¨Handling real-world motion planning: a hospital transport robot¨, IEEE Control Systems Magazine 1992
3. Y. Takahashi ,M. Kohda ,Y. Kanbayashi , K. Yamahira , T. Hoshi , ¨Tray carrying robot for hospital use¨, IEEE International Conference on Industrial Technology 2005
4. https://www.pyimagesearch.com/2018/06/18/face-recognition-with-opencv-python-and-deep-learning
5. https://github.com/valarpirai/video-chat-app
6. Maison Glad Jeju, Jeju, "Performance Analysis of Scheduling Multiple Robots for Hospital Logistics" Korea June 28 - July 1, 2017
7. https://www.pyimagesearch.com/2020/05/04/covid-19-face-mask-detector-with-opencv-keras-tensorflow-and-deep-learning/
8. http://wiki.ros.org
9. Xianqun Huang , Qixin Cao , Xiaoxiao Zhu , “Mixed path planning for multi-robots in structured hospital environment”, The 14th Asian Conference on Computer Aided Surgery (ACCAS) 2018
10. Jinshan Yu, Hao Wu , Xin Wang , “The Research on Obstacle Avoidance of Hospital Ward Inspection Robots in Complex Environment” , Chinese Control and Decision Conference (CCDC) , May 2016
11. T. Skewis! J. Evans: V. Lumelsky! B. Krishnamurthy: B. Barrows, "Motion Planning for a Hospital Transport Robot" Proceedings of the 199 1 IEEE International Conference on Robotics and Automation Sacramento, California April 1991
12. Richard Bormann, Florian Jordan, Joshua Hampp, Martin Hagele, "Indoor Coverage Path Planning: Survey, Implementation, Analysis" IEEE International Conference on Robotics and Automation (ICRA) , 2018
13. Raul Mur-Artal, J. M. M. Montiel, "ORB-SLAM: A Versatile and Accurate Monocular SLAM System" IEEE Transactions on Robotics , 2015
14. Abishek B, Gautham S, "ROS based Stereo Vision System for Autonomous Vehicle" IEEE International Conference on Power, Control, Signals and Instrumentation Engineering , 2017
15. Murat Koseoglu, Orkan Murat Celik and Omer Pektas ,"Design of an Autonomous Mobile Robot Based on ROS",IEEE , 2017

Design And Development Of Stylometric Based Fake News Detection On Social Media Using Natural Language Processing And Machine Learning

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***Abstract* - Social media is a medium that helps us to stay close with friends and family and they also are helpful platforms to connect to people with similarities. As Social Media plays a crucial role in connecting people, it is necessary to distinguish fact from fake. Due to these reasons, the authenticity of social media is vulnerable where fake news can be easily circulated. The social media platform is the best way to spread fake news faster as it is cheaper than traditional news media(Newspaper and Television). People usually start to believe in the information which they often hear and see and this can be amplified by using the Echo Chamber effect on social media. So if the information which gets circulated on social media is created, fake, or manipulated, then the decisions we make will be completely wrong. So it is mandatory for us as a user of social media to know the information which we see, share are either true or fake as it may lead to serious consequences. Distinguishing a piece of information that is either true or false differs from people's perspectives based on their pre-existing beliefs. So everything must be taken into account while detecting a piece of fake news on social media. In this project, we have reviewed the authenticity of the news articles using Natural Language Processing, Feature Extraction technique, Machine Learning, and Ensemble models. We have also reviewed different Machine learning models, evaluation metrics. We have also mentioned related research areas and future work on fake news detection on social media.**

Keywords-Fake news detection, stylometric approach, Natural Language Processing, Machine Learning

I.INTRODUCTION

Fake news became predominant during the 2016 Presidential election. This type of news is not new in the post-print social media age, the misleading situation is increasing and goes viral. Usually, Fake news has catchy headlines,so individuals get attracted instantly which makes them share through social media. This fake news dispenses as true news but contains deceptive and biased information. It is difficult to drag down the source from which fake news originated.The ultimate motive of fake news is to mislead public opinion and to attain profit on businesses related to online publishers.There are also situations where fake news is produced by mistake, but it may sometimes confuse. Here we distinguish between several concepts that frequently occur with fake news. Fake news can always be called using many terms such as Satire news - a literacy work of holding up human vices and follicles to ridicule or scorn, Misinformation - incorrect information that is communicated regardless of an intention to deceive. Disinformation - false information which is intended to mislead and it is a subset of misinformation, Deceptive news - defined as intentionally, knowingly, and/or purposely misleading another person, Clickbait - a sensationalized headline or piece of text on the internet that is intended to attract attention and encourage people to click on links to particular websites. Cherry-picking - the fallacy of incomplete evidence or suppressive evidence. Further, we discuss the overview on fake news where we review the definitions, rise, types of fake news, detecting fake news from four perspectives and their comparative analysis, then we discuss dataset and model construction, different machine learning models, and evaluation metrics. In continuation with this, we present their related areas, then results and conclusion.

The information which gets circulated on social media is created, fake, or manipulated, then the decisions we make will be completely wrong. So it is mandatory for us as a user of social media to know the information which we see, share are either true or fake as it may lead to serious consequences. Distinguishing a piece of information that is either true or false differs from people's perspectives based on their pre-existing beliefs. The main motivation of the project is to avoid false interpretation of information which we come across on social media.

II.OVERVIEW OF FAKE NEWS

A. Definition

Fake news has been existing for a very long period. However, there is no concurred definition for the term "fake news". Fake news can be defined as a false news article to mislead people. It indicates false information that is published under the semblance of being factual news. Hoax news (Fake news) represents the misinformation or false news article that aims to exploit public opinions. It is shared via traditional news media or social media. There are two highlights in this definition: Authenticity and Intention. The authenticity part means false news content that can be confirmed as such. In the second part, the news is created to manipulate their opinions.

B. Rise of Fake News

The purposeful making up of false news stories to grab attention or entertain us is not new. It has become a trending topic since 2017. Earlier we got our news from reliable newspapers, journalists, mass media which strictly followed the practice code. In the 21st century, the term fake news and the effect of fake news has become global. The increased popularity and immense access to the internet have resulted in its growth. It enabled a whole new way to publish, share and view the content with very few editorial and regulation standards. It has also contributed to the increasing growth of fake news and its publishers. New articles and stories are constantly published at a faster rate. But often it can be hard to tell whether the news articles are trustworthy or not. Due to information overload, it lacks the verification of authenticity media platforms play a major role in the reach of stories as it has excellent algorithms to present us with news, articles, and content based on our recent searches.

C.Types Of Fake News

There are various differing views regarding fake news. The features listed below may help us to evaluate and identify the false news content we need to be aware of.These include Clickbait, Propaganda, Satire/parody, Sloppy journalism, Misleading headings, Biased/Slanted news. Clickbait stories often use exaggerating, misleading, sensationalistic headlines to gain the attention of the viewers at the cost of truth. These stories are purposefully created to gain more website visitors and increase revenue via advertisement. Propaganda stories are deliberately created to promote an agenda or cause or biased point of view(especially in Politics) to mislead readers. Satire/Parody websites publish false information as humorous attempts but have the potential to be shared as true news. Sometimes journalists publish information without verifying all the facts which can mislead audiences. It is referred to as Sloppy journalism. Misleading or sensationalistic types of stories spread faster as they have small snippets of the whole story on the viewers' newsfeed to grab the attention. Social media tends to present us with the news feeds that we will like based on our personalized searches. Many people were attracted to confirm their own beliefs or biased thoughts and fall prey to false news.

D.Detection of Fake News From Four Perspectives

In the previous subsections, we have discussed the definition, rise, and different types of fake news. Here the detection of fake news from four perspectives is listed below.

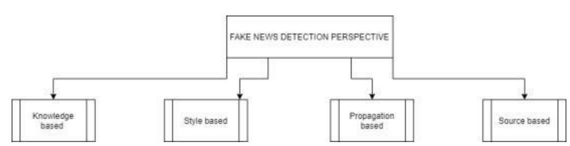

Fig.1 Fake News Detection Perspectives

1) Knowledge-based Fake News Detection

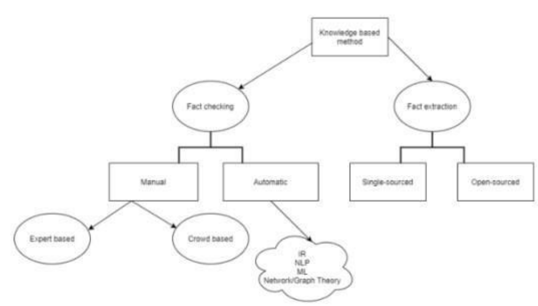

Fig.2 Knowledge-based Fake News Detection

The knowledge-based method aims to verify the truthfulness of the knowledge extracted by the factchecking approach. Fact-checking can be done in both manual and automated ways. The manual factchecking further can be classified into two types as expert-based and crowd-based fact-checking. The former method depends on a group of experts' opinions for content verification. It is accurate but costly and has very poor scalability with the to-be-verified contents. In latter method, fact-checking happens based on collective or crowd intelligence. The crowd didn't find the news to be checked is consistent or not based on the facts. If very large people find it true or false, then it is verified as such. It is not accurate compared with expert-based, the results may be biased, but it has good scalability than the previous method. To address the scalability issue due to information overload, we have moved on to another approach called automatic fact-checking. It uses the techniques of Information Retrieval(IR), Natural Language Processing(NLP), Machine Learning(ML), and also Network/Graph Theory. It consists of two stages: Fact-extraction and Fact-checking. The facts can be extracted from single-sourced or open-sourced. In single-source extraction, we extract facts from only one source. It is more efficient than open-sourced but leads to an incomplete state. In the latter method, more distinct resources are used to obtain the completeness of facts. Further, these raw facts are processed and cleaned to construct the Knowledge Graph(A graph representation that is created using a knowledge base ie. a set of facts or truth). Ultimately, the result is obtained by comparing the input data or news with a knowledge graph or base.

2)Style based Fake News Detection

Fig.3 Style based Fake News Detection

Style-based fake news detection assesses the intention of the article whether it is misleading the people or not. Here the news content style is represented using textual features (news text) and visual features (news images). Textual features can be grouped into general and latent features. Observable or general features are used to detect fake news using Machine learning and deep learning frameworks. The content style features are described at four language levels. These include lexicon, Syntax, Disclosure, Semantic levels. The frequency of the lexicon is determined using the Bag of Word technique. At the syntax level, the frequency of POS and rewrite rules are determined by Part-of-speech taggers and Probabilistic Context-free Grammars. The rhetorical relation frequencies are calculated using the Rhetorical Structure Theory(RST). Finally, at the semantic level, these frequencies fall into lexicons as defined in Linguistic Inquiry and Word count. Latent features are hidden features that are extracted from general features. Here the news embedding can be done in machine learning and deep learning techniques. News text embedding happens at word-level, sentence-level, and document-level. Here the news articles are represented by vectors and given as input to classifiers such as SVM classifiers to predict the fake news. These embeddings can be further processed using Convolutional Neural Networks(CNN), Recurrent Neural Network(RNN), and the Transformers which are Deep Learning Frameworks to predict the fake news. News images are embedded as pixel matrices to find fake news.

3) Propagation based Fake News Detection

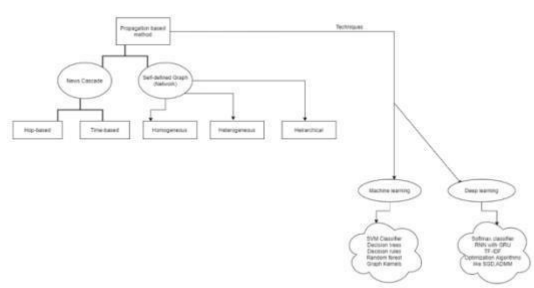

Fig.4 Propagation-based Fake News Detection

Propagation-based Fake News Detection explains how the news spreads or propagates. It is often formulated as a binary (or multilabel)classification problem with different inputs. Input to propagation-based methods can be classified as News Cascade and Self-defined

graph. News Cascade is a tree or tree-like structure and is the direct representation of news propagation. The root node represents the user who first shares the news article (initiator). News Cascade can be represented in terms of several steps(ie., hops) that the news was traveled (ie., Hop-based news cascade) or the times that it was posted(ie., Time-based news cascade).To classify its cascade as true or false, some proposed methods rely on traditional machine learning and Deep Learning. In traditional Machine Learning, to classify a news cascade one relies on supervised learning methods such as Support Vector Machine, Decision tree, Decision rules, Naïve Bayes, and random forest. In deep learning, to represent news cascade relies on neural networks such Softmax function acts as a classifier, Recurrent Neural Network with Gated Recurrent Units(GRU), TF-IDF and optimization algorithm such as Stochastic Gradient Descent(SGD), Adam and Alternating Direction Methods of Multipliers(ADMM). When detecting fake news using Self- defined Propagation Graphs one constructs a flexible network to capture indirectly fake news propagation. These networks are Homogeneous networks, Heterogeneous networks, and Hierarchical networks. Homogeneous networks contain a single type of node or edge. Heterogenous networks contain multiple types of nodes or edges. Hierarchical networks contain various types of nodes and edges that form a set-subset relationship. other applications
4)
Source-based Fake News Detection

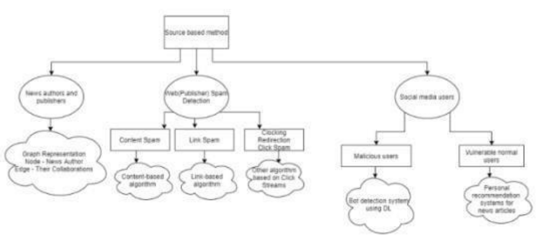

Fig.5 Source-based Fake News Detection

Source-based Fake News Detection assesses the credibility of its source. There are three stages with a [fake]news life cycle namely News writers, News publishers, and the sources that spread the news stories on social media. News writers and publishers are in the form of Graph representation where Nodes represent news authors and edges represent their collaborations. In Web(Publisher) Spam Detection, News publishers often publish their news articles on their websites. To access website credibility, many practical techniques have been developed. Traditional Web ranking algorithms like PageRank, HITS are used to improve search engine responses. Web Spam can be categorized as Content Spam, Link Spam, and others like Redirection, Click Spam and Cloaking. The algorithms to identify web spam are classified as a Content-based algorithm, Link-based algorithm, and other algorithms, etc. To identify the sources that spread the news on social media there are two ways. First, identify Malicious users, it can often be reduced to detect social bots using Deep Learning. Second, Identifying Vulnerable users. That fake news unlike information such as fake reviews can "attack" both malicious users and normal users. Malicious users such as some social bots often spread fake news intentionally. But normal users spread frequently and unintentionally without recognizing its falsehood.

D.Comparative Analysis

In this section, we discuss the limitations and difficulties of all four approaches to fake news detection. In a Knowledge-based approach, it is unsure whether the sources from which we extract the facts are credible or not. It requires the construction of dynamic Knowledge base KBs, that automatically remove the invalid data and insert new data or facts. Content writing style can be manipulated in a stylebased approach. The propagation-based method is inefficient as it is difficult to detect fake news before it spreads. There are limited ongoing researches in the source-based method.

III.FAKE NEWS DETECTION

A.Dataset

Online data regarding fake news can be collected from various sources like online websites, social media platforms. There are many publicly available datasets like BuzzFeedNews which contains a sample of data published in Facebook, LIAR which is a dataset collected from PolitiFact, fact-checking website, and CREDBANK which is a large crowdsourced dataset regarding millions of tweets.

B.Model Construction

In this section, construction of the models using existing methodologies is discussed. In the previous section, we have discussed four methods in detail. Out of four approaches, we have chosen the style-based method because there is a lot of ongoing research as said in comparative analysis. In style based method, we had chosen textual features. Then preprocessing of data happens where we remove stop words followed by tokenization and lemmatization. After preprocessing, we have converted our labels into numerical for output. Next, testing of our models using various machine learning models and each machine learning model is discussed below.

C.Different Machine Learning models: We have used different machine learning models for classification.
They are Logistic Regression, MultinomialNaiveBayes, Decision Tree Classifier, Passive Aggressive Classifier, StochasticGradient Descent Classifier, Linear Support Vector Classifier, and Ensemble Classifier.

Logistic Regression: It is a machine learning algorithm that is widely used for classification problems. Logistic regression is very effective when it comes to textual classification. It also gives good accuracy for simple data sets.

Multinomial Naive Bayes: It is a very suitable classifier for working with discrete features like word count in text classification. Naive Bayes is one of the best algorithms when it comes to text classification and text analysis.

Decision Tree Classifier: It is a supervised machine learning algorithm. It builds classification in a form of a tree-like structure. The decision tree is one of the best algorithms to choose when it comes to multiclass classification.

Passive-Aggressive Classifier: It is a machine learning algorithm and it is also an online-learning algorithm. That's why it is very efficient when it comes to detecting fake news as the data would be large to handle.

Stochastic Gradient Descent Classifier: Stochastic Gradient Descent is a very simple approach for linear classification and regression. It is the best optimization algorithm for minimizing the cost function. It is the go-to algorithm when you need a speedier result.

Linear Support Vector Classifier: It is a nonparametric clustering algorithm. It is considered one of the best classifiers for text classification.

Ensemble Classifier: It uses a set of classifiers whose individuals results are combined based on voting(Soft/Hard)to give new results.

D.Evaluation metrics

To evaluate the performance of the algorithm there are different evaluation metrics like accuracy, precision, recall, F1 and it is noted that the performance increases with the increase in value.

True Positive(TP): when the model predicts fake news articles as fake news.

True Negative(TN): when the model predicts true news articles as true news.

False Positive(FP): when the model predicts fake news articles as true news.

False Negative(FN): when the model predicts true news articles as fake news.

Accuracy = $|TP| + |TN| / |TP| + |FP| + |TN| + |FN|$ (1)

Precision = $|TP| / |TP| + |FP|$ (2)

Recall = $|TP| / |TP| + |FN|$ (3)

F1-Score = $2 * (\text{Precision} * \text{Recall} / \text{Precision} + \text{Recall})$ (4)

IV.RELATED RESEARCH AREA

A.Social Bot Detection

Social bots are software that runs automated tasks on the internet. Twitter executives have testified that as many as 5% of Twitter accounts are operated by bots. It is difficult to detect how many social media accounts are social bot accounts as the bots are designed to mimic human accounts. Even humans fail to detect a bot account from a legitimate human account. The main threat imposed by the social bot is that it gives a false impact on the information which has been circulated and it is also endorsed by many people which triggers the Echo Chamber effect of social media which makes the false information propagate much faster. Ongoing research on social bot detection mainly relies on social network information, discriminative features.

B.Troll Classification

A troll is someone who intentionally ignites conflicts or affronts other social media users either to cause division or distraction by posting agitational posts in any online community or social media platform. Ongoing researches on troll classification mainly rely on natural language processing, social network analysis, identifying heterogeneous groups of features and it also includes the analysis of writing style, sentiment, behaviors, social interactions, linked media, and publication time.

C. Clickbait Detection

The term "Clickbait detection" is a form of fake advertisement which uses a thumbnail link or hyperlink text that is designed to seek attention and to tempt the people to follow that link and view, listen or read to the connected piece of online content, with a defining characteristic of misleading, being deceptive or typically sensationalized. Now there are a lot of researches going on on this topic. In that, clickbait and non-clickbait articles are separated by fusing different features, clustering, and sentence structure using Hybrid categorization.

V.RESULT

Our model has used many classifiers in predicting accurate results. The performance metrics of each classifier are listed in table1.

MODEL NAME	ACCURACY	PRECISION		RECALL		F1 SCORE	
		0	1	0	1	0	1
Logistic Regression	0.99	0.99	0.98	0.99	0.99	0.99	0.99
Multinomial Naïve Bayes	0.94	0.93	0.94	0.95	0.92	0.94	0.93
Decision Tree	0.99	1.0	1.0	1.0	1.0	1.0	1.0
Passive Aggressive	0.99	0.99	0.99	0.99	0.99	0.99	0.99
Stochastic Gradient Decent	0.99	0.99	0.99	0.99	0.99	0.99	0.99
Linear SVC	0.99	1.0	1.0	1.0	0.99	1.0	1.0
Ensembler	0.99	0.99	1.0	1.0	0.99	1.0	0.99

TABLE 1 PERFORMANCE METRICS

From the results of each of the classifiers, it is inferred as the Decision Tree classifier has the maximum accuracy of 99% and precision, recall, and f1-score of 100% whereas, on the other hand, the Multinomial Naive Bayes classifier gives the least accuracy of 94%. Therefore, the best and least performing classifiers in our model is the Decision Tree and Multinomial Naive Bayes classifiers respectively. For the Ensemble classifier, the accuracy of the best performing classifier is taken into consideration, which is 99%.

VI.CONCLUSION AND FUTURE WORK

With the increase in the rise of social media, sharing information online has become prevalent. So we must identify the fact from the fake. In this article, in section 3, we have an overview of fake news where we have discussed the definition of fake news, the rise of fake news, its types, ways of detecting fake news from four perspectives and we've also comparatively analyzed all the methodologies. In section 4, our model has used textual features of the news articles based on a style based method to identify the fake news using natural language processing and machine learning techniques. In section 5, we have discussed the related research areas to fake news detection like Social bot detection, Troll classification, and Clickbait detection. Our model, for now, has used a single feature for predicting the result. In the future, we will be working to create a better model which considers many features in predicting the result.

REFERENCES

[1]Kaliyar, R.K., Goswami, A. &Narang, P. EchoFakeD: improving fake news detection in social media with an efficient deep neural network. Neural Comput&Applic (2021).

[2]Braşoveanu, A.M.P., Andonie, R. Integrating Machine Learning Techniques in Semantic Fake News Detection. Neural Process Lett (2020). [3] Vereshchaka, A., Cosimini, S. & Dong, W. Analyzing and distinguishing fake and real news to mitigate the problem of disinformation. Comput Math Organ Theory 26, 350–364 (2020).

[4]Kaliyar, Rohit Kumar, Anurag Goswami, and Pratik Narang. "DeepFakE: improving fake news detection using tensor decomposition-based deep neural network." The Journal of Supercomputing 77.2 (2021): 1015-1037. [5]Habib, Ammara, et al. "False information detection in online content and its role in decision making: a systematic literature review." Social Network Analysis and Mining 9.1 (2019): 1-20.

[6]Monica, C., and N. Nagarathna. "Detection of Fake Tweets Using Sentiment Analysis." SN Computer Science 1.2 (2020): 1-7.

[7]Islam, Md Rafiqul, et al. "Deep learning for misinformation detection on online social networks: a survey and new perspectives." Social Network Analysis and Mining 10.1 (2020): 1-20.

[8]Dong, Xishuang, Uboho Victor, and Lijun Qian. "Two-Path Deep Semisupervised Learning for Timely Fake News Detection." IEEE Transactions on Computational Social Systems (2020).

[9]M. Umer, Z. Imtiaz, S. Ullah, A. Mehmood, G. S. Choi and B. -W. On, "Fake News Stance Detection Using Deep Learning Architecture (CNN-LSTM)," in IEEE Access, vol. 8, pp. 156695-156706, 2020, doi: 10.1109/ACCESS.2020.3019735.

[10]Liu, Yang, and Yi-Fang Brook Wu. "Fned: a deep network for fake news early detection on social media." ACM Transactions on Information Systems (TOIS) 38.3 (2020): 1-33.

[11]Van Der Walt E, Eloff J. Using machine learning to detect fake identities: bots vs humans. IEEE Access. 2018;6:6540–9.

[12]Shu K, Mahudeswaran D, Wang S, Lee D, Liu H (2020) FakeNewsNet: a data repository with news content, social context, and spatiotemporal information for studying fake news on social media. Big Data 8(3):171–188.

[13]Alkhodair SA, Ding SH, Fung BC, Liu J (2020) Detecting breaking news rumors of emerging topics in social media. Inf Process Manag 57:102018.

[14]Berghel H (2017) Lies, damn lies, and fake news. IEEE Comput 50(2):80–85. https://doi.org/10.1109/MC.2017.56.

[14]Hunt Allcott and Matthew Gentzkow. 2017. Social me-dia and fake news in the 2016 election. Journal of economic perspectives, 31(2):211–36.

[15]ArkaitzZubiaga, Maria Liakata, and Rob Procter.2016a. Learning reporting dynamics during break-ing news for rumour detection in social media.

SMART Mobility Model for Driver Assistance in Semi-Autonomous Vehicles

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***Abstract*— The National Highway Traffic Safety Administration database reveals that drowsy driving causes more than 100,000 vehicle crashes a year. The increase in toll percentage is due to loss of driver control, human errors, and vehicle malfunctions. A driver assistance model to lead the vehicle to the nearest safe zone is proposed to automate the driver control system. EAR and ETV are the metrics used to detect the abnormalities of the driver. Safe zones are identified using GPS and Google API keys and the nearest safe zone is selected using Haversine geographic distance formula. Further, the lane detection to support the autonomous movement of the vehicle to the selected zone is guided by the YOLO algorithm. The algorithms are coded using Python scripts and trained with a predefined, generalized public database.**

Keywords—Advanced driver assistance system (ADAS), Automatic driver control system, Drowsiness detection, YOLO algorithm.

I. Introduction

Drowsiness is a biological disorder before falling asleep. Save Life Foundation (SLF), a non-profit, private organization committed to improving road safety and emerging medical care across India reports the death of 13, 81,314 people in preventable road crashes in the last 10 years. And further, 80% of these fatal accidents are due to drowsy driving [1]. The measures employed for drowsiness detection are categorized as physiological, behavioural, and vehicle-based. Monitoring the ECG / EMG / EEG signals of the driver, while driving the vehicle is suggested as a solution for the detection of abnormalities.

Further actions to prevent accidents due to drowsiness include the generation of alarm and informing the driver through the generic Smartphone APP etc [2]. However, the proposed technique is based on behavioural measures.

II. Related Work

Amna Rahman [3] presented a method for detecting the drowsiness of a person using the midpoint of the eye layers and calculated the blink rate with a high-resolution web camera (16MP) and obtained 94% accuracy under good lighting conditions and clear visibility of eyes. Moreover, the algorithm would fail, if the eyes are covered with sunglasses.

A component for the Advanced Driver Assistance System (ADAS) to automatically detect drowsiness is discussed in [4]. The module uses AI algorithms along with the visual data being captured. The system identifies and monitors the face and eyes and determines drowsiness using Support Vector Machines (SVMs). The system is designed to work under changeable light conditions in real-time. This system considers other distractions of the driver like yawning, head tilts, and face orientation along with eye blinking. These additional feature extractions improved the system's reliability. But this system suffers from a significant error percentage in generating unexpected false alarms.

Chuang-Wen et al[5] introduced “Car Safe”, the first android smartphone application for drowsiness detection. The application requires a dual-camera Smartphone and operates by switching between two camera pipelines. The front camera pipelines monitor the driver’s eye blinks rate and head pose to determine drowsiness. The back camera determines the vehicle’s distance from other vehicles on the road. It also checks the lane change situation and has an 83% precision and 17% recall.

Sahayadhas et al., [6], used ElectroOculoGraphy(EOG) signal in 2013 to measure the cornea-retina potential difference and monitored the eye movements related to drowsiness. The measures such as ElectroEncephaloGraphy (EEG), ElectroCardioGraphy (ECG), and ElectroMyoGraphy (EMG) could also be used to improve the system efficiency. In the future, ECG and EMG signals can be combined with vision-based measures for yielding better accuracy in decision making.

III. Proposed Work

The proposed model has three modules.

- Drowsiness detection through Eye-tracking
- Safe zone identification using geographical distance estimation
- Object detection for self-driving vehicles on the way to nearest safe zone.

A. *Drowsiness detection through Eye-tracking*

In paper [7], the safety technique algorithm demanding the continuous monitoring of the driver’s eyes to detect abnormal activities is elaborated. The tracking of eyeballs involves the measurement of horizontal and vertical distances between the edges of the eyes named Euclidean Distance (ED). The Eye Aspect Ratio (EAR) is computed and compared with the threshold value of the average blink rate to determine the abnormality. The average threshold value computation that involves the survey of blink rates at different scenarios is discussed in [8]. Fig. 1 depicts the steps involved in the tracking of eyeballs to detect drowsiness. From the video stream file of the driver's face, each frame is resized and converted into grayscale. The (x,y) coordinates of the left and right eyes are extracted from the face and the EAR and eye blink threshold values are calculated for each eye. The shape predictor.dat (Dataset for eyelid outline) is the predefined library used for extraction of the shape from the video or an image. Each eye is represented by 68 numbers of (x, y) coordinates, starting from the left corner of the eye, and moving clockwise around the remaining region. The relation

- Obtain video frames of the vehicle driver's face from the camera
- Detect face frames from the video and extract eye co-ordinates
- Convert to Grayscale using Luminosity algorithm
- Compute EAR with edges of both eyes to calculate blink rate
- If distance ≈ 0, eye-state is closed.
- If the eye state is "closed" constantly ≥2, {confirm drowsy driving;

  Enable alarm};

Fig. 1. Drowsiness detection algorithm

between the width and height of these coordinates is given in (1).

EAR = (Verti_ED1+Verti_ED2)/(2*Hori_ED) (1)

The coordinate points of (1) are shown in (2).

EAR = (P2– P6) + (P3– P5) / (2*(P1 – P4)) (2)

Where P1 to P6 are the 2D facial landmark locations shown in Fig. 2.

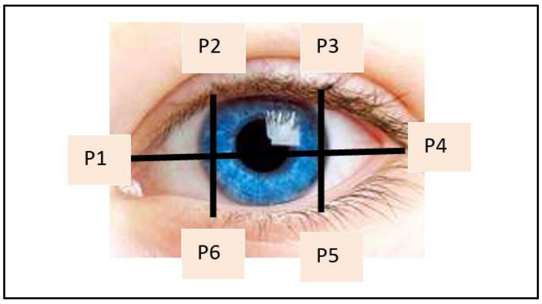


Fig. 2. Eye co-ordinates

The distance between the vertical eye landmarks and horizontal eye landmarks is computed. The ratio of eye landmark distances is used to determine the blinking status of the person. Hence, the simple equation avoids the use of image processing techniques. If an eye is fully open, the EAR would be larger and relatively constant over time. Whenever the person blinks the EAR decreases and approaches zero. The mathematical distance between the two coordinate points is called ED and is computed for vertical and horizontal eye coordinates as shown in (3).

$$\mathrm{ED} = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \quad (3)$$

Where, x_1, x_2, y_1 and y_2 are the co-ordinate points.

If EAR varies above and below the threshold, it is registered as a "blink" and is termed as EYE_AR_THRESH. Its optimal value is referred to as 0.24 [9].

If (EAR <EYE_AR_THRESH)

then {Eye Lid is closed}

Else {Eye lid is open}

Fig. 3. Condition for drowsiness detection

Further, two counter variables namely COUNTER and TOTAL are incorporated to ascertain the conditions for drowsiness. COUNTER is the total number of successive frames that have an EAR < EYE_AR_THRESH. TOTAL is the total number of blinks that are obtained during the run time of the Python script.

Also, EYE_AR_CONSEC_FRAME, an important constant is set to 3 to indicate that three consecutive frames with an EAR < EYE_AV_THRESH must happen for a blink to be registered. This condition is depicted in Fig. 4.

if (COUNTER>= EYE_AR_CONSEC_FRAME)

then {TOTAL = TOTAL +1}

Fig. 4. Blink detection and update

B. Safe Zone Identification using Geographical Distance Estimation

The confirmation of abnormality demands the redirection of the vehicle to a safe zone. The position of the vehicle (Source) and the safe zone places (Destination) is obtained from the GPS module and its API keys. Using GPS output, the Latitudinal and Longitudinal coordinates of the entire safe zone and the vehicle are obtained. Each place in the safe zone has a unique ID. The nearest safe zone is finalized with the shortest distance algorithm. The distance from the source and destination Latitudes and Longitudes is calculated by using the HAVERSINE method guided by (4), (5), and (6) [10]. This method remains well-conditioned for numerical computation even at small distances. Equations (4a) and (4b) calculate the hypotenuse distance between the two sets of coordinates. Equation (5) defines the angle in the Euclidean plane (2-argument arctangent) and (6) determines the distance between the two points.

Distance _btw_lon = Dest_lon – Src_lon (4a)

Distance _btw_lat = Dest_lat – Src_lat (4b)

S = {[sin (Distance _btw_lat/2) ^2)] + [cos (Src_lat * cos (Dest_lat) * sin (Distance _btw_lon /2) ^2} (5)

$$\text{Distance} = 2{*}R{*}S{*}\tan^2\left(\sqrt{S}, \sqrt{(1-S)}\right) \quad (6)$$

Where R= Approximate Radius of Earth = 6371Km.

C. Object detection for Self-driving of vehicles

For the self-driving of the vehicle to the selected safe zone destination, the You Only Look Once (YOLO) algorithm for lane detection is applied [11]. The objective of the algorithm is to make the driverless vehicle move in the desired path through the Computer vision-based Line Follower technique. YOLO is a Convolution Neural Network (CNN) developed for object detection in real-time. The algorithm applies a single neural network to the full image, and then divides the image into regions and predicts the bounding boxes and probabilities for each region. These bounding boxes are weighted by the predicted probabilities. YOLO looks into the entire image during training and testing. Hence, it implicitly encodes contextual information about classes as well as their appearance. The flowchart in Fig. 5 illustrates the YOLO operation.

The CNN is trained using Adam optimizer with the loss parameter of Categorical Cross-Entropy (CCE). Using this loss parameter, CNN can be trained to output a probability over C classes for each image.

$$CCE = -\frac{1}{N}\sum_{i=0}^{N}\sum_{j=0}^{J} y_j \cdot \log(\hat{y}_j) + (1-y_j)\cdot \log(1-\hat{y}_j) \quad (7)$$

Where, N = Number of training samples

Y = Actual output

Y^ = Predicted Output

The Gradients are calculated using Adam Optimizer and the weights of DCNN are obtained as Θ_t.

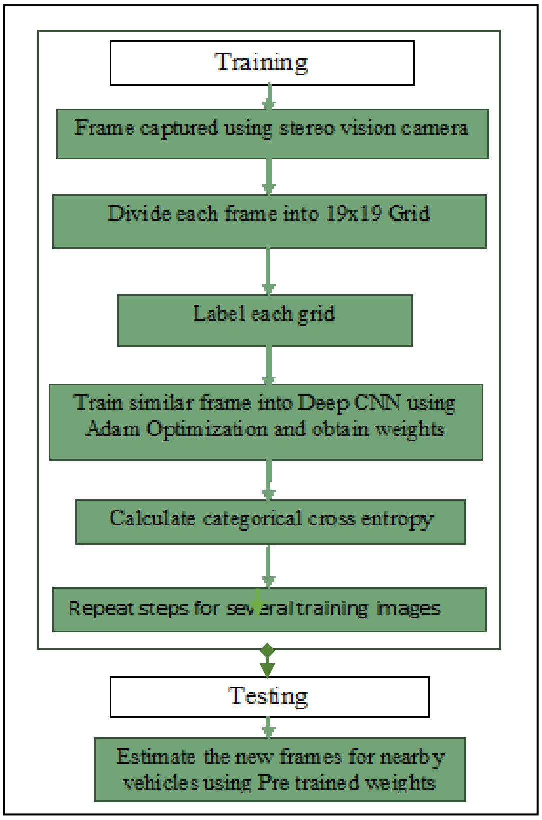


Fig. 5. YOLO flow operation

Adam – The adaptive moment estimation algorithm shown in Fig. 6, is an extension to stochastic gradient descent for deep learning applications in computer vision. It is appropriate for non-stationary objectives and problems with very noisy/sparse gradients.

$m_0 \leftarrow 0$ (Initialize first moment vector)
$v_0 \leftarrow 0$ (Initialize first moment vector)
$t \leftarrow 0$ (Initialize timestep)
While θ_t not converged **do**
$t \leftarrow t+1$
$g_t \leftarrow \nabla_\theta f_t(\theta_{t-1})$(Get gradients w.r.to stochastic objective at timestep t)
$m_t \leftarrow \beta_1 \cdot m_{t-1} + (1-\beta_1)\cdot g_t$ (update biased first moment estimate)
$v_t \leftarrow \beta_2 \cdot v_{t-1} + (1-\beta_2)\cdot g_t^2$ (update biased second raw moment estimate)
$\widehat{m}_t \leftarrow m_t/(1-\beta_1{}^t)$ (compute bias corrected first moment estimate)
$\hat{v}_t \leftarrow v_t/(1-\beta_2{}^t)$ (compute bias corrected second raw moment estimate)
$\theta_t \leftarrow \theta_{t-1} - \alpha \cdot \widehat{m}_t/(\sqrt{\hat{v}_t}+\epsilon)$ (update parameters)

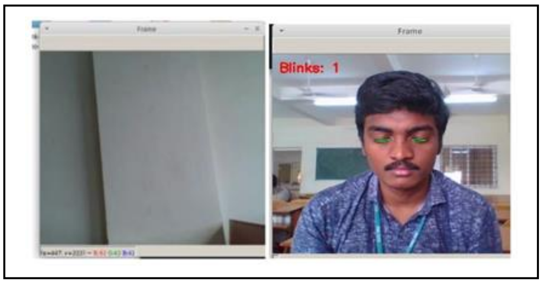
Fig. 6. Adam-optimizer algorithm

IV. Implementation and Test Results

A. *Drowsiness Detection*

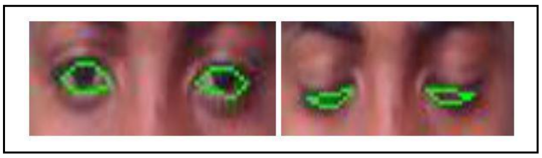
The drowsiness detection algorithm is implemented using python script. In Fig. 7a only the capture wall is shown. The human eyes are absent. Hence, there is no detection of the eyes. Therefore, the blink rate and frame counter values are calculated as zero. In Fig. 7b the face of the human is present and his eyes are detected and the number of blinks is calculated as 1.

The detection of the eye is indicated by using green lines and the Blinks = 1 is displayed. Similarly, in Fig. 7c, the eye is detected and the number of blinks is calculated and incremented whenever the conditions are met. In the first part of Fig.7d, the eyelid is above the threshold value and hence eye is open. There is no blinking that takes place. And in the second part, the eyelid is below the threshold value and hence eye is closed.



a) Absence of eye b) Detection of blink

c) Detection of the number of blinks

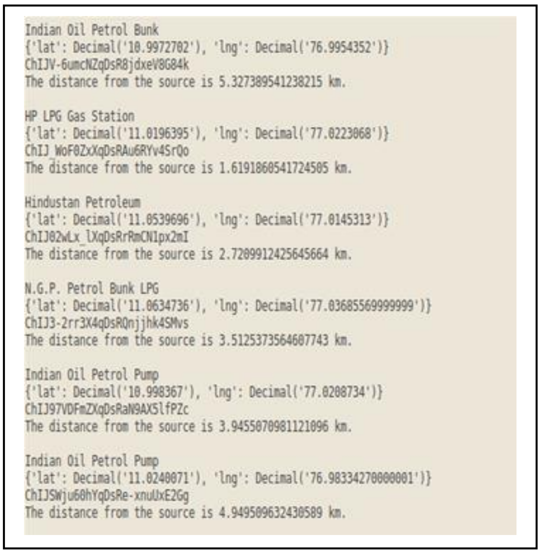


d)Threshold level

Fig. 7. Test Results

B. *Safe zone identification*

By using the Google API key - “AIzaSyBl7kIA_zo70Jnpo_zlTnWs1nzYFRvZ_KM” the information about the latitude and longitude of the safe zone is displayed. In Fig. 8, the name of the place, latitude and longitude, unique code for that place, and the distance from the source is displayed. Unique code is displayed because two safe zones can have the same name. After getting the geographical coordinates of all nearby safe zones, the distance from the source to each of them is calculated and the nearest zone is obtained. Fig. 9 displays the sample selection.



```
Indian Oil Petrol Bunk
{'lat': Decimal('10.9972702'), 'lng': Decimal('76.9954352')}
ChIJV-6umcNZqDsR8jdxeV8G84k
The distance from the source is 5.327389541238215 km.

HP LPG Gas Station
{'lat': Decimal('11.0196395'), 'lng': Decimal('77.0223068')}
ChIJ_WoF0ZxXqDsRAu6RYv4SrQo
The distance from the source is 1.6191860541724505 km.

Hindustan Petroleum
{'lat': Decimal('11.0539696'), 'lng': Decimal('77.0145313')}
ChIJ02wLx_lXqDsRrRmCN1px2mI
The distance from the source is 2.7209912425645664 km.

N.G.P. Petrol Bunk LPG
{'lat': Decimal('11.0634736'), 'lng': Decimal('77.03685569999999')}
ChIJ3-2rr3X4qDsRQnjjhk4SMvs
The distance from the source is 3.5125373564607743 km.

Indian Oil Petrol Pump
{'lat': Decimal('10.998367'), 'lng': Decimal('77.0208734')}
ChIJ97VDFmZXqDsRaN9AX5lfPZc
The distance from the source is 3.9455070981121096 km.

Indian Oil Petrol Pump
{'lat': Decimal('11.0240071'), 'lng': Decimal('76.98334270000001')}
ChIJSWju60hYqDsRe-xnuUxE2Gg
The distance from the source is 4.949509632430589 km.
```

Fig. 8. Parameters of safe zone

```
INDIAN OIL PETROLEUM
{'lat': Decimal('11.0428365'), 'lng': Decimal('77.04489049999999')}
ChIJfW0aKMZXqDsReGO-Vkdrzq0
The distance from the source is 2.1612468276396757 km.

Krishna Auto Service
{'lat': Decimal('11.0220396'), 'lng': Decimal('76.9963348')}
ChIJp7BugshXqDsRLBCRGlAfT_8
The distance from the source is 3.642390772660434 km.

Bharat Petroleum, Petrol Pump -Balamurugan Agencies
{'lat': Decimal('11.045837'), 'lng': Decimal('77.03565019999999')}
ChIJL_zwZl1XqDsRVqar5se2Zsc
The distance from the source is 1.6519854420160458 km.

The nearest place is
Indian Oil Petrol Pump {'lat': Decimal('11.0331511'), 'lng': Decimal('77.02766')
} ChIJ____5NXqDsRiWkVEUd71Gw 0.006975280874887382
bmk@bmk-HP-Notebook:/media/bmk/beta/pro$
```

Fig. 9. Nearest Place

C. *YOLO object detection*

In YOLO, an input image is divided into 19X19 grids and each grid is passed on to DARKNET architecture, which converts images of any size into a 7x7x1024 Tensor. The Tensor is passed on to a Fully Connected network with 4096 Neurons and its output is up sampled to give a 7x7x30 Tensor. This Tensor is then down sampled to a Tensor of size given as,

$$[1x\ (5+\text{Total number of Classes Trained})]$$

The network used is trained with the COCO Dataset having 80 Classes. Here, the algorithm is used to detect 3 classes namely,

- Car
- Light
- Pedestrian

For YOLO to work properly the Training Labels have to change, instead of having a one-hot vector. It should have individual labels per grid and stack them together to obtain a label for an image.

1) *YOLO Decoding Process*: YOLO is applied to the sample input image given in Fig. 10. The YOLO architecture is shown in Fig. 11. For simplicity, the image is divided into 4X4 grids. For each grid, the following vector is obtained.

$$[P_x, B_x, B_y, B_h, B_w, C_1, C_2, C_3]$$

Where,

P_x -> Presence of an Object [if yes 1, else 0]

B_x, B_y, B_h, B_w -> Bounding Box Co-Ordinates

C_1 -> Presence of Class 1(Car) [if yes 1, else 0]

C_2 -> Presence of Class 2(Light) [if yes 1, else 0]

C_3 -> Presence of Class 3 (Pedestrian)[if yes 1else 0]

Hence, 16 labels are obtained for a single image divided into 4X4 grids. Stacking them one on top of each other obtains an 8X16 vector. Then, DCNN has trained to output an 8X16 vector for the given input image. Categorical Cross Entropy is used for the calculation of error. The output is shown in Fig. 12.

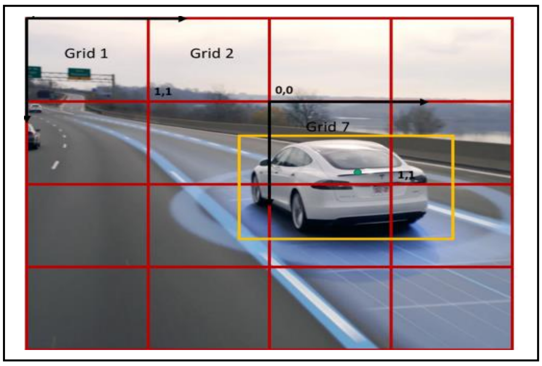


Fig. 10. Sample input image

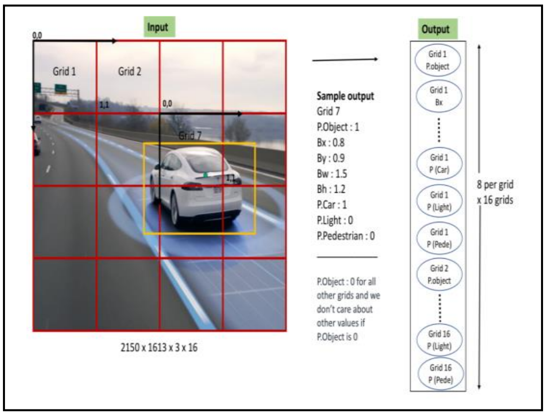


Fig. 11. YOLO algorithm Architecture

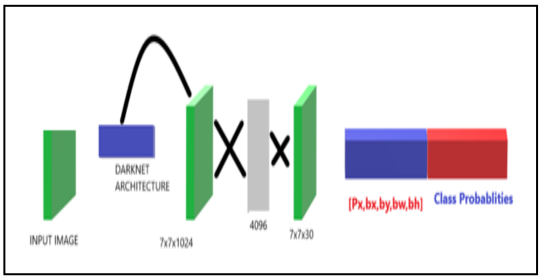


Fig. 12. Input- output relation of YOLO process

V. CONCLUSION

Through the implementation of the proposed algorithm, accidents due to drowsy driving could be prevented. By detecting the abnormalities of the driving person, the vehicle is led to the nearest safe zone. The limitation exists in detecting the abnormality of the driver. Differentiating the reason for drowsiness such as consumption of alcohol or any medical emergency would be carried out in the future.

REFERENCES

[1] https://savelifefoundation.org/

[2] M. T. Tombeng, H. Kandow, S. I. Adam, A. Silitonga and J. Korompis, "Android-Based Application To Detect Drowsiness When Driving Vehicle," 2019 1st International Conference on Cybernetics and Intelligent System (ICORIS), pp. 100-104, 2019.

[3] AmnaRahman, MehreenSirshar, Aliya Khan, "Real-Time Drowsiness Detection using Eye Blink Monitoring", In 2015 National Software Engineering Conference (NSEC 2015).

[4] M. J. Flores, J. M. Armengol, and A. Escalera, "Real-time warning system for driver drowsiness detection Using Visual Information", Journal of Intelligent & Robotic Systems, Volume 59, Issue 2, pp 103-125, August 2010.

[5] C. W. You, N. D. Lane, F. Chen, R. Wang, Z. Chen, T. J. Bao, M. Montes-de-Oca, Y. Cheng, M. Lin, L. Torresani and A. T. Campbell, "CarSafe App: Alerting Drowsy and Distracted Drivers using Dual Cameras on Smartphones", In MobiSys'13, June 25-28, 2013.

[6] Sahayadhas, K. Sundaraj, and M. Murugappan," Drowsiness detection during different times of day using multiple features", Australasian Physical & Engineering Sciences in Medicine, Volume 36, Issue 2, pp 243-250, June 2013.

[7] Asma-Ul-Husna., Amit Roy, Gautam Paul, MilonKanti Rah. "Fatigue Estimation through Face Monitoring and Eye Blinking", the 3rd International Conference on Mechanical, Industrial and Energy Engineering (ICMIEE 2014), 25-26 December 2014, Khulna, Bangladesh.

[8] Calculating Geographic Distance: Concepts and Methods – Frank Ivis. [online].

[9] Eyeblink detection with OpenCV, Python, and Libby Adrian Rosebrock on April 24, 2017 [online].G. Eason, B. Noble, and I. N. Sneddon, "On certain integrals of Lipschitz-Hankel type involving products of Bessel functions," Phil. Trans. Roy. Soc. London, vol. A247, pp. 529–551, April 1955.

[10] Z. Arifin, M. R. Ibrahim and H. R. Hatta, "Nearest tourism site searching using Haversine method," 2016 3rd International Conference on Information Technology, Computer, and Electrical Engineering (ICITACEE), pp. 293-296, 2016.

[11] A. Forero and F. Calderon, "Vehicle and pedestrian video-tracking with classification based on deep convolutional neural networks," 2019 XXII Symposium on Image, Signal Processing and Artificial Vision (STSIVA), pp. 1-5, 2019.

Application of Deep Learning for Solid Waste Trash Classification using Deep CNN

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Abstract- In the present era, with the rate of generation of wastes in concern, it is important to find an efficient solution to treat the wastes effectively. Segregation of wastes, being the most important part of waste management, is still done involving human labor. Our only hope to efficiently handle the wastes is to automate the segregation process and there arises a need for an efficient and robust classification model for segregating the wastes. This research proposes an advanced classification model DDR-net (Double fused Deep CNN using ResNext), which is an enhancement of the ResNext model boosted with double fusion and regularization. The proposed model can be implemented in real-time to any classification setup mechanism that feeds the trash image as input using a camera and based on the output from the model, actuators can be activated. The DDR-net classifies the solid wastes into their respective category with an accuracy of 97.81%. The performance of the proposed architecture was evaluated, experimented and compared with state-of-the-art architectures and it is observed that DDR-net outperforms the state-of-the-art methods on our dataset.

Keywords— Deep neural networks, Convolutional neural network, Deep learning, Fusion, Transfer learning, Waste classification.

I. INTRODUCTION

On the part of the local and urban bodies concerned the task of collecting, segregating and properly disposing of the solid wastes is a tedious task. Classification of solid wastes into biodegradable and non-biodegradable which is based on the nature of the solid waste is the key task when it comes to solid waste management. It takes lots of time and more manpower to classify the solid waste or in the worst case leaving the dump yards in dilemma. We are utilizing deep learning for accomplishing this task more efficiently. India, being a fast-growing economy with a massive population and expanding manufacturing infrastructure, discharges solid waste of 1.5 Metric Tons every day either into some water bodies by individuals and industries or in open lands. The existing techniques in solid waste management involve detecting the types of wastes using manpower and this solution is not efficient anymore as wastes are generated at an unmanageable rate and this concerns the wellbeing of our environment. Moreover, humans employed in the task of segregation are highly prone to many diseases. Thus to automate this process with a classifier mechanism a highly efficient classification model is in need. Many methodologies were proposed in various literature involving various methodologies such as sensors, etc. to address this issue, which was not reliable and efficient to be implemented in real-time scenarios. Various machine learning-based approaches are also available in solid waste management but when implemented in real-time applications they fail to produce the desired level of accuracy. Attempting to solve this highly impacting problem and to benefit mankind with technology is the major motivation behind this research. The major traits of this research are summarized as follows:

1. Creation of dataset comprising 7000 images belonging to seven different classes namely, cardboard, paper, wood, glass, metal, plastic and e-waste. Among them, cardboard, paper and wood are Biodegradable wastes and glass, metal, plastic and e-waste are non-biodegradable wastes.

2. Experimentation with various deep neural architectures based on ResNet and playing around with the features extracted, with fusion mechanisms and harnessing the combined power of transfer learning along with double fusion.

3. DDR-net, an advanced and reliable classifier for solid waste classification, is developed, which can be implemented in any real-time mechanism for the classification of solid wastes.

The rest of this research proceeds as follows: Section 2 analyses many works of literature of the related work in this domain thoroughly. Section 3 describes the technology behind this research, while detailed explanations of the proposed methodology and its behavior are studied in section 4. Section 5 describes the preparation and preprocessing of data, followed by section 6 which suggests a methodology to prevent overfitting. Section 7 describes the learning methodology followed in this research and the details of the training environment are also provided here. The model is evaluated and analyzed in section 8 and the experimental setup including the work environment is also mentioned here. Finally, the experiments along with the observed results and conclusions are presented in sections 9 and 10, respectively.

II. RELATED WORK

For image-based classification of solid wastes, many different algorithms namely Support Vector Machine (SVM), Artificial Neural Networks(ANN), Convolutional Neural Network(CNN), etc., have been developed in recent years. Chu, Y et al. [30] have studied a Multi-layer Hybrid Deep Learning System (MHS) to sort the waste thrown by individuals in public places. They have used a CNN-based algorithm and they were able to achieve classification accuracy levels of 90% and above. Bircanoğlu, C et al. [29] have developed a model namely RecycleNet, where they have carefully optimized deep CNN architecture for the classification of selected recyclable object classes. For training without any pre-trained weights, they were able to get the best accuracy of 90%, whereas, for transfer learning and fine-tuning of weight parameters, the best test accuracy achieved by them was 95%.

Hulyalkar, S et al. [12] have designed a system for automatic segregation of wastes into metal, plastic, glass and paper at the source itself. They have adopted a combination of CNN, image pre-processing and IoT. Sakr, G.E. et al. [15] have developed an automated system wherein waste materials like paper, metal and plastic can be segregated using CNN and Support Vector Machine (SVM) and made a comparison between these two techniques.

It is inferred from the above discussion that the Convolutional Neural Network surpasses most of the known algorithms in the task of image classification. Olugboja et al. [7] proposed an intelligent waste material classification system, which is developed using the 50-layer residual net pre-trained ResNet-50 model and Support Vector Machine (SVM). It was able to classify solid wastes like glass, metal, paper and plastic, etc. by achieving 87% accuracy on the trashnet dataset but the research has been carried out on a very small collection of trash image dataset containing only 1989 images of four different classes namely plastic, metal, glass, paper. In the research [14], Yu Liu et al. introduced and discussed the feasibility and superiority of Convolutional Neural Networks in the field of image fusion. They proposed a state-of-the-art CNN-based multi-focus image fusion method which also shows potential improvement in other-type image fusion methods.

In recent years many methods such as ResNet [2] and [8], ResNeXt [19], DenseNet121 [13], ImageNet [17] etc were introduced for classification using Convolutional Neural Networks (CNN). Saifuddin Hitawala et al. [19] implemented and evaluated the ResNext model architecture on the subset of the CIFAR-10 dataset that uses a homogeneous, multi-branch architecture for image classification. This research is evident to conclude that the ResNext model outplays most of the state-of-the-art models developed for image classification.

The proposed work is an effort made to make use of the benefits of multiple ResNext models by employing fusion mechanisms to develop a robust solid waste trash classification model using deep CNN (Convolution Neural Network)

III. ADVANCED SOLID WASTE CLASSIFICATION USING DEEP CNN

A. ResNext model

Residual Transformations Network for image classification, proposed by Xie et al. [27], is developed by utilizing the advantages of the split transform-merge strategy and the advantages of the residual block with extending its feature by the introduction of **cardinality**, which represents the number of different paths in the network. The ResNext model not only surpasses most of the state-of-the-art models but is also simple in terms of design when compared to other models like the Inception model, etc. Considering many such advantages and improvements, this research further proceeds with ResNext as base architecture.

B. Fusion methodology

Multiple deep CNN models have been developed since the emergence of CNN and deep learning and these models were able to achieve greater results and have been implemented to solve many problems. Fusion technology is based on the assumption that when multiple CNN models combined employing many fusion techniques, can yield promising results and can even outperform those individual deep CNN models. For improved and enhanced results, in early fusion, the features are extracted from images using multiple CNN models and these feature sets are fused, while the late fusion tries to fuse the classified outputs of multiple CNN models.

IV. PROPOSED METHODOLOGY

Here, the research involves utilizing the combined advantages of a fine-tuned ResNext-101 model and a Resnext-50 model fully trained from scratch, on our dataset, by a double fusion process. Here, the features are extracted from the input images, using both the models separately and the early fusion process takes place. Early fusion of the obtained feature vectors from both the models is fused by DCA followed by simple concatenation [2]. Then features undergo classification using the softmax layer and the outputs from both the models are fused using PSO-based weight optimization, a late fusion method. Then, at last, the result of early fusion and late fusion undergo Double fusion. The following section describes further the above-mentioned processes thoroughly.

A. Phase 1- Extracting features and Classification:

The research mainly aims to harness the power of double fusion. Inferred from the research [27], ResNext is chosen as the base model to proceed with and we use two models for feature extraction, where both of them are different versions of ResNext. Both the models are used to extract features from the images upon which both early fusion and late fusion are to be employed at later phases. The overview of the proposed methodology is given by the fig 1. The extracted features are fed into their respective classifier layers (log softmax layers) and the features are classified accordingly. The two models used are as follows:

1. The first CNN model is a pre-trained ResNext-101 model with cardinality C=32, enhanced by fine-tuning. As [3] suggests, the bottom layers are better for feature extraction as they are generic in nature and thus we use them to extract the features from the images, upon which early fusion is to be employed. Then the model's fully connected layers are removed and four new fully connected layers are added to the network, which is used for the classification of the features.

2. The second CNN model in the proposed methodology is a ResNext-50 model, with cardinality C=32, which is fully trained from scratch on our dataset and the features are extracted using the model, which is fed to the classifier.

B. Phase 2- Early fusion :

The features extracted from both the models discussed above in phase 1 are fused using the Discriminant Correlation Analysis (DCA) method. As the research [4] suggests, the DCA is employed for the early fusion of the features extracted from the models, as it vanquishes the problems faced in Canonical Correlation Analysis (CCA). Here the feature vector of length 1000, from both the models are extracted from the fully connected layer (FC-1000). Once, the feature sets from both the models are processed with DCA, they are combined using the summation process [27]. After fusion takes place, the fused feature set is fed into the classifier and the classifier predicts the output based on the fused feature set.

C. Phase 3- Late Fusion:

The classified outputs corresponding to each model, obtained from phase 1 are fused using the late fusion method: Particle Swarm based optimization of the weights (PSO method), as PSO is easy and flexible to implement as it combines both social concepts [6] and swarm intelligence principles. Here, the accumulation accuracy (1) on the validation set, that represents the weights to be assigned, is computed as Eq. 1.

$$A_{acc} = x\,(1) * P1 + x\,(2) * P2 + \ldots + x(n) * Pn \quad (1)$$

where, Pn represents the probabilities obtained through the nth model and x (n) represent the value (weight) to be used for the model.

D. Phase 4- Double fusion:

Once both the predictions from phase 2 and 3 are calculated, they undergo the double fusion based on the accumulative accuracy represented by Eq. 2.

$$A_{acc} = x\,(1) * P_{early\ fusion} + x\,(2) * P_{late\ fusion} \quad (2)$$

where, $P_{early\ fusion}$ and $P_{late\ fusion}$ represent the posterior probabilities obtained with early and late fusion on the validation set, respectively.

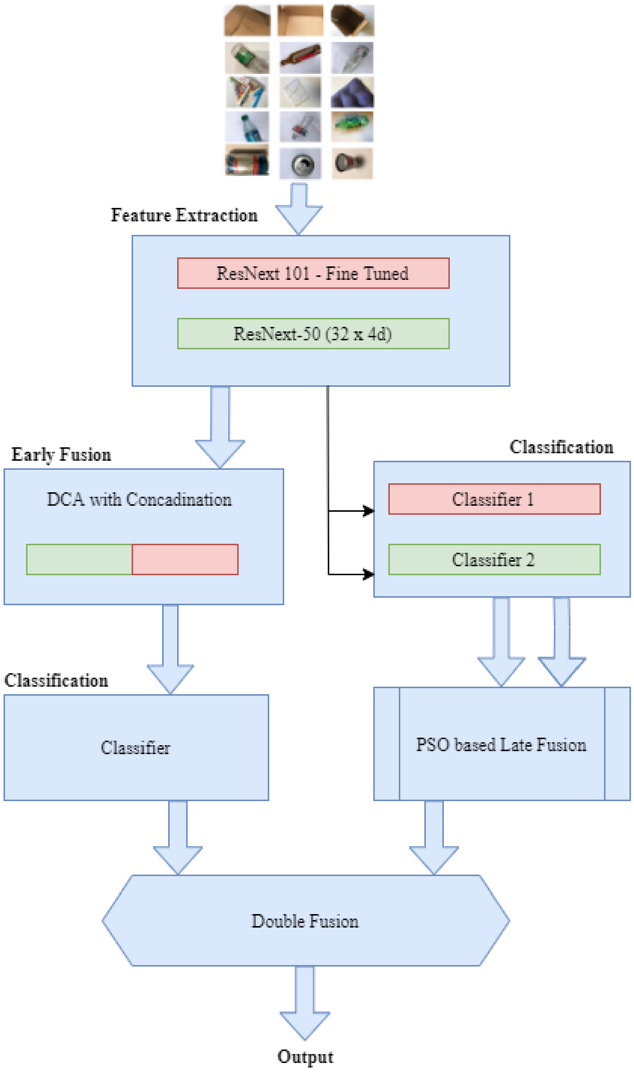

Fig.1 Overview of the proposed methodology

V. EXPERIMENTAL DATASET

The dataset used in this work consists of:

1. Images from Kaggle (www.kaggle.com/dimonisochecolo/trash-dataset).
2. Images from GitHub (https://github.com/garythung/trashnet).
3. Images collected from Google and Bing searches.
4. Images captured manually under a controlled environment.

The dataset consists of 7000 images split equally into seven categories namely cardboard, paper, wood, e-waste, glass, metal and plastic. The images of type[I] and [II], being synthesized, don't require much preprocessing, but the images of type [III] and [IV] are preprocessed by resizing and cropping into optimal sizes if needed. The unwanted noise in the images has been filtered and removed for better accuracy.

Table 1. Bio Degradable

Cardboard	Paper	Wood
		

Table 2. Non Bio Degradable

E - waste	Glass	Metal	Plastic
			

VI. AVOIDING OVERFITTING

As the trainable parameters of deep CNN are very huge in number and there needs the care to be taken during the training phase and the most important concern is that there is a high risk of overfitting, if the data available is relatively inadequate. The following measures are taken in this work to prevent overfitting from happening. An attempt has been made to enhance the dataset during the training phase, using data augmentation techniques like the creation of transformations of zooms, flips, shifts of images, etc. as represented in figure 2.

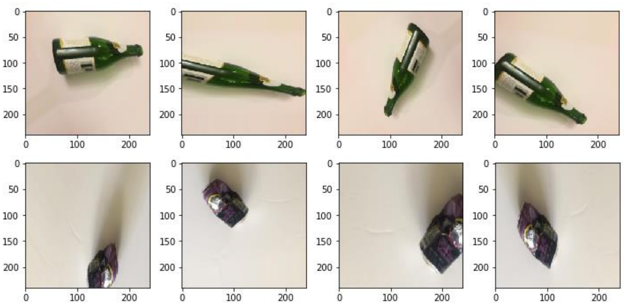

Fig.2 Results from employing various augmentation techniques on training images.

The most efficient step in preventing overfitting is regularization, which penalizes the model through the addition of some penalty to the loss function and this helps in compensating the unavailability of huge data. So, inferred from [31], L2 regularization along with dropouts of rate p=0.4 [11] has been employed. The research incorporates the above-discussed regularization methods to prevent overfitting.

VII. LEARNING METHODOLOGY AND TRAINING ENVIRONMENT

The proposed methodology was implemented using python 3.7 with Pytorch, an open-source deep learning framework. The model was trained on NVIDIA Tesla P100 PCIe 16 GB GPU using Ubuntu 16.04LTS.

Both the ResNext models were trained using the stochastic gradient descent (SDG) optimizer, with a batch size of 256 images and with a learning rate, α=0.0001. A weight decay of 0.001 has been used to reduce the training error. Adam optimizer with α =0.001 has been used for the base network in model 1 and SDG is used for fine-tuned layers of model 1, while model 2 is fully trained using SDG optimizer. Both the models are trained for 50 epochs. The maximum number of stall iterations was kept at 10 and the swarm size was fixed as 20 for the fusion techniques. The results are tabulated as a confusion matrix in table 3.

Further, the performance of the proposed model must be compared with the state-of-the-art models to understand and interpret how better the proposed model performs. For this purpose, this research utilized the architecture DNN-TC proposed by [2], which is a version of ResNext-101, a state-of-the-art model, enhanced with predictive performance. DNN-TC was run for 50 epochs (suggested by [2]) on our dataset, using SDG optimizer with α=0.0001 and the results are tabulated in table 4.

VIII. EVALUVATION METRICS

Table 3. Confusion matrix of the proposed method (DDR-net)

	Actual positive	Actual negative
Predicted positive	602	10
Predicted negative	13	425

Table 4. Confusion matrix of state-of-the-art model (DNN-TC)

	Actual positive	Actual negative
Predicted positive	514	34
Predicted negative	36	446

Table 5. Comparison of evaluation metrics

	DDR-net	DNN-TC
Accuracy	0.9781	0.9333
F1 Score	0.9813	0.9362
Matthews Correlation Coefficient	0.9549	0.8664
Precision	0.9837	0.9380
Recall	0.9788	0.9345

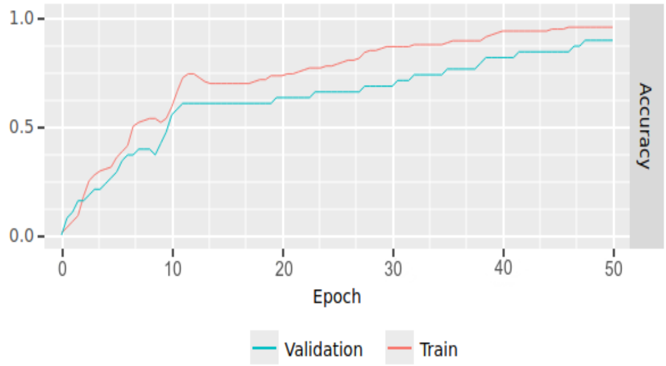

Fig 3. Training and validation accuracy of the proposed model

IX. RESULTS

Here, the detailed interpretation of the evaluations of the proposed work and also the state-of-the-art method is discussed. Table 5 displays the confusion matrix of our proposed work from which it is evident that our proposed model (DDR-net) classifies the solid wastes with an accuracy of 97.3%, which is a great improvement over the DNN-TC, implemented on our dataset with an accuracy of 93%. Further, table 5 represents the comparison of other evaluation metrics between the proposed model and the existing state-of-the-art model. Figure 3 represents the training-validation accuracy graph of the proposed methodology respectively. By inspecting table 5, it is concluded that the proposed model of this research performed better on our dataset and the double fusion method along with data augmentation and regularization has contributed well to the efficiency of the model and the results are promising, as the model outperformed the DNN-TC, while implemented on our dataset.

X. CONCLUSION

An advanced deep CNN, DDR-net with the combined advantage of residual connections and double fusion, which is robust, efficient and reliable in the task of classification of solid wastes has been proposed in this research. After analyzing various works of literature and understanding the advancement in deep CNN models, an attempt has been made here, through our experiments, to justify and support the idea that more than one deep CNN models synthesized together by double fusion of features of individual models, can have improved efficiency and can even outperform the state-of-the-art models in the task of classification of solid wastes.

This work can further be enhanced by attempting to increase the size of the dataset by collecting more valid and relevant data, by tuning various hyperparameters. In future work, a real-time implementation of the model in an IoT-powered bin kind of structure is planned to be developed, that is suitable in both indoor and outdoor environments, capable of segregating the solid wastes based on the model's output.

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REFERENCES

[1] Ahmad, K., Khan, K. and Al-Fuqaha, A., 2020. Intelligent fusion of deep features for improved waste classification. IEEE Access, 8, pp.96495-96504.

[2] Vo, A.H., Vo, M.T. and Le, T., 2019. A novel framework for trash classification using deep transfer learning. IEEE Access, 7, pp.178631-178639.

[3] Yosinski, J., Clune, J., Bengio, Y. and Lipson, H., 2014. How transferable are features in deep neural networks?. arXiv preprint arXiv:1411.1792.

[4] Haghighat, M., Abdel-Mottaleb, M. and Alhalabi, W., 2016, March. Discriminant correlation analysis for feature level fusion with application to multimodal biometrics. In 2016 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP) (pp. 1866-1870). IEEE.

[5] Sun, Q.S., Zeng, S.G., Liu, Y., Heng, P.A. and Xia, D.S., 2005. A new method of feature fusion and its application in image recognition. Pattern Recognition, 38(12), pp.2437-2448.

[6] Li, X.L., 2010. A particle swarm optimization and immune theory-based algorithm for structure learning of Bayesian networks. International Journal of Database Theory and Application, 3(2), pp.61-69.

[7] Adedeji, O. and Wang, Z., 2019. Intelligent waste classification system using deep learning convolutional neural network. Procedia Manufacturing, 35, pp.607-612.

[8] Srinilta, C. and Kanharattanachai, S., 2019, July. Municipal solid waste segregation with CNN. In 2019 5th International Conference on Engineering, Applied Sciences and Technology (ICEAST) (pp. 1-4). IEEE.

[9] Sudha, S., Vidhyalakshmi, M., Pavithra, K., Sangeetha, K. and Swaathi, V., 2016, July. An automatic classification method for environment: Friendly waste segregation using deep learning. In 2016 IEEE

Technological Innovations in ICT for Agriculture and Rural Development (TIAR) (pp. 65-70). IEEE.

[10] Abdallah, M., Talib, M.A., Feroz, S., Nasir, Q., Abdalla, H. and Mahfood, B., 2020. Artificial intelligence applications in solid waste management: A systematic research review. Waste Management, 109, pp.231-246.

[11] Srivastava, N., Hinton, G., Krizhevsky, A., Sutskever, I. and Salakhutdinov, R., 2014. Dropout: a simple way to prevent neural networks from overfitting. The journal of machine learning research, 15(1), pp.1929-1958.

[12] Hulyalkar, S., Deshpande, R., Makode, K. and Kajale, S., 2018. IMPLEMENTATION OF SMARTBIN USING CONVOLUTIONAL NEURAL NETWORKS.

[13] Mao, W.L., Chen, W.C., Wang, C.T. and Lin, Y.H., 2021. Recycling waste classification using optimized convolutional neural networks. Resources, Conservation and Recycling, 164, p.105132.

[14] Liu, Y., Chen, X., Peng, H. and Wang, Z., 2017. Multi-focus image fusion with a deep convolutional neural network. Information Fusion, 36, pp.191-207.

[15] Sakr, G.E., Mokbel, M., Darwich, A., Khneisser, M.N., and Hadi, A., 2016, November. Comparing deep learning and support vector machines for autonomous waste sorting. In 2016 IEEE International Multidisciplinary Conference on Engineering Technology (IMCET) (pp. 207-212). IEEE.

[16] Yang, M. and Thung, G., 2016. Classification of trash for recyclability status. CS229 Project Report, 2016.

[17] Krizhevsky, A., Sutskever, I. and Hinton, G.E., 2012. Imagenet classification with deep convolutional neural networks. In Advances in neural information processing systems (pp. 1097-1105).

[18] Del Valle, Y., Venayagamoorthy, G.K., Mohagheghi, S., Hernandez, J.C. and Harley, R.G., 2008. Particle swarm optimization: basic concepts, variants and applications in power systems. IEEE Transactions on evolutionary computation, 12(2), pp.171-195.

[19] Hitawala, S., 2018. Evaluating ResNeXt Model Architecture for Image Classification. arXiv preprint arXiv:1805.08700.

[20] Hussain, M., Bird, J.J. and Faria, D.R., 2018, September. A study on cnn transfer learning for image classification. In UK Workshop on computational Intelligence (pp. 191-202). Springer, Cham.

[21] Wang, J., Wei, Z., Zhang, T. and Zeng, W., 2016. Deeply-fused nets. arXiv preprint arXiv:1605.07716.

[22] Ozkaya, U. and Seyfi, L., 2019. Fine-tuning models comparisons on garbage classification for recyclability. arXiv preprint arXiv:1908.04393.

[23] Liu, Y., Guo, Y., Georgiou, T. and Lew, M.S., 2018. Fusion thatmatters: convolutional fusion networks for visual recognition. Multimedia Tools and Applications, 77(22), pp.29407-29434.

[24] He, K., Zhang, X., Ren, S. and Sun, J., 2016. Deep residual learning for image recognition. In Proceedings of the IEEE conference on computer vision and pattern recognition (pp. 770-778).

[25] Pang, S., Du, A., Orgun, M.A. and Yu, Z., 2019. A novel fused convolutional neural network for biomedical image classification. Medical & biological engineering & computing, 57(1), pp.107-121.

[26] Gu, J., Wang, Z., Kuen, J., Ma, L., Shahroudy, A., Shuai, B., Liu, T., Wang, X., Wang, G., Cai, J. and Chen, T., 2018. Recent advances in convolutional neural networks. Pattern Recognition, 77, pp.354-377.

[27] Xie, S., Girshick, R., Dollár, P., Tu, Z. and He, K., 2017. Aggregated residual transformations for deep neural networks. In Proceedings of the IEEE conference on computer vision and pattern recognition (pp. 1492-1500).

[28] Wang, J., Yang, Y., Mao, J., Huang, Z., Huang, C. and Xu, W., 2016. Cnn-rnn: A unified framework for multi-label image classification. In Proceedings of the IEEE conference on computer vision and pattern recognition (pp. 2285-2294).

[29] Bircanoğlu, C., Atay, M., Beşer, F., Genç, Ö. and Kızrak, M.A., 2018, July. RecycleNet: Intelligent waste sorting using deep neural networks. In 2018 Innovations in Intelligent Systems and Applications (INISTA) (pp. 1-7). IEEE.

[30] Chu, Y., Huang, C., Xie, X., Tan, B., Kamal, S., and Xiong, X., 2018. Multilayer hybrid deep-learning method for waste classification and recycling. Computational Intelligence and Neuroscience, 2018.

[31] Krizhevsky, Zeeshan, K., 2018. The Impact of Regularization on Convolutional Neural Networks.

RF Module based Automated Toll Collection System

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***Abstract*—In the conventional system of Toll Plazas, the operators collect the toll fee from the vehicle drivers and acknowledge with a receipt. This manual process is time-consuming and causing a longer waiting time for the vehicles to stay in the queue. In recent days, one of the advancements made in the Toll Collection system to reduce the waiting time of the vehicles is the RFID FASTag method. It permits electronic payment and speeds up the toll collection process. This paper proposes a solution to overcome the drawbacks of the currently used RFID FASTag - such as double deduction of payment from the customer account and the physical damages to RFID FASTag. This method ensures the automated cashless quick transaction at toll centers with the assured single deduction of payment for the trip. Arduino IDE is used to program Node-MCU, having an in-built Wi-Fi facility to notify the owner about the location of the car.**

Keywords- RF Transmitter, RF Receiver, Toll plaza, Cashless transaction, Node-MCU, Liquid Crystal Display, Servo motor

I. Introduction

The Government builds highways for better connectivity between the states and that costs lots of money. This is later recovered by charging the toll tax from people who use the highways. Traditionally, toll fee is collected manually via cash/ card payment at dedicated-toll booths. However, processing time at such plazas is extremely high due to manual intervention. This results in traffic jams and a huge concentration of vehicles causing inconvenience to travelers. This problem also leads to long waiting times, fuel inefficiency, and sometimes road rage, further leading to violence. Demand for faster and greater vehicle throughput has resulted in new concepts such as all-electronic, non-stop, open road tolling, etc.., The existing technology of cashless RFID-based system has the drawbacks of double deduction of e-payment for toll fee and the physical damages of RFID Tag.

In this paper, an RF module-based automated toll collection system is proposed. The RF module used to transmit and receive the signals between the vehicles to the toll booth is placed inside the vehicle. This minimizes the chances of its physical damages. With the use of a switch inside the vehicle, the fee transaction is completely brought under the control of the client (vehicle). This technique avoids the double (or multiple) time e-payment of toll fees.

II. Literature Survey

In paper [1], the RFID-based system implementation is divided into the design of two modules- the Vehicle Module (Active Tag) and the Base Module. The two modules communicate via an RF modem connected to each module. The base module comes with a user interface that allows the administrator to monitor the current activities in the range, including the vehicles in the range, their status, and detailed information about any registered vehicle. The cost of implementation for this project proposed here is higher than the options available in the market. This is due to the increased capabilities incorporated into the system to counter the problems of scalability, power requirements, and shielding effects.

This paper [2], deals with the Automated Toll collection and Check-Post system using Radio Frequency Identification (RFID) and Global System for Mobile communications (GSM) module. The RFID tag is rupturable and there may be chances that it may be lost. Also, double detection of the ID may happen so that the money will also be detected twice. In the paper [3], there may be a chance the scanning mechanisms are not able to read a FASTag. In this case, someone has to be technically sound to troubleshoot such issues. In rare cases, the FASTag might become unreadable after a few transactions. The government or issuer has to have a backup plan to reissue the same to the customer. In paper [4], the FASTag is a simple sticker that is placed on the inside of the windscreen. Under any circumstances, may this FASTag gets tampered with or damaged, it would result in another trouble to the customer. It may become unusable, which means, it must be repurchased another FASTag for your vehicle. Though the money is refundable, one has to go through the registration process again. And since RFID tag is deployed the heavy or oversized vehicles take the advantage of using the RFID tags of 2-axile vehicles.

III. PROPOSED METHODOLOGY

The overall system view is shown in Fig. 1. which overcomes the disadvantages mentioned in II. The pressing of the button initiates the whole process and is interfaced with the Node MCU. When the car nears the toll, the button is pressed and the RF transmitter placed inside the car transmits the Engine number of the car. Since the RF transmitter inside the car and the RF receiver in the toll are within a distance of 50m, the reception takes place effectively.

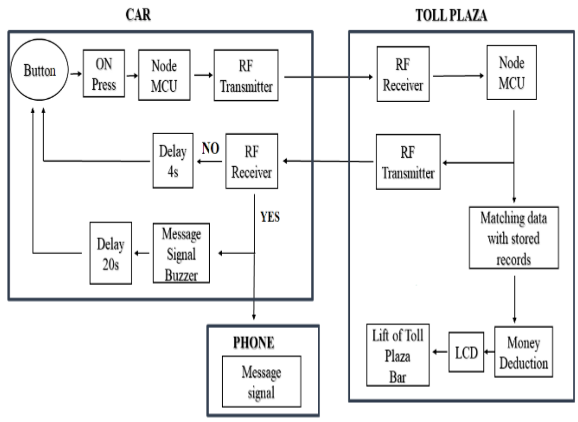

Fig. 1. Overview of the Proposed System

A. Proper reception at Toll Plaza

When the RF receiver in the toll receives the engine number of the car, the matching process begins by comparing the received data with the database to obtain the bank account linked with the Engine number. The toll fee amount is then deducted from that account. An acknowledgment is sent from the RF transmitter of the toll and is received by the RF receiver inside the car. The owner whose mobile number will be registered need not drive the car always. Hence, the acknowledgment from the toll turns on the buzzer which is placed inside the car indicating the completion of the toll fee payment to the person who is driving. Also, a message is sent to the registered mobile number. The signal from the button press is then disabled for few seconds to avoid double deduction (that is, even if the client unknowingly presses the button, the RF transmitter inside the car stops the transmission of signals for the next 20 seconds). The deducted amount is displayed on the LCD and the toll plaza bar is lifted with help of a servo motor.

B. No/Improper reception at the Toll plaza

When the RF receiver in the toll is not received with the signal (if the client has pressed but the RF receiver is not in the range of 50m or for any other reasons), then the RF transmitter transmits a logic 0 as a negative acknowledgment. Hence, the RF receiver inside the car enables the button to be pressed again for proper transmission after which the same procedure of "*Proper reception at Toll Plaza"* occurs.

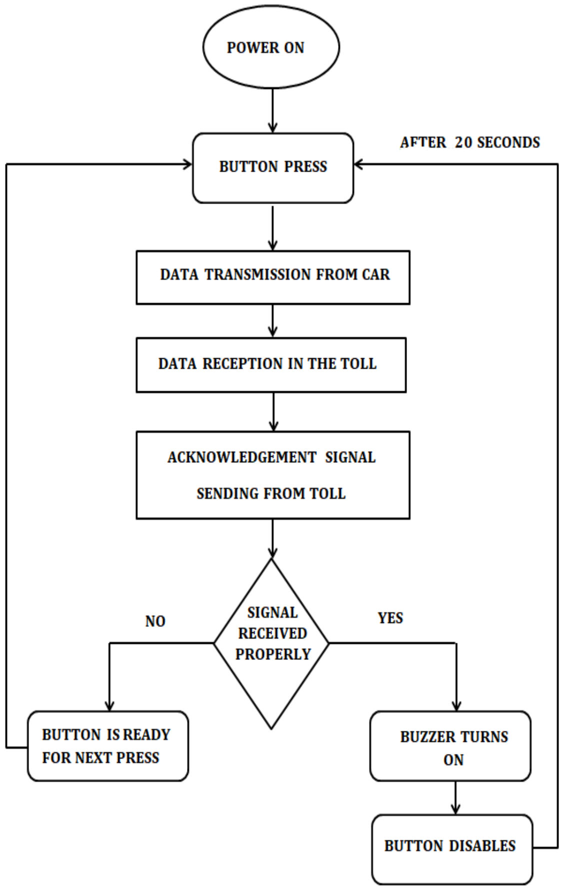

Fig. 2. The Workflow of the Proposed System

IV. IMPLEMENTATION

The workflow of the proposed system is shown in fig. 2. The process is initiated once the button is pressed when it nears the toll plaza effectively when the distance is less than 50m.

The data (unique engine number) is transmitted. Toll plaza receives the data and it sends the acknowledgment that whether the data is properly received or not. If properly received, the buzzer in the car buzzes and the button is disabled for the next 20 seconds which prevents the double deduction. If the proper reception has not taken place, the button will be ready for the next press and the procedures mentioned above will be continued.

A. Transmission of Data from Car

The transmitter and receiver module is tested and the transmitter module is interfaced with the ESP8266 board and with the RC Switch library installed. The code is dumped into the board and the engine number of the car is transmitted. The button is then connected and the transmission is controlled. Only after the button press, the data transmission is enabled.

B. Reception of Data at Toll

The data transmitted from the car is received by the receiver module interfaced with another ESP8266. The same

RC Switch library is used for the reception of data at the toll side and the received data is printed on the serial monitor.

C. Matching Process

The received data is compared with the previously stored records (database) and if it matches, the account number linked with that data is accessed and the amount is deducted from that account number based on the type of vehicle. The account number and the balance in that account number are stored previously in the database.

D. SMS Reception

Once the data has been received and the amount gets deducted, the node MCU triggers an SMS to the registered mobile number of the corresponding engine number with the help of IFTTT and ESP8266Wifi library. The mobile number registered will be uploaded along with the code. The SMS delivers the message stating that the car has crossed the toll.

E. Displaying the Amount In LCD

When the amount is deducted from the registered bank account, the amount deducted is displayed in the LCD by interfacing it with node MCU provided the code below with the library LiquidCrystal_I2C. Since the LCD is placed in the line of sight of the car, the amount displayed in it is seen clear enough by the person in the car.

F. Lift of Toll Plaza Bar

The toll bar is then lifted with the help of a servo motor. The servo motor is rotated 90 degrees and then brought to the initial position after some delay. This is done by interfacing the servo motor with ESP8266 and the below code dumped with the help of the Servo library.

G. Retransmission of Received Data to Car

When the data is received in the toll via the RF receiver, an acknowledgment signal is transmitted back to the car, to indicate that the data sent from the car has been properly received in the toll.

H. Data Reception in the Car

The signal sent from the toll is received by the RF receiver in the car which turns on the buzzer in the car to indicate that the data sent from the car is properly received in the toll. And the button in the car is disabled for the next few seconds to avoid another press which may lead to a double deduction of amount.

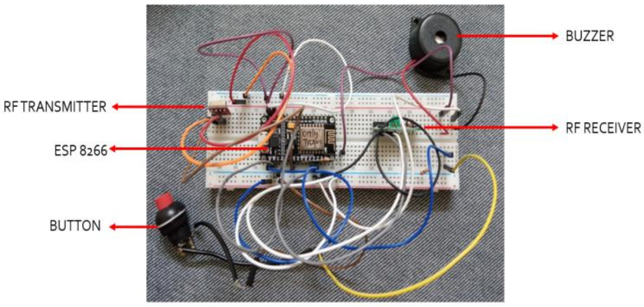

Fig. 3. Circuit Connection – Car Side

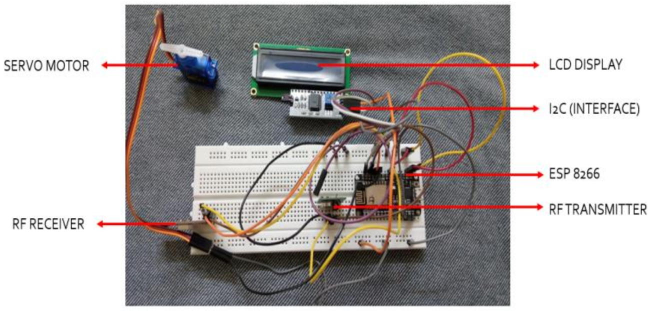

Fig. 4. Circuit Connection – Toll Side

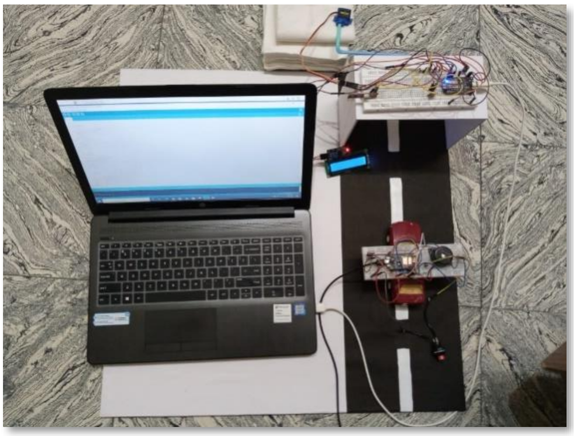

Fig. 5. Top view of the implementation of the proposed system

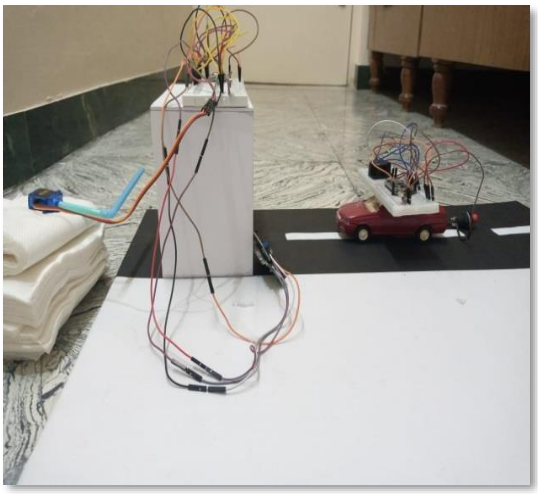

Fig. 6. Side view of the Implementation of the Proposed System

V. Result Analysis

The Node MCU in the car is interfaced with an RF transmitter so that the data to be transmitter which the unique engine number of the car is fed to the Node MCU and by interfacing Node MCU with the RF transmitter, this data can be transmitted. The transmission of data is controlled by a push-button. When the button is pressed, the data is being transmitted.

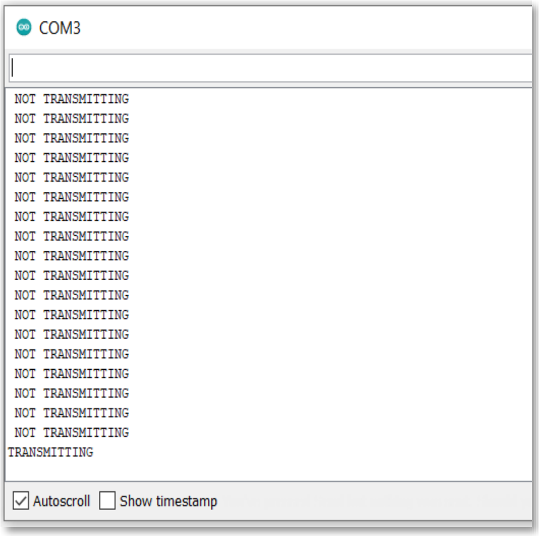

Fig. 7. The RF transmitter transmitting once the Button is pressed.

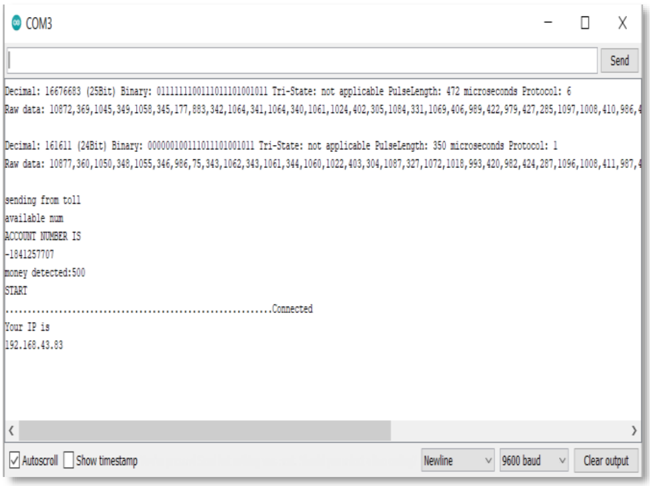

Fig. 8. The serial monitor (details of transaction displayed)

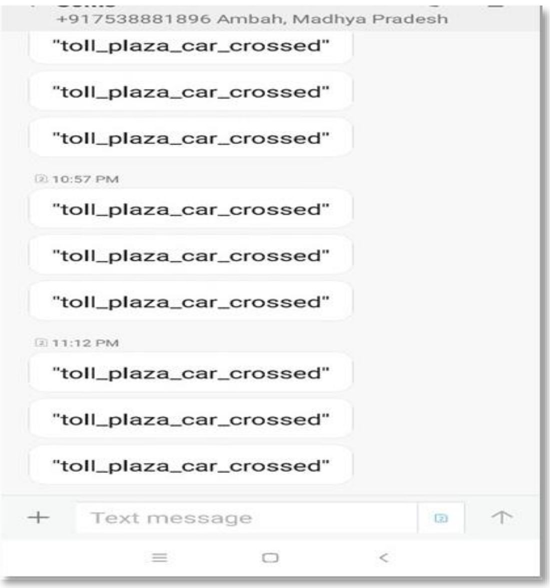

Fig. 9. SMS Received by the Registered Mobile Number

The data signal transmitted by the RF transmitter of the car as shown in Fig. 7. is received by the RF receiver when the car moves nearer to the toll. When the signal is received, a particular amount will be deducted from the registered bank account and an SMS is sent to the mobile number linked with the account. The details of the transaction performed are shown in Fig. 8. and the SMS received by the user is shown in Fig. 9. To ensure that the signal is properly received, an acknowledgment signal is sent from the RF transmitter interfaced with the Node MCU.

The signal transmitted by the RF transmitter of toll is received by the RF receiver in the car. When the signal is received, a buzzer connected to the Node MCU turns on to indicate that the signal has been properly received. And the button will be disabled for the next twenty seconds to avoid a double deduction.

VI. Conclusion

The problems addressed in this paper are to avoid double-time deduction, usage of RF modules to avoid damages caused to RFID tags. The approach of the proposed framework is as achieving control over a transaction is achieved using a button. The establishment of communication between Toll and car using RF module which overcomes the damages caused to RFID labels is done. Using the buzzer and message facility, the transaction is indicated to the user as well as the worker at toll. After all the procedures the servo motor is used to lift the toll bar. For easiness, the amount deducted is displayed using a liquid crystal display in the view of the sight of the driver.

References

[1] Atif Ali Khan, Adnan I. ElberjaouiYakzan, Dr. MaarufAli, "Radio Frequency Identification (RFID) Based Toll Collection System" International Conference on Trends in Engineering and Technology, pp. 103-107, January 2017.

[2] K. Balamurugan, Dr.R. Mahalakshmi, Dr.S. Elangovan, R. Pavithra, "Automatic Check-Post and Fast Track Toll System Using RFID and GSM Module with Security System" in International Carnahan Conference on Security Technology (ICCST), pp. 83-87, October 2017.

[3] Dr.A.Amutha, Kiruthika. R, Annapoorani. B, Preethi. A Priyanga. P, Inderjeeth.M, "Rfid And Gsm Module Based Automated Toll Plazas On Highways" in *International Journal of Advanced Research in IT and Engineering*, vol. 5, pp. 352-357, 2017.

[4] Vishnupriya. R, Dr.N.P.Ananthamoorthy, " Automatic Toll Collection System Using RFID & GSM Technology" in International Journal of Pure and Applied Mathematics, vol. 118, pp. 421-424, October 2017.

[5] AungMyintWin, Chaw MyatNwe, KyawZinLatt, "RFID-Based Automated Toll Plaza System" in International Journal of Scientific and Research Publications, vol. 4, June 2014.

[6] Rafiya Hossain, Moonmoon Ahmed, Md. Mozadded Alfasani, Hasan U. Zaman, "An advanced security system integrated with RFID based automated toll collection system" in Third Asian Conference on Defence Technology (3rd ACDT), pp. 59-64, January 2017.

[7] Datasheet:https://components101.com

[8] CircuitDigest-Wi-Fi:https://circuitdigest.com/microcontroller-projects/sending-sms-using-esp8266

Malware Detection and Classification

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***Abstract*—The Growth of Technology used on the Internet, Computers, Smartphones, and Tablets have been favourable to the emergence and spread of cyber threats, resulting in cyber attacks. The number of attacks has grown exponentially and has resulted in discovering various malware detection approaches. Multiple machine learning and big data technologies have been used for the detection of malware. Current malware detection solutions that adopt traditionalMachine Learning techniques take time but have been shown to be successful at detecting unknown malware in real time. The feature engineering process can be absolutely eliminated by employing advanced Machine Learning Algorithms such as deep learning.Various malware classification and identification methods are discussed in this paper. To identify the sample as benign or malware, machine learning and deep learning-based solutions have been addressed.**

***Keywords*—Cybersecurity, Malware detection, Machine learning, Ransomware**

I. INTRODUCTION

Cyberattack is the most common problem in current technology. It usually involves hacking into a vulnerable device and stealing, changing, or destroying a specific target.. They have become increasingly sophisticated and dangerous.

Malware is one such cyber attack.It refers to any programme that is created with the intent of causing harm to a device, server, client, or network.

Viruses, Trojan horses, ransomware, spyware, adware, rogue applications, wiper, scareware, and other forms of malware exist.. Programs are called malware if they perform actions against the authorization of the computer user.

Malware impacts on the digital systems also include:

- Disrupts operations.
- Steals sensitive information.
- Hardware Failure.
- Allowing unauthorized access to the system and all its resources.
- decreases computer or web browser speeds.
- Creates issues and problems connecting to networks.
- Results in crashing or frequent freezing of the system.

A Malware detection module determines if a program or connection is a threat, based on the collected and trained data. Preferably a machine-learning algorithm that can discover and formalize the principles that underlie the data it sees. A machine-learning algorithm is a program with a specific way to adjust its own parameters based upon the feedback on its previous performance in making predictions about a test dataset.

II. LITERATURE REVIEW

Daniel Gibert et al in [1] represented as images elucidates the conversion of PE Files to Images. then these are converted into grayscale images of (256 x 256). The maximum number of bits in the given image for a PE file is 256x256x8. Portable executable files that are malignant include four major types and benign are given as input. 8 bits are read at a time and converted to integer following which we get 65 KB if it's less than that then it's padded with zeros. Thus after this, a model was trained on these images which gets an accuracy of 66%. E files to Image.

Large-scale malware classification **[2]** using random projections and neural networks was published in 2013. Logistic regression and Neural Networks are primarily used. The input vector's dimensionality is reduced from 179 thousand to 4000 features using random projections. It is used to train 2.6 million labelled malware using neural networks, resulting in a 0.49 percent error rate for a single neural network and 0.42 percent for an ensemble of neural networks. Adding more hidden layers did not result in a major improvement in accuracy. As compared to the one-layer neural network, the two and three hidden layer models perform marginally worse. It's believed that the explanation for the poor results is that there aren't enough errors to properly learn additional layers.

A study in M. Ijaz, et al (2019) **[3]** explains the traditional machine learning approaches peculiarly in malware detection. The process is generally categorized into two groups depending on the type of analysis as static and dynamic analysis. Static analysis involves examining the malware sample without running it. On the other hand, Dynamic analysis is carried out systematically in a controlled environment where the malware is executed in a controlled system.

Malware detection based on the deep learning algorithm was published in" The Natural Computing Applications Forum 2017" in July 2017. In this paper, they [4] portrayed malware as opcode sequences, used a deep belief network (DBN) to detect malware, and compared the performance of DBNs to three baseline malware detection models that used vector machines, decision trees, and the KNN algorithm. This system has a 96 percent accuracy rating.. They have proposed that using unlabeled data can improve the accuracy of malware detection models.

Robust Intelligent Malware Detection Using Deep Learning was published by IEEE Volume 7 of 2019. This paper evaluates various Machine learning Algorithms and Deep Learning algorithms for the categorization of multiple private and public datasets. **[5]** Experimental analysis is done to remove dataset bias using time scales. Finally, they propose an Image processing technique to arrive at an efficient zero-day model. By adopting CNN 2 layer + LSTM, they have reached an accuracy of 98.8%. In the work which was proposed, the robustness of the deep learning architectures was not being discussed.

Machine Learning Methods for Malware Detection was published by Kaspersky. It is a two-stage design **[6]** that reduces the number of false positives. In the first stage, unbiased regions are detected and second stage classifiers are trained only on a single bucket. Hence these regional classifiers used to detect the malware are quite efficient.

Bazrafshan, Z et al in **[7]** explains the three main strategies used in the detection of malware files: Signature based, Behavioral based, and Heuristic based detection. Here Pattern matching method and signature based detection techniques are widely used for malware detection. Data Collector- Interpreter- Matcher. The major benefits of Behaviour based malware detection techniques is the ability to detect unknown and polymorphic malware variants. Heuristic malware detection methods use various kinds of machine learning approaches to render the pattern of an executable file.

Malware and Detection Techniques: A Survey was published on 12 December 2013. In this paper **[8]**, they have compared the benefits and limitations of malware detection techniques. Various issues are discussed. **Signature-based** approaches can't identify unknown malware variants, and extracting specific signatures takes a lot of manpower, time, and resources. It was impossible to identify mutated codes**.** **Behaviour-based** approaches have a high scanning period and a non-availability of promising False Positive Ratio (FPR). Handling a large number of genera is one of the heuristic features constraints.

Malware Classification with Deep Convolutional Neural Networks was published in 2018(IEEE). This paper targets **[9]** convolution neural networks used to classify malware samples. These binary samples are first converted to Grayscale images through visualization. They have developed a CNN model and trained the same. This method has achieved 98.52% and 99.97% on Microsoft datasets that are available for public use.

Gupta, P et al **[10]** elucidated the hybrid approach to malware detection, which incorporates static and dynamic analysis aspects. Experts believe that AI-powered anti-malware software would aid in the detection of new malware attacks and the improvement of scanning engines. Neural networks have recently made a name for themselves in learning features from raw inputs in a variety of fields.

III. MALWARE DATA ANALYSIS

A. *Data Description*

The data was taken for entire analytics obtained from the Canadian Institute for Cybersecurity. Dataset possesses pcap files with log details of applications under each malware category. These log features can be extracted and thus trained for various models. The samples come from 42 unique malware families. It contains over 10,854 samples (4,354 belong to malware class while 6,500 belong to benign class) from several sources. Malware types include Ransomware, Adware, Scareware, and SMS malware.

B. Exploratory Data Analysis

This entire project was carried out using Python. Importing all necessary libraries for model deployment includes Pandas, sci-kit learn, seaborn, Matplotlib, NumPy, TensorFlow. The dataset contains 88 attributes based on the structure and network configuration of malware. The correlation matrix for all the features has been drawn and based on that, certain columns are dropped. The entire dataset is truncated to 77 attributes. A Label encoder was used to mutate the Non-numerical data into a machine-readable format for easy interpretation by the system. Normalization was carried out on Flow ID, Source IP, Destination IP, Label, and source values.

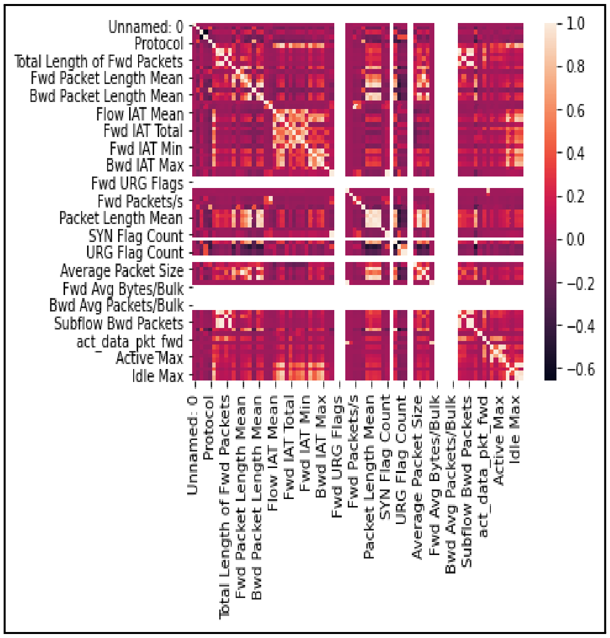

Fig.1 Correlation Matrix

C. *Predictive Data Analysis*

The robust classification of the malware type is imperative to backtrack the cybersecurity threats. The comparative analysis of all algorithms and fine-tuning methods are given. Since the given dataset is abstract and highly skewed, Multi-Layer Perceptron is deployed with 10 layers and an input of 72 attributes. The Activation function used here is Sigma and optimizer as adam and the loss function is Mean Absolute Error (MAE). The accuracy of the MLP obtained was 29.6 percent.

Then, Machine Learning techniques like random forest classifier and KNN (K Nearest Neighbour) are implemented, accuracy about 50 percent and 39.7 percent are attained. Train and test split ratio are given as 70:30, The number of attributes passed is the same as deployed in the MLP model.

Fine-tuning the Random Forest algorithm with K-fold, grid search results in increased accuracy of about 62.2 percent. Further, the algorithm is tuned by adjusting the optimization parameters like max depth with an increased number of layers. Finally, 95.6 percent accuracy has been achieved through the Random Forest classification method.

D. Results and Discussion

TABLE I. PREDICTIVE RESULTS

Result Overview	**Model**	**Accuracy score (Percentage)**
	Multi-Layer Perceptron	29.6
	K Nearest Neighbour	37.9
	Random Forest classifier (Before tuning)	62.2
	Random forest classifier (after tuning)	95.6

Data is the primary source for all applications functioning in the digital world. The measures to be taken to protect the data from many cybersecurity threats are crucial. Indeed, Machine Learning techniques are an inventive approach that paves the way for accurate prediction, although feature selection is a challenging task to build any kind of model. The algorithm which can also process irregular data has to be circumvented.

Future attacks can be controlled and stopped only by analyzing the malware samples and its behaviour that exists now. This is done by cybersecurity experts by making use of some professional malware analysis tools.

Cybersecurity teams can use a malware detection tool to identify and analyse malware samples and see whether they are malicious or not, and if they are, they can be removed from the system and prevented from spreading further. These tools can be used to monitor security alerts and avoid malware attacks in the future. Organizations are adopting new security measures as malware attack vectors become more sophisticated..

REFERENCES

[1] Daniel Gibert, Carles Mateu, Jordi Planes & Ramon Vicens, “Using convolutional neural networks for classification of malware represented as images” -Journal of Computer Virology and Hacking Techniques volume.

[2] George E. Dahl, Jack W. Stokes, Li Deng, Dong Yu, Microsoft Research,” Large-scale Malware Classification Using Random Projections And Neural Networks”-IEEE.

[3] M. Ijaz, M. H. Durad and M. Ismail, "Static and Dynamic Malware Analysis Using Machine Learning," 2019 16th International Bhurban Conference on Applied Sciences and Technology

(IBCAST), Islamabad, Pakistan, 2019, pp. 687-691, doi: 10.1109/IBCAST.2019.8667136.
[4] Ding Yuxin, Zhu Siyi, “Malware detection based on the deep learning algorithm”, Springer.
[5] R. Vinaya Kumar, Mamoun Alazab, K.P.Soman, Prabaharan Poornachandran, And Sitalakshmi Venkatraman, “Robust Intelligent Malware Detection Using Deep Learning”, IEEE.
[6] “Machine Learning Methods for Malware Detection”, Kaspersky, https://media.kaspersky.com/en/enterprise-security/Kaspersky-Lab-Whitepaper-Machine-Learning.pdf.
[7] Bazrafshan, Z., Hashemi, H., Fard, S. M. H., & Hamzeh, A. (2013),” A survey on heuristic malware detection techniques.”
[8] “Malware and Malware Detection Techniques: A Survey”, Jyoti Landage, Prof. M. P. Wankhade Professor, International Journal of Engineering Research & Technology (IJERT) Vol. 2 Issue 12, December - 2013
[9] Mahmoud Kalash, Mrigank Rochan, Noman Mohammed, Neil D. B. Bruce, Yang Wang, Farkhund Iqbal, “Malware Classification with Deep Convolutional Neural Networks”, -IEEE.
[10] S. Gupta, P. Bansal, and S. Kumar, "ULBP-RF: A Hybrid Approach for Malware Image Classification," 2018 Fifth International Conference on Parallel, Distributed and Grid Computing (PDGC), Solan Himachal Pradesh, India, 2018, pp. 115-119, doi: 10.1109/PDGC.2018.8745989.
[11] Qublai K. Ali Mirza, Fatima Hussain, Irfan Awan, Muhammad Younas, Salah Sharieh, "Taxonomy-Based Intelligent Malware Detection Framework", Global Communications Conference (GLOBECOM) 2019 IEEE, pp. 1-6, 2019.
[12]Ahmad Azab, Mahmoud Khasawneh, "MSIC: Malware Spectrogram Image Classification", Access IEEE, vol. 8, pp. 102007-102021, 2020.

A Novel Temporal-spatial Interpolation Method for Spatio-temporal Air Quality Forecasting

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***Abstract*—The air pollution problem has become a critical issue worldwide due to its severe harmful impact on human health. Among all the pollutants, particulate matter particles are small enough to enter the lungs quickly and affecting the human body's respiratory system badly. Nowadays, air quality modeling has become an important research area to take supporting preventive action against the rising pollution level. However, air quality monitoring at every part of an area has been a complicated issue due to unstructured pollution monitoring sites. Much research has been conducted to predict air quality levels for pollution monitoring sites only, not for every part of a particular location, which is not useful for real-world scenarios. Therefore, this work proposes the CNN-GRU-RBF model based on the neural network approach, which considers both time and spatial features to solve this type of temporal-spatial interpolation issues of pollution prediction. The Convolutional Gated Recurrent Unit (CNN-GRU) is employed for feature learning and long-term temporal air quality modeling. Each site's time series prediction results are implemented as input for Radial Basis Function (RBF) spatial prediction layer to interpolate those time series prediction results, ultimately producing a better temporal-spatial interpolation map the study area. The proposed model shows its effectiveness during Spatio-temporal air quality prediction.**

***Index Terms*—Air quality, Spatio-temporal prediction, GRU, RBF**

I. Introduction

Ambient air pollution is one of the critical concerns for both developing and developed countries all over the world [1]. The increasing level of population growth and traffic congestion is the primary reason behind this critical issue. The deterioration of ambient air quality has a high negative impact on human health [2]. According to a few research studies, particulate matter pollutant is easy to inhale by causing a severe threat to the human body. According to the world health organization (WHO) report, the number of deaths is more than two million per annum in developing countries. Milion of fatalities occurs due to heart diseases, strokes, lung cancer, chronic respiratory problems, and many more related diseases. Many research analysis reveals the positive correlation among lung cancer, cardiovascular mortality with particulate matter concentration. Several research studies have noticed that ambient air quality levels in most cities do not meet the WHO guidelines for acceptable air quality. People of these cities have increased severe health risks related to the ambient air pollution level. The produced experimental results and analysis suggested a few public policies to control and mitigate ambient air pollution concentration.

Therefore, improving ambient air quality is one of the crucial steps in smart cities worldwide. Primarily, it will improve the poor health condition and also helps to gain economic growth significantly. In recent years, much research was conducted to perform air quality modeling to manage air quality in urban areas. Air quality modeling's primary goal is to predict the ambient air pollution level. Ultimately, it is used to ensure that the impact of air pollution levels on the human body should be minimal in the future.

Ambient air pollution concentration is not uniform in city areas, having a high value at smart cities, industrial estate, and traffic-congested roads. Its frequency varies over space and time due to several factors like meteorological variables and traffic. In various cities, many countries have developed air pollution monitoring sites. The number of monitoring stations in a town is not substantial due to the high cost of building monitoring sites. Therefore, air quality data should be perceived accurately before developing any air quality management system. Learning both spatial and temporal features gives better prediction results than training time and space dimensions separately. It arises the need of developing an efficient Spatio-temporal air pollution forecasting models.

There have been employed several Spatio-temporal air pollution forecasting models; still, the prediction results are not so accurate because most of the models predict air pollution levels for the existing monitoring sites only. Limited studies have conducted to predict air pollution level without monitoring stations, which arises missing values in space during Spatio-temporal air quality modeling. This is often called as temporal-spatial interpolation [3] issues of air quality predictions. It has observed that most of the traditional prediction models only focus on attributing the time series missing values, not missing values in space. These issues can be resolved by applying deep learning techniques by improving air pollution prediction results.

To overcome this problem, this research study works on both missing attributes in time series and space for a better air quality prediction results. This research paper employed deep learning and machine learning-based temporal-spatial interpolation methods to impute the missing value for a better Spatio-temporal forecasting model. This paper combines the

CNN layer [4] with GRU unit [5] to perform better temporal, spatial feature learning and time series modeling of pollutant value. The model then added an RBF interpolation layer, which imputes the missing values in space to perform spatial interpolation of data. Particulate matter PM_{10} is considered for the model evaluation purposes due to its severe negative impact on public health.

II. Related work

Time series based air quality modeling is a broad area in environmental research. Different types of statistical [6], machine learning, and deep learning research have been conducted based on temporal variations of air quality data. The statistical model includes an Autoregressive Moving Average (ARIMA) [7], Seasonal ARIMA (SARIMA) [8], Prophet [8] and the machine learning model comprises Decision Tree, Support Vector Machine (SVM) [9], Artificial Neural Network (ANN) [10], Adaptive Neuro-fuzzy Inference Systems (ANFIS) models, Multi-layer Perceptron, Principle Component Analysis (PCA) [11], Xgboost and Random Forest (RF) [12]. These models can provide better air quality prediction performance than traditional numerical air quality models. However, these models fail to handle the long term dependencies of the large historical dataset.

With the rapid development of artificial intelligence techniques, the concept of deep learning, an advanced variety of machine learning techniques evolved. These models are capable enough to train a large amount of input data for air quality modeling such as a Recurrent Neural Network (RNN) [13], Long Short Term Memory Network (LSTM) [14]–[17], Gated Recurrent Unit (GRU), Elman Neural Network, Temporal Convolutional Network (TCN) [18] and Time Delay Neural Network (TDNN). However, these shallow models consider either temporal features or spatial features at a time for air quality predictions. This research gap extends the further research study to develop a deep learning-based Spatio-temporal air pollution prediction model that can efficiently extract and learn both spatial and temporal features to improve prediction accuracy. Very few research was conducted to develop Spatio-temporal forecasting model [19] like Graph Convolutional Neural Network Long Short-Term Memory (GC-LSTM) [20], CNN-BILSTM [21] and Geo-LSTM [22]. Few of the spatial-temporal forecasting model uses satellite data as a source type to get better quality of prediction results. However, these models do not predict air pollution levels for each point in space, causing missing values in air pollution prediction results of a particular location. So, these models fail to predict the pollutant level where no monitoring stations are available. To remove these significant restrictions of air quality prediction, this research paper proposes a novel neural network-based temporal-spatial interpolation method that imputes the missing values in space and yields better Spatio-temporal prediction values.

Following the introduction, the rest of this research paper is organized as follows: Section 2 reviewed some existing related research work, and Section 3 describes the experimental study area of this work. Section 4 presents the proposed model architecture, named as CNN-GRU-RBF. Results and discussions are represented in Section 5, and the conclusion of the research is drawn in Section 6.

III. Study area

The study of this research paper is carried out at Odisha, an eastern part of Indian country. The state shares its boundaries with West Bengal, Chhattisgarh Jharkhand, and Andhra Pradesh spread over an area of 155,707 km^2. The state is blessed with several mineral reserves like coal, iron ore and chromite. This state is recorded as the second highest reserve of coal in the country [23]. Odisha is witnessed as the most top coal producer in the country. As per the environmental research report, coal extraction causes a severe negative impact on the human body due to the particulate matter generation during coal extraction. The neighborhood of coal mining areas witnesses a high concentration of air pollution. The coal mining process releases several toxic pollutants that adversely affect nearby locations. Traffic emission [24] air pollution is another primary source of toxic pollutants in Odisha. As per the National Clean Air Programme, Odisha has 6 six non-attainment cities that do not meet the air quality standard decided by Central Pollution Control Board. Therefore there is a requirement to analyze and predict the air quality level in Odisha so that necessary steps can be taken in advance against this critical situation. So Odisha is considered as the experiment location to perform temporal, spatial analysis [25] of air quality.

The primary data source considered for this study that comes from Odisha State Pollution Control Board [26], [27], having pollutant value for the duration 2004-2015. The experiments for this study are carried out over 16 air pollution monitoring stations of Odisha, having the most hazardous particle pollutant PM_{10} (μg/m^3) concentration value and its geographical attributes.

IV. Proposed Method

A. Data preprocessing

The long term air quality data often face data missing issues due to sensor shutdown or some unusual activity. The missing attributes need to be replaced. It is necessary to have a pollutant concentration value for each day to analyze the time-varying air quality data. The proper analysis is conducted to find adequate interpolation techniques to impute those missing values for time series analysis. It is observed from the experimental study that linear interpolation provides better results than the other nonlinear interpolation methods. Therefore, this interpolation technique is employed to handle those missing values in the preprocessing step. It can be formulated as below [28],

$$\hat{x}(t) = \frac{x_{i+1} - x_i}{t_{i+1} - t_i}(t - t_i) + x_i \tag{1}$$

where $\hat{x}(t)$ is the linear interpolation function over time $t_{i+1} - t_i$.

Before performing the temporal and spatial analysis of the dataset, unnecessary outliers are removed and standardized using Z-Score normalization. The Z-score normalization can be formulated as below,

$$Z - Score_m = \frac{\sum_{m=1}^{n} p_m - \widehat{x}}{S} \tag{2}$$

where p_m presented the pollutant concentration value, $\widehat{x}$ and S represent mean and standard deviation respectively. In the process of training the model, 90 % of the dataset is utilized for training, 10 % for testing purposes. The proposed model has three stages, i.e., feature extraction layer (CNN layer), temporal analysis layer (GRU layer), and spatial analysis layer (RBF interpolation layer), as represented in Figure 1.

The detailed description of each step of the proposed architecture is presented in the following sections.

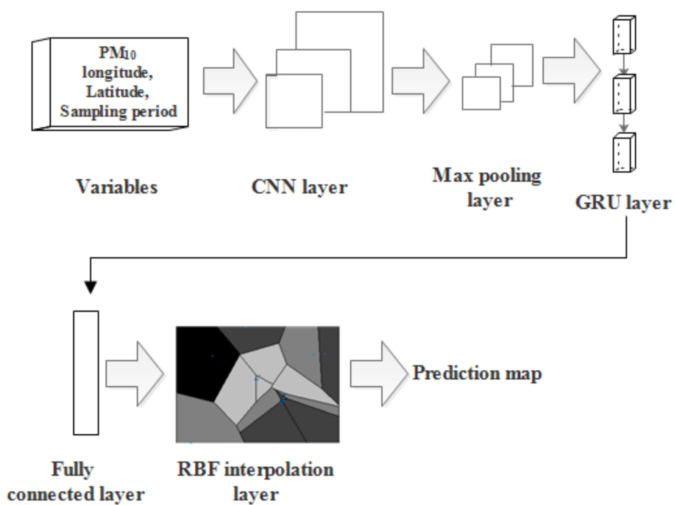

Fig. 1. The proposed model architecture

B. Convolutional neural network for feature learning

The normalized air quality dataset is utilized as the input for the Convolutional Neural Network (CNN) [29]. The CNN network has widely implemented image processing and computer vision applications, but we can use one-dimensional CNN for sequential modeling applications. The max-pooling operation of CNN reduces the dimensionality of the network and increases the model's speed and computational performance. Sparse connectivity and weight sharing are the key features of 1D CNN.

C. Long term time series modeling layer

In the case of a time series pollution dataset, as we need to deal with the longer sequential dataset, selective read, write and forget strategy should be followed to fetch the useful information only. Traditional Recurrent Neural Network architecture is not efficient enough to handle long term dependency and also suffer from vanishing gradient or exploding gradient issue in a sequence model. To handle this type of situation, GRU has applied to the output of the CNN layer, which overcomes the vanishing gradient issues, as well as analyzes the long term dependency in the air pollution dataset. It is simpler than Long Short Term Memory Neural Network (LSTM) and easy to implement. GRU is having reset gate and update gate where update gate works similar to the input gate and forget gate of LSTM model. GRU can be represented as [30],

$$\begin{aligned}
&z = \sigma(W_Z x_t + U_z h_{t-1} + b_z) \\
&r = \sigma(W_r x_t + U_r h_{t-1} + b_z) \\
&m = \phi(W_m x_t + U_m(h_{t-1} \circ r) + b_m) \\
&h_t = (1 - z)h_{t-1} + z \circ m
\end{aligned} \tag{3}$$

where, sigmoid function σ is used as activation function, x_t is used as the input at current time t, h_{t-1} is the past data at time $t-1$. (W_Z, U_z), (W_r, U_r), (W_m, U_m) are the weight parameters for update gate z, reset gate z and cell memory respectively. It combined the feature of the input gate and forgot the gate to form an update gate to make it simpler than LSTM. Update gate decides how much information should keep around and what to through away, while the reset gate decides the amount of information need to forget. The output of the GRU layer gives the prediction value of PM_{10} for each existing monitoring stations for the next 28 days (1-28 December 2015). Two-layer of GRU is used with 200 batch size, 1e-3 learning rate, 675 iterations, and 0.2 dropout value. It utilized Adam as an optimizer and Mean Square Error (MSE) as a loss function during the training process of the CNN-GRU model. The basic structure of GRU model is represented in Figure 2.

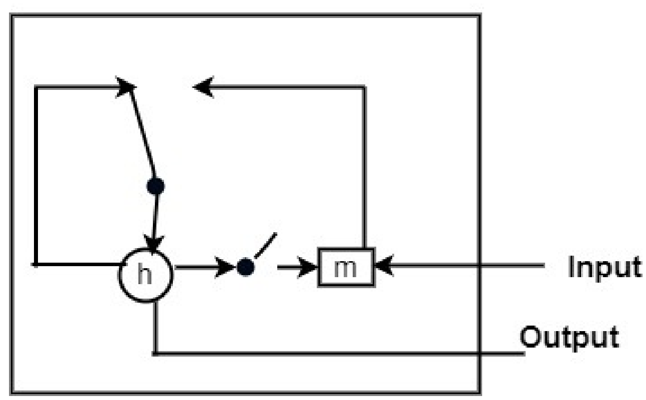

Fig. 2. Basic structure of GRU

D. Spatial interpolation layer

All the existing time series prediction models predict the pollution level at existing monitoring sites only. So it becomes challenging to perform air quality monitoring at unmeasured points [31]. It is also tough and cost-effective to construct monitoring sites in each part of a location. So it is essential to predict the spatial distribution of ambient air quality. To address this issue, we applied the RBF interpolation layer at the end of the CNN-GRU time series prediction layer so that it can predict PM_{10} value at each corner of the study area at each time instance. Radial basis function (RBF) [32] interpolation has been used in many applications; it has a vital role in handling missing attributes in the geospatial dataset. To handle large computational tasks and to model complicated surfaces, it has shown its efficiency in many applications. This model is a series of exact interpolation techniques, having five basis kernel function, i.e., thin plate spline, spline with tension, completely regularized spline, multiquadric function, and inverse multiquadric function [33]. This is a function to compute the distance from each location in d-dimensional space. Unlike the inverse distance weighting technique, it is able to predict above the maximum of observed values and also below the minimum of the observed value. It can be utilized to generate a smooth surface from a large amount of dataset and can be computed mathematically as the weighted average of the data point value. It is basically based on the distance computation between two locations in d-dimensional space and can be represented by $f(x_0)$ function as below,

$$f(x_0) = \sum_{i=1}^{N} \lambda_i \varphi(\|x_0 - x_i\|) \tag{4}$$

where λ_i is the weight parameter, N represents the number of sampling point, φ represents a radial basis function, $(\|x_0 - x_i\|)$ represents the radial basis distance between the unknown point for which the new x_0 value is calculated and the measured point having known value x_i [34].

V. Results and Discussions

After training the CNN-GRU deep learning model, prediction value of PM_{10} for each spatial feature is obtained. The temporal modeling results show the prediction results for each monitoring station of the study area for the next 28 days, i.e., for December 2015. However, still, the prediction data are missing at the unmeasured points. Hence, the current paper performs both temporal modeling and spatial modeling to overcome this type of critical issues. Therefore, the RBF interpolation layer added at the top of the CNN-GRU model. The final results predict the PM_{10} concentration in the study area and for each geographical point where monitoring stations are not available and generate a temporal-spatial interpolation prediction map of the study area.

Figure 3-6 shows the prediction result of average PM_{10} value for every week in December 2015 in the study area. It can be seen from the weekly predicted map that the fourth week of December 2015 has more pollution levels than the other week, where the color scale indicates PM_{10} concentration level over the layer. A web Application is developed to display temporal-spatial interpolation map as shown in Figure 7.

The proposed CNN-GRU performance in temporal modeling is compared with the other state of the art neural network models like the GRU, LSTM and CNN-LSTM model, as shown in Table I. Root Mean Square Error (RMSE), Mean Absolute Error (MAE), and Mean Absolute Percentage Error are utilized as error metrics to compare CNN-GRU's prediction performance in temporal modeling.

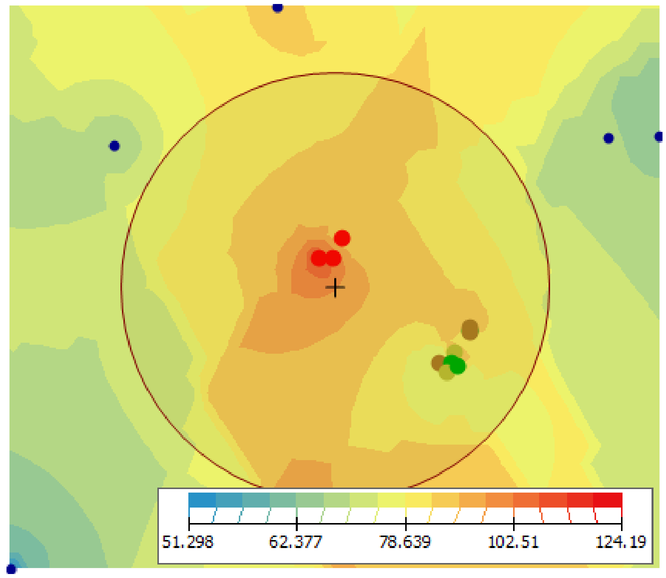

Fig. 3. Average predicted PM_{10} ($\mu g/m^3$) concentration distribution for first week of December 2015.

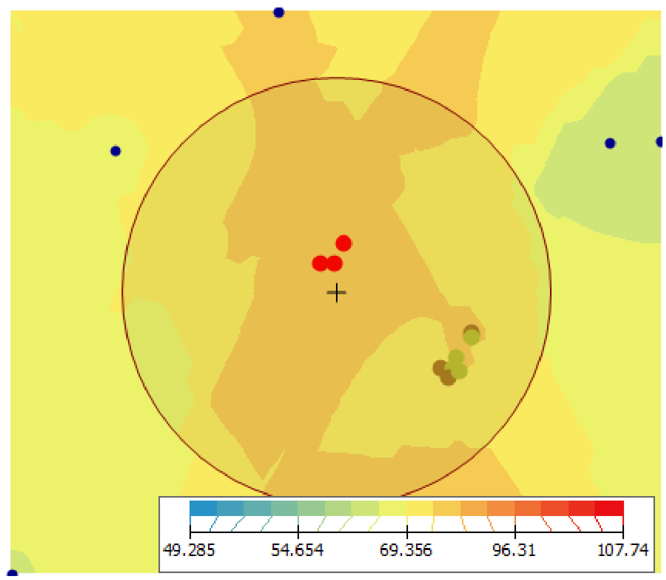

Fig. 4. Average predicted PM_{10} ($\mu g/m^3$) concentration distribution for second week of December 2015.

Table I shows that the CNN-GRU is a better performing prediction model due to lower RMSE, MAE, and MAPE values.

To verify the interpolation efficiency of the CNN-GRU-RBF model, Exponential Kriging (EK) [35], Universal Kriging (UK), Inverse Distance Weighting (IDW) [36] and Spherical Kriging (SK) models' interpolation performance conducted using CNN-GRU time-series prediction results for a fair comparison. Root Mean Square Error (RMSE) and Mean Error (ME) error metrics are utilized to evaluate the proposed

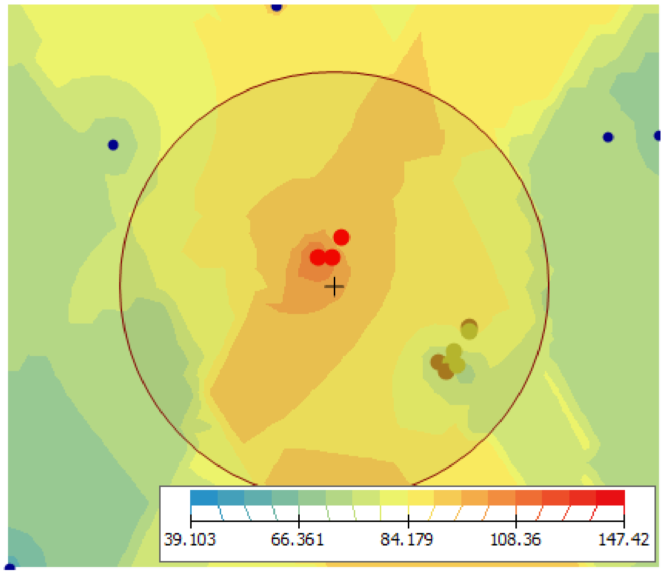

Fig. 5. Average predicted PM_{10} ($\mu g/m^3$) concentration distribution for third week of December 2015.

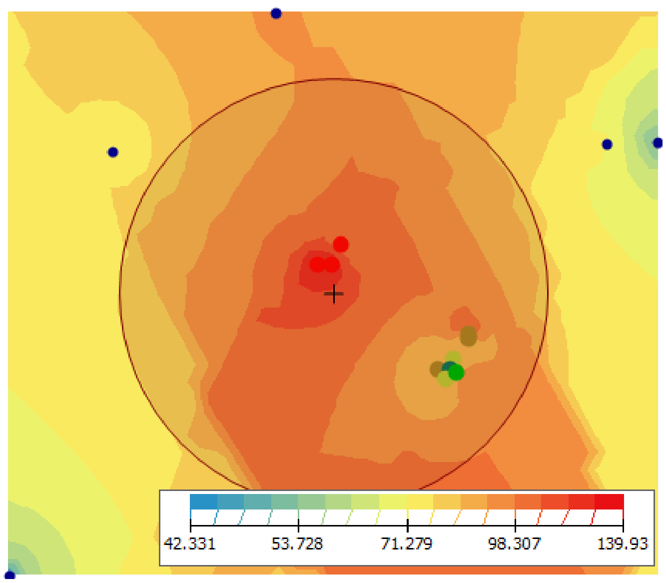

Fig. 6. Average predicted PM_{10} ($\mu g/m^3$) concentration distribution for fourth week of December 2015.

model's interpolation performance. The comparative analysis of these models is represented in Table II.

As shown in Table II, CNN-GRU-EK, CNN-GRU-UK, CNN-GRU-SK, CNN-GRU-IDW have higher RMSE and ME value as compared to the proposed model. In contrast, CNN-GRU-EK and the CNN-GRU-UK have similar performance. Furthermore, CNN-GRU-IDW performed well than the CNN-GRU-EK and CNN-GRU-UK methods. More significantly, the proposed model has superior performance in generating temporal-spatial interpolation maps as compared to other existing models. The key contribution of this research work can be summarized as follows,

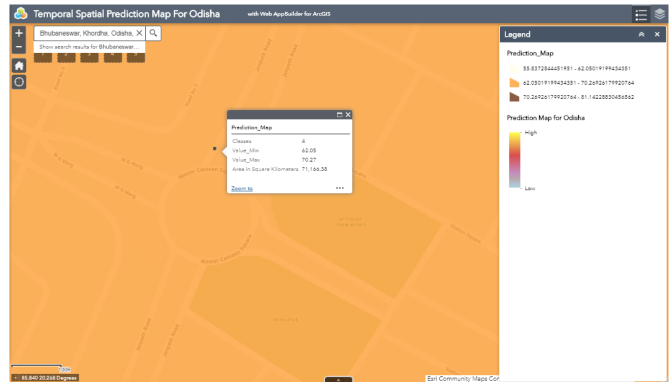

Fig. 7. Web Application

TABLE I
TIME SERIES PREDICTION PERFORMANCE COMPARISON OVER THE 28 DAYS

Model	RMSE	MAE	MAPE
GRU	56.43	46.43	38.48
CNN-LSTM	71.55	59.80	47.62
LSTM	57.24	49.16	37.51
CNN-GRU	53.40	40.03	31.30

- This is the first research experiment that integrated studies of deep learning techniques and machine learning-based interpolation techniques to solve the temporal-spatial interpolation issue of Spatio-temporal air quality modeling.
- The Traditional spatial prediction model imputes the missing values in the historical time series dataset. However, the proposed temporal-spatial interpolation model imputes the missing value both in the time domain and spatial domain to predict the pollutant concentration more accurately in advance at high temporal granularity.
- The CNN-GRU-RBF model can predict the long term exposure of PM_{10} concentration at each geographical point in the study area.

VI. CONCLUSION

In this work, spatial-temporal prediction experiments have conducted using the proposed CNN-GRU-RBF model. The CNN-GRU-RBF model utilizes both the neural network and the geostatistical concept to solve the temporal-spatial interpolation issues of the unmeasured point. The performance of the CNN-GRU-RBF model is investigated against the existing prediction models. The results show that the CNN-GRU-RBF model can solve the temporal-spatial interpolation issues

TABLE II
INTERPOLATION PERFORMANCE COMPARISON OVER THE 28 DAYS

Model	RMSE	ME
CNN-GRU-EK	25.60	4.05
CNN-GRU-UK	25.60	4.05
CNN-GRU-IDW	24.07	6.76
CNN-GRU-SK	23.67	4.00
CNN-GRU-RBF	22.30	2.86

more accurately than others. As compared to other models, the proposed method improves the prediction performance more significantly due to both temporal and spatial modeling abilities.

Due to the data unavailability, only PM_{10} concentration values are used for the period 2004-2015. The performance can be improved in the future by considering the correlation of pollution with the other affecting variables like traffic and meteorological factors.

VII. Acknowledgment

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References

[1] K Krishna Rani Samal, Korra Sathya Babu, and Santos Kumar Das. Ors: The optimal routing solution for smart city users. In *Electronic Systems and Intelligent Computing*, pages 177–186. Springer, 2020.

[2] Ying Chen, Oliver Wild, Luke Conibear, Liang Ran, Jianjun He, Lina Wang, and Yu Wang. Local characteristics of and exposure to fine particulate matter (pm2. 5) in four indian megacities. *Atmospheric Environment: X*, 5:100052, 2020.

[3] Mathieu Lepot, Jean-Baptiste Aubin, and François HLR Clemens. Interpolation in time series: An introductive overview of existing methods, their performance criteria and uncertainty assessment. *Water*, 9(10):796, 2017.

[4] Haofei Xie, Lin Ji, Quan Wang, and Zhejian Jia. Research of pm2. 5 prediction system based on cnns-gru in wuxi urban area. In *IOP Conference Series: Earth and Environmental Science*, volume 300, page 032073. IOP Publishing, 2019.

[5] Xinxing Zhou, Jianjun Xu, Ping Zeng, and Xiankai Meng. Air pollutant concentration prediction based on gru method. In *Journal of Physics: Conference Series*, volume 1168, page 032058. IOP Publishing, 2019.

[6] A Alimissis, K Philippopoulos, CG Tzanis, and D Deligiorgi. Spatial estimation of urban air pollution with the use of artificial neural network models. *Atmospheric environment*, 191:205–213, 2018.

[7] Shalini Jain and VL Mandowara. Study on particulate matter pollution in jaipur city. *International Journal of Applied Engineering Research*, 14(3):637–645, 2019.

[8] K Samal, Korra Sathya Babu, Santosh Kumar Das, and Abhirup Acharaya. Time series based air pollution forecasting using sarima and prophet model. In *Proceedings of the 2019 International Conference on Information Technology and Computer Communications*, pages 80–85. ACM, 2019.

[9] Nam-Uk Lee, Jae-Sung Shim, Yong-Wan Ju, and Seok-Cheon Park. Design and implementation of the sarima–svm time series analysis algorithm for the improvement of atmospheric environment forecast accuracy. *Soft Computing*, 22(13):4275–4281, 2018.

[10] Khaled Bashir Shaban, Abdullah Kadri, and Eman Rezk. Urban air pollution monitoring system with forecasting models. *IEEE Sensors Journal*, 16(8):2598–2606, 2016.

[11] Anikender Kumar and Pramila Goyal. Forecasting of air quality in delhi using principal component regression technique. *Atmospheric Pollution Research*, 2(4):436–444, 2011.

[12] Min Zhu, Jing Xia, Xiaoqing Jin, Molei Yan, Guolong Cai, Jing Yan, and Gangmin Ning. Class weights random forest algorithm for processing class imbalanced medical data. *IEEE Access*, 6:4641–4652, 2018.

[13] Hongqian Qin. Comparison of deep learning models on time series forecasting: a case study of dissolved oxygen prediction. *arXiv preprint arXiv:1911.08414*, 2019.

[14] K Krishna Rani Samal, Korra Sathya Babu, Ankit Kumar Panda, and Santos Kumar Das. Data driven multivariate air quality forecasting using dynamic fine tuning autoencoder layer. In *2020 IEEE 17th India Council International Conference (INDICON)*, pages 1–6. IEEE, 2020.

[15] K Krishna Rani Samal, Korra Sathya Babu, Abhirup Acharya, and Santos Kumar Das. Long term forecasting of ambient air quality using deep learning approach. In *2020 IEEE 17th India Council International Conference (INDICON)*, pages 1–6. IEEE, 2020.

[16] K. K. R. Samal, K. S. Babu, and S. Das. Spatio-temporal prediction of air quality using distance based interpolation and deep learning techniques. 2021.

[17] K Krishna Rani Samal, Ankit Kumar Panda, Korra Sathya Babu, and Santos Kumar Das. An improved pollution forecasting model with meteorological impact using multiple imputation and fine-tuning approach. *Sustainable Cities and Society*, page 102923, 2021.

[18] K Krishna Rani Samal, Korra Sathya Babu, and Santos Kumar Das. Multi-directional temporal convolutional artificial neural network for pm2. 5 forecasting with missing values: A deep learning approach. *Urban Climate*, 36:100800, 2021.

[19] Reza Asadi and Amelia Regan. A spatial-temporal decomposition based deep neural network for time series forecasting. *arXiv preprint arXiv:1902.00636*, 2019.

[20] Yanlin Qi, Qi Li, Hamed Karimian, and Di Liu. A hybrid model for spatiotemporal forecasting of pm2. 5 based on graph convolutional neural network and long short-term memory. *Science of the Total Environment*, 664:1–10, 2019.

[21] Shengdong Du, Tianrui Li, Yan Yang, and Shi-Jinn Horng. Deep air quality forecasting using hybrid deep learning framework. *arXiv preprint arXiv:1812.04783*, 2018.

[22] Jun Ma, Yuexiong Ding, Jack CP Cheng, Feifeng Jiang, and Zhiwei Wan. A temporal-spatial interpolation and extrapolation method based on geographic long short-term memory neural network for pm2. 5. *Journal of Cleaner Production*, 237:117729, 2019.

[23] Tapaswini Nayak and Indrani Roy Chowdhury. Health damages from air pollution: Evidence from open cast coal mining region of odisha, india. *Ecology*, 1(1):42–66, 2018.

[24] Anu Rani Sharma, Shailesh Kumar Kharol, and KVS Badarinath. Influence of vehicular traffic on urban air quality–a case study of hyderabad, india. *Transportation Research Part D: Transport and Environment*, 15(3):154–159, 2010.

[25] Jannah Baker, Nicole White, and Kerrie Mengersen. Missing in space: an evaluation of imputation methods for missing data in spatial analysis of risk factors for type ii diabetes. *International journal of health geographics*, 13(1):47, 2014.

[26] OpenGovermentDataPlatformIndia. Ambient air quality data of odisha, 2017, Oct 16.

[27] CentralPollutionControlBoard. Air pollution, 2018, Jan 6.

[28] Albrecht Gnauck. Interpolation and approximation of water quality time series and process identification. *Analytical and bioanalytical chemistry*, 380(3):484–492, 2004.

[29] Bendong Zhao, Huanzhang Lu, Shangfeng Chen, Junliang Liu, and Dongya Wu. Convolutional neural networks for time series classification. *Journal of Systems Engineering and Electronics*, 28(1):162–169, 2017.

[30] Jaehyun Ahn, Dongil Shin, Kyuho Kim, and Jihoon Yang. Indoor air quality analysis using deep learning with sensor data. *Sensors*, 17(11):2476, 2017.

[31] Phuong T Vu, Timothy V Larson, and Adam A Szpiro. Probabilistic predictive principal component analysis for spatially misaligned and high-dimensional air pollution data with missing observations. *Environmetrics*, page e2614, 2019.

[32] Vaclav Skala. Rbf interpolation with csrbf of large data sets. *Procedia Computer Science*, 108:2433–2437, 2017.

[33] Pengwei Qiao, Peizhong Li, Yanjun Cheng, Wenxia Wei, Sucai Yang, Mei Lei, and Tongbin Chen. Comparison of common spatial interpolation methods for analyzing pollutant spatial distributions at contaminated sites. *Environmental geochemistry and health*, pages 1–22, 2019.

[34] Maxim Arseni, Mirela Voiculescu, Lucian Puiu Georgescu, Catalina Iticescu, and Adrian Rosu. Testing different interpolation methods based on single beam echosounder river surveying. case study: Siret river. *ISPRS International Journal of Geo-Information*, 8(11):507, 2019.

[35] SB Choi, Geneveve Parreno, Kyu Kon Kim, and CW Kang. A study on imputation for missing data using the kriging. *Journal of the Korean Data Analysis Society*, 17(6):2857–2866, 2015.

[36] Mohammed M Shareef, Tahir Husain, and Badr Alharbi. Optimization of air quality monitoring network using gis based interpolation techniques. *Journal of Environmental Protection*, 7(6):895–911, 2016.

Electricity Theft Detection using Deep Learning and IoT

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***Abstract*—Electricity is an inevitable factor in our day-to-day life. Electricity plays a key role in expediting the socio-economic growth of the country. With the increase in the usage of electricity, we are witnessing a hike in electricity theft. Electricity theft results in wastage of huge amounts of energy and revenue due to which the customers have to pay excessive electricity bills, for the poor power supply they receive. Here we are introducing a novel hybrid CNN-XGBoost model for electricity theft detection, which outperforms the existing systems. In addition to this, our system is capable of locating the area of theft along with warning the concerned users. Here Convolutional Neural Network(CNN) is used to automatically extract the features from the input smart meter data, which consists of the electricity consumption pattern of residential and non-residential users on a half-hourly basis. XGBoost is used as a classifier that distinguishes between fraudulent and normal users. An IoT(Internet Of Things) system is implemented to locate and send warning signals to fraudulent users. Using Ubidots we can create real-time dashboards to analyze data, locate and control devices.**

***Index Terms*—CNN, XGBoost, IoT, Arduino, Ubidots**

I. Introduction

Electricity plays a vital role in our society. It acts as a pillar for economic development. Unethical usage of electricity is increasing in our daily lives. Electricity theft is the act of stealing electricity through meter tampering, meter hacking, illegal tapping, etc. Power losses due to electricity theft are mainly classified into technical and non-technical losses. Technical losses are the losses that occur within the distribution network during the transmission of electricity, due to the cables, overhead lines, and transformers. Non-technical losses occur due to unidentified, misallocated, or inaccurate energy flows, bypassing the electricity meter, or hacking the meter. Electricity theft comes under the category of non-technical losses. Therefore non-technical losses create a hindrance to power sectors all over the world. The world is losing around 89.3 billion US dollars due to electricity theft. The highest contributors to these losses are from India(16.2 billion USD) followed by Brazil(10.5 billion USD) and Russia(5.1 billion USD). Besides, electricity theft carries deadly risks. It is not just dangerous for those who steal but a menace to public safety. Awareness about the conduct of electricity theft in our society is generally low, so early detection of electricity theft assures public safety.

A better understanding of the existing system helps us to give a clear-cut idea of power theft detection. Latest machine learning algorithms along with k means clustering helps to cluster the data according to fraudulent and normal users. Here Artificial Neural Network (ANN) is used for classification of customer's profile [1], the clustered data is classified using machine learning algorithms like Random Forest [2]. Several Deep Learning methodologies are also used to detect electricity theft in smart meter data. CNN as a feature extractor used along with Lstm follows such an approach [3]. The idea of the Wide and Deep Convolutional Neural Networks (CNN) model is to identify the occurrences of electricity theft based on the consumption patterns of customers. Converting one-dimensional data to two dimensional helps to identify the periodicity and non-periodicity in the data as well as it helps to improve feature extraction. This model combines the power of memorization and generalization brought by both wide component and deep component respectively [4]. CNN-based deep learning method for identifying consumer socio-demographic information. CNN automatically extracts features from smart meter data. [5], CNN along with Random Forest approach is used, which is an ensemble technique used for classification [6]. Locating the non-technical loss using A - star algorithm is used in [7]. Unsupervised learning like Mean shift clustering along with convolutional neural network is used in [8]. Electricity theft can be detected and located with the help of IoT. Multiple transformers placed at specific distances help the authorities in identifying the exact location of the theft. [9] [10].

In this paper, we design a novel CNN-XGBoost model for effective electricity theft detection using smart meter data along with an IoT system intended to locate areas of theft and warn the concerned users.

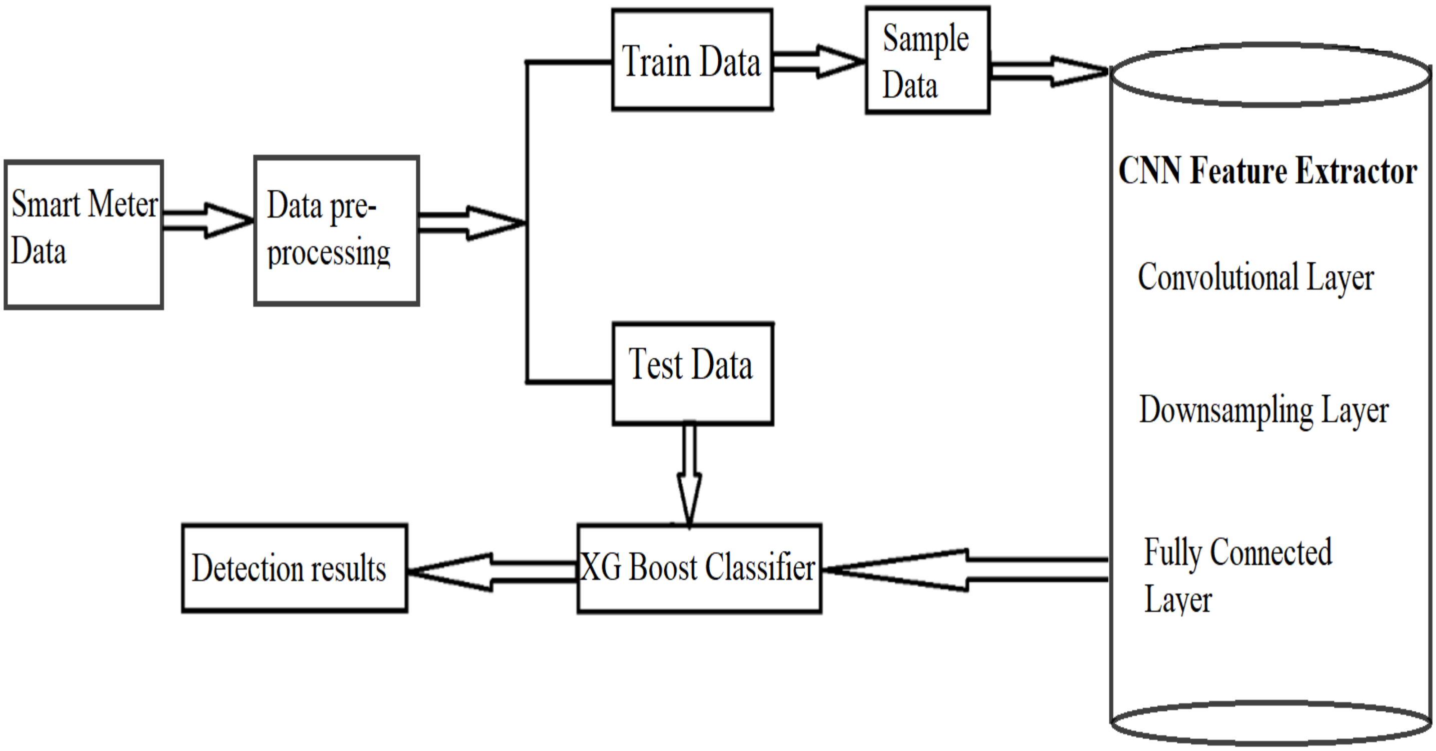

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Fig. 1. ARCHITECTURE

II. PROPOSED SYSTEM

Our proposed system is capable of detecting and locating the areas of electricity theft and alert the users of the same. Smart meter data is given as input to our system, which consists of the electricity usage data of the customers. The dataset was collected from the Sustainable Energy Authority of Ireland (SEAI) in January 2012. It consists of customer's electricity usage data from over 6000 residential and non-residential users. This dataset contains the half-hourly records of the electricity consumption of customers. Since the dataset was created for research purposes, it mostly contained honest users. Hence we added 1200 malicious customers as described in [11].

Exploratory Data Analysis is performed to understand the varying load profiles. This dataset contains a certain amount of erroneous values, which leads to changes in consumption patterns. Missing values arise in the dataset due to various reasons such as smart meter failure, storage issues, etc. The interpolation method is used to recover the missing values. Normalization is done to change the values into a common scale. Min-max scaling is used to rescale the values to a range from 0 to 1. Data pre-processing is an essential step as it improves the efficiency of the proposed model.

Generation of train test data is needed to evaluate the performance of the model. Dataset is divided into two parts train and test in the ratio 70:30. Train data is used to train the model so that the model will learn the features that are required for predicting. Test data is used to evaluate the model by measuring its accuracy based on actual and predicted values. The data needs to be sampled to maintain the ratio between majority and minority carriers. SMOTE methodology is used for sampling the dataset.

CNN is used as an automatic feature extractor. Different layers of CNN are represented in Fig. 2. CNN consists of a convolutional layer, downsampling layer, and fully connected layer. The main purpose of the convolutional layer is to learn the feature map. It is performed by sliding the kernel over the entire input. Different filters are utilized to perform multiple convolutions to produce distinct feature maps. The pooling layer reduces the number of dimensions and spatial size of the activation map. It helps to control overfitting in networks. Max pooling is the pooling operation conducted here. We get a summarized version of the features detected in the input. Small changes are not addressed but retain the important contents. Fully connected layers are applied for flattening feature maps into one vector. An activation function is to add non-linearity to the model. Without activation function, our neural network will not be able to learn. ReLu activation function is commonly used for hidden layers of a neural network because it is differentiable and efficient for backpropagation.

The features extracted are used as an input to the XGBoost classifier. XGBoost is a decision-tree-based ensemble Machine Learning algorithm that uses a gradient boosting framework. In prediction problems involving unstructured data (images, text, etc.) artificial neural networks tend to outperform all other algorithms or frameworks. However, when it

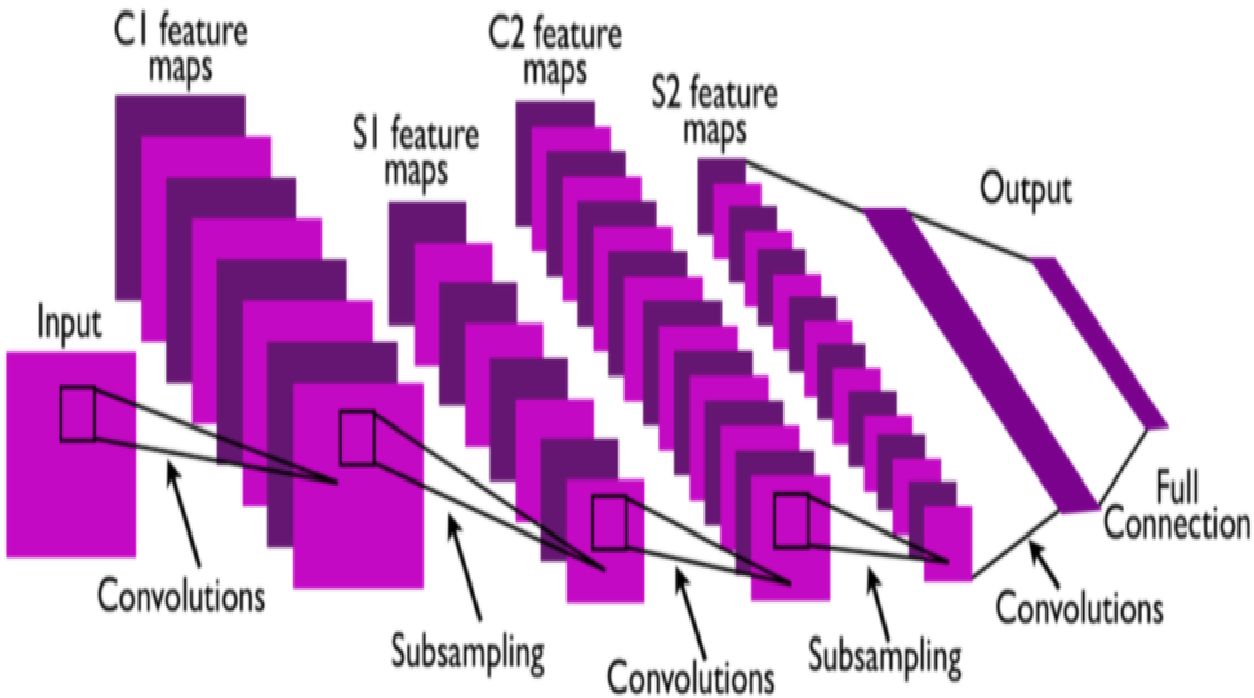

Fig. 2. Convolutional Neural Network (CNN)

comes to small-to-medium structured/tabular data, decision tree-based algorithms are considered best-in-class right now. XGBoost and Gradient Boosting Machines (GBMs) are both ensemble tree methods that apply the principle of boosting weak learners (CARTs generally) using the gradient descent architecture. However, XGBoost improves upon the base GBM framework through systems optimization and algorithmic enhancements.

The Internet Of Things refers to an embedded system with sensors, software, and internet-connected objects that are used to connect and exchange data over a wireless network without human intervention. In an ideal case, the outgoing amount of electricity should be equivalent to the sum of current consumed by users belonging to that particular area. The difference in the outgoing and consumed amount of electricity indicates the chances of occurrence of electricity theft. In practical cases, transmission losses may arise which results in a mismatch of the outgoing and consumed electricity [12]. A threshold value can be calculated by taking the average of differences in outgoing and consumed electricity. The location of power theft can be determined by placing multiple transformers in the load line. The serial number specified in the transformers is used to locate the areas prone to theft.

Electricity consumption data obtained from the smart meters are given to the Arduino UNO to monitor the consumption patterns. In our system, the threshold value will be sent via Arduino Ethernet Shield with an internet connection to the Ubidots IOT Cloud [13]. The Ubidots stores the collected electricity consumption data into the IoT database. Whenever the consumption value exceeds the threshold value, the Ubidots Event manager invokes a notification alert to the end-users.

Fig.3 describes how the Events Manager triggers alerts inside an active event window. Whenever the data (blue line) passes through the Threshold an event is triggered, i.e when the electricity consumption data exceeds the threshold value an alert message is sent to the corresponding users. For the Ubidots to trigger the next event, the data must fall below the threshold again. After an alert is triggered, subsequent values will not be triggered again, even if they comply with the trigger conditions. A second trigger cannot take place unless the data values return below the threshold value and exceed the threshold again.

III. Result

In this paper, electricity theft detection is considered as a binary classification problem, which distinguishes between normal and malicious users. By using CNN - XGBoost model the accuracy increases comparing to other existing models.

An ROC curve (receiver operating characteristic curve) is a graph showing the performance of a classification model at all classification thresholds. This curve plots two parameters:

- True Positive Rate
- False Positive Rate

A ROC curve plots TPR vs. FPR at different classification thresholds. Lowering the classification threshold classifies

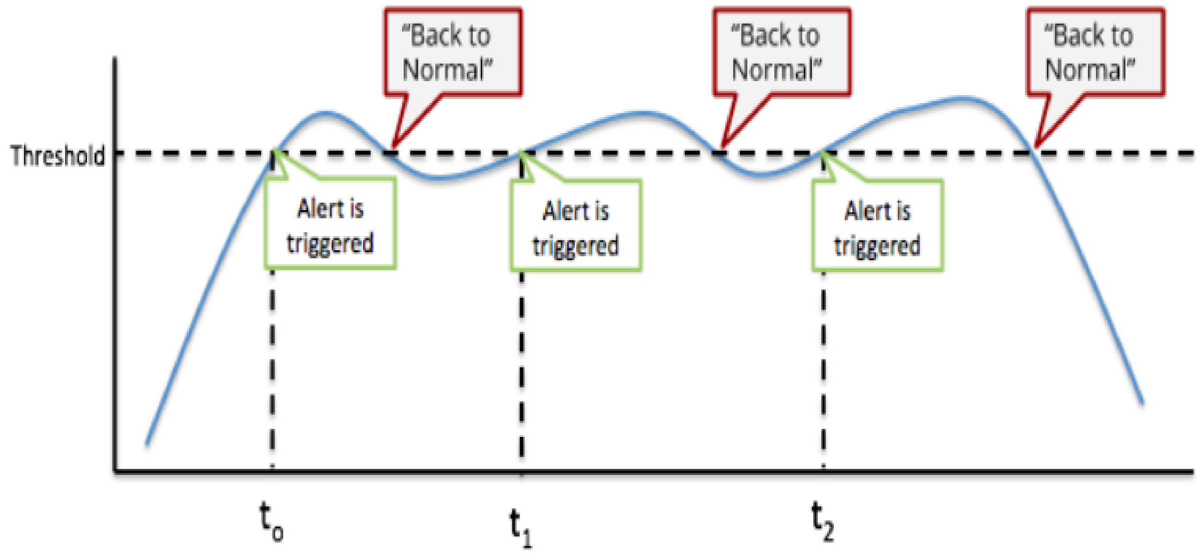

Fig. 3. Ubidot Event Manager

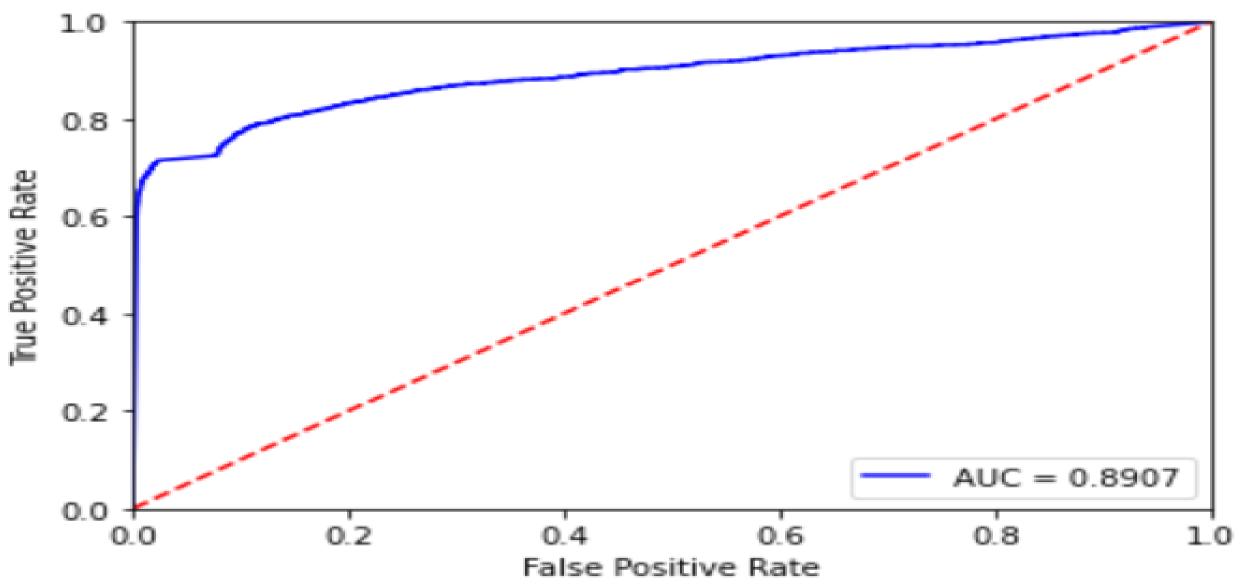

Fig. 4. ROC Curve and AUC

more items as positive, thus increasing both False Positives and True Positives. AUC stands for "Area under the ROC Curve." AUC provides an aggregate measure of performance across all possible classification thresholds. One way of interpreting AUC is the probability that the model ranks a random positive example more highly than a random negative example.

Classifiers that give curves closer to the top-left corner indicate better performance. The higher the AUC, the better the performance of the model at distinguishing between the positive and negative classes. In Fig.4 we observe that the positive (blue) line moves closer to the top left corner with an AUC value of 0.8907, which indicates that the model is having high accuracy.

IV. Conclusion

Here we are using deep learning techniques to detect and locate electricity thefts, overcoming the limitations of the existing theft detecting systems thus providing an efficient solution to tackle the issues caused. We have outlined the design of the proposed project, which aims to identify algorithms and features that can best detect and locate the electricity thefts occurring using the abnormal changes in the consumption pattern of customers from the smart meter. The proposed model is based on the combination of CNN and XGBoost classifier, integrated with an IoT module. Here the CNN is similar to an automatic feature extractor in investigating smart meter data and the XGBoost is the output classifier. The mismatch in the outgoing electricity from the transformer and the consumed electricity by the users is identified and located. Whenever a mismatch is encountered a warning message is sent to the concerned users. The use of the technique proposed here will help the power utilities in detecting theft within a lesser amount of time and with comparatively high accuracy. The use of a hybrid neural network for electricity theft detection is presumed to improve the performance of detection. It can be concluded that this model is capable of effectively detecting power theft, thus reducing the rate of its occurrences.

REFERENCES

[1] J Jeyaranjani and D Devaraj. Machine learning algorithm for efficient power theft detection using smart meter data. International Journal of Engineering Technology, 7(3.34):900–904, 2018.

[2] Rohit Bamane, Mervyn Vinod, Jahnavi Shah, Shweta Ahuja, and Aditya Sahariya. Smart meter for power theft detection using machine learning.

[3] Md Hasan, Rafia Nishat Toma, Abdullah-Al Nahid, MM Islam, Jong-Myon Kim, et al. Electricity theft detection in smart grid systems: a cnn-lstm based approach. Energies, 12(17):3310, 2019.

[4] Zibin Zheng, Yatao Yang, Xiangdong Niu, Hong-Ning Dai, and Yuren Zhou. Wide and deep convolutional neural networks for electricity-theft detection to secure smart grids. IEEE Transactions on Industrial Informatics, 14(4):1606–1615, 2017.

[5] Yi Wang, Qixin Chen, Dahua Gan, Jingwei Yang, Daniel S Kirschen, and Chongqing Kang. Deep learning-based socio-demographic information identification from smart meter data. IEEE Transactions on Smart Grid, 10(3):2593–2602, 2018

[6] Shuan Li, Yinghua Han, Xu Yao, Song Yingchen, Jinkuan Wang, and Qiang Zhao. Electricity theft detection in power grids with deep learning and random forests. Journal of Electrical and Computer Engineering, 2019, 2019.

[7] Jônatas Boás Leite and José Roberto Sanches Mantovani. Detecting and locating nontechnical losses in modern distribution networks. IEEE Transactions on Smart Grid, 9(2):1023–1032, 2016.

[8] G Johncy and A Anisha Felise. An efficient power theft detection using mean-shift clustering and deep learning in smart grid. In IOP Conference Series: Materials Science and Engineering, volume 983, page 012003. IOP Publishing, 2020.

[9] IOT based Power Theft Detection. R Giridhar Balakrishna, P Yogananda Reddy, M L N Vital.. International Journal of Innovations in Engineering and Technology (IJIET) ISSN: 2319-105, Volume 8, Issue 3, June 2017

[10] Ajay Mahato, Abhishek Nanda, Ajay Kumar Pal, Chandan Kumar Singh, ”Electric Power theft detection and location Tracking using IOT”, International Journal of Scientific Research in Computer Science, Engineering and Information Technology (IJSRCSEIT), ISSN : 2456-3307, Volume 4, Issue 5, pp.35-39, March-April-2018.

[11] P. Jokar, N. Arianpoo, and V. C. M. Leung, “Electricity theft detection in AMI using customers’ consumption patterns,” IEEE Transactions on Smart Grid, vol. 7, no. 1, pp. 216–226, 2016

[12] Z. H. Che Soh, I. H. Hamzah, S. A. Che Abdullah, M. A. Shafie, S. N. Sulaiman and K. Daud, ”Energy Consumption Monitoring and Alert System via IoT,” 2019 7th International Conference on Future Internet of Things and Cloud (FiCloud), Istanbul, Turkey, 2019.

[13] H. N. Saha, S. Gon, A. Nayak, S. kundu and S. Moitra, ”Iot-BasedGarbageMonitoring and Clearance Alert System,” 2018 IEEE 9thAnnual Information Technology, Electronics and MobileCommunication Conference (IEMCON), Vancouver, BC, 2018, pp.204-208.

A secured novel classifier for effective classification using Light Gradient Boosting Machine(LightGBM) Algorithm

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Abstract— This paper presents an anomaly detection method based on LightGBM(Gradient Boosting Machine) classification methodology. To improve the privacy and security of the data in the cloud environment, the RSA algorithm is used. For providing security, the RSA algorithm is employed for the key generation process. Furthermore, to perform the classification task, the LightGBM algorithm is used within the cloud environment to classify the anomalies. For efficient classification, feature selection is an important task. So, RFE(Recursive Feature Elimination) algorithm is employed to select the best features. To evaluate the proposed method, we conducted experiments on the NSL-KDD dataset and compared the results with the Decision Tree algorithm. Experimental results have shown that the proposed model obtained better performance than the Decision Tree classifier in terms of classification accuracy.

Keywords— Light Gradient Boosting Machine, Anomaly, classification, Recursive Feature Elimination, Decision Tree

I. INTRODUCTION

In today's computing world, one of the fastest, flexible and most used technologies in the IT (Information Technology) sector is cloud computing technology [1]. Cloud computing offers various on-demand services to users. The usage cost is based on the services accessed by the user, which is named pay-as-usage [2]. The cost of accessing these services from the cloud is less. Cloud computing includes network, storage and other computing resources which are combined as a pool of cloud resources. It allows many users to share resources, which increases the usage of resources [3]. Cloud provides platform services to develop various software, Infrastructure services to access hardware resources and software services to develop various applications by the users. The recent survey by Gartner stated that the use of cloud computing in the industries is increasing at a rate of 40%. It is predicted that the rate increases by greater than 25% per year, with a total income of $55 billion [4]. Storage services are considered important services since most of the users migrate their huge volume of data from their local system to the cloud systems.

Moreover, when performing computations at the local system, it is not capable of handling such a massive amount of data and the computation time required is more. So, to make the computation in a fast and smooth manner, users are started using cloud services. Though the cloud is offering all these valuable services, the security in the cloud remains a challenge in accessing the cloud services.

In the cloud, the two security issues to be focused on are; first, one focus on the service provider should assure the cloud services delivered, and the infrastructure is secure and safe, the second one guarantee the users that the data and information of the users are secured[6,7]. These security challenges threaten the users to store their private data in the cloud. Data confidentiality, data integrity and privacy preservation are considered the biggest hurdles against the adoption of cloud storage [8]. Thus, data privacy and security issues make the researchers develop various cryptographic algorithms. Cryptographic algorithms increase the security and privacy of the data by converting the raw or original data into an unreadable format known as ciphertext. There are two main types of cryptographic algorithms, such as Symmetric key cryptography and asymmetric key cryptography. In symmetric-key cryptography, a single key is shared among all the authorized users. This single key is known as the secret key, which is shared among the users. The shared secret key is used for both the encryption and decryption process. The encryption process is used to convert the data into some other format known as the ciphertext to store in cloud storage. The decryption process is used to convert cipher text to plain text while retrieving it from the cloud data storage. Since a single secret key is shared among several users, security is again a major problem, since an unauthorized user can hack the key easily to access the original data. Hence, asymmetric key cryptography or public key cryptography came into existence. In this scheme, there are two keys, known as public and private keys. The encryption process uses the public key, and the decryption process uses the private key. Here, the private key is the secret key. The user who is having the private key alone can decrypt and view the original data. The security of the data is greatly increased with this technique. Asymmetric cryptography technique is thus more powerful than symmetric key cryptography. Among the public key cryptographic algorithms, the RSA algorithm is the most powerful algorithm since the key size generated is more, so it is not easy to break the key. Hence, the RSA algorithm is used in the proposed approach for privacy preservation and security of the data stored in the cloud.

Data anomaly is the abnormal behaviour of the data. There are various approaches to detect the abnormalities present in the data. Today machine learning algorithms are employed to use in anomaly detection systems [5]. Both the types of machine learning algorithms namely supervised and unsupervised methods are used in the anomaly detection process. Both these techniques use classification and clustering approaches respectively. In some applications, semi-supervised algorithms are also used. LightGBM algorithm is used in our work, for classifying the anomalies. While processing large datasets to detect anomalies, feature selection is an important task to select the required features among a large number of available features. Significant feature selection plays a vital role in improving the accuracy of the anomaly detection model. We have used the RFE algorithm along with logistic regression to select the important and required features. The processing time greatly varies based on the number of chosen features. Varying the features may vary the classification accuracy also. The standard dataset is always used for the experimental validation of the proposed model. To obtain accurate validation results, the dataset plays an important role. So, the NSL-KDD dataset in our work, which is a standard dataset used for intrusion detection purpose.

The remaining portions of the paper are structured as follows: the related work on cloud based anomaly detection using machine learning is discussed in section 2. The system model of the proposed work is presented in section 3. Section 4 presented the privacy preservation and security of the data using the RSA algorithm. Feature selection using the RFE algorithm is discussed in section 5. Anomaly detection using the LightGBM algorithm is discussed in section 6. Section 7 presented the Results and Discussions. Finally, Section 8 presented the conclusion and the future work.

II. RELATED WORK

A. Selecting a Template (Heading 2)

In [9], the authors combined the two supervised machine learning algorithms namely Naive Bayesian classifier and Iterative Dichotomiser 3 (ID3) and proposed a hybrid model to analyze the network data and the complex properties of network attacks. The detection speed and accuracy is improved. Huang et al.[10] stated that the number of observed features is reduced into a smaller set. which is sufficient to obtain the information necessary to the goals of the anomaly detection technique. Feature selection methods are used to reduce the dimensionality of the datasets. Thottan et al.[11] reviewed the anomaly detection methods which used artificial intelligence, machine learning and state machine modelling. Garg et al.[12] proposed an Ensemble-based classification model for network anomaly detection in massive datasets and stated that data with a large number of features cause overfitting problem and the overall performance of the model get reduced. Thus optimal feature selection is required to reduce the computational overhead and over-fitting problems. Xu et al. [13] proposed a dynamic extreme learning machine for the classification of patterns present in the continuous data stream. Their proposed technique was faster, but the accuracy rate was less. Moshtaghi et al. [14] proposed a model for anomaly detection in data streams and fuzzy rule-base methods were used to learn the incoming samples. Columbus[15] stated that 49% of businesses are deferring cloud utilization due to cybersecurity problems. Hence, privacy and security are important factors to be considered in cloud technology. Recently, anomaly detection emerged as the main research area among researchers [16,17,18,19].

To summarize, the advancements in the cloud and machine learning techniques provide a way for developing a robust model for anomaly detection techniques. We have followed these technological advancements to develop a robust, reliable and flexible anomaly detection model.

III. SYSTEM MODEL

The proposed system model consists of the components such as user, Trusted Authority and Computation engine. Among these, the Trusted Authority and Computation engine components reside in the cloud environment. The main components in the system model in fig.1 are, (1) Trusted Authority (TA) and (2) Computation Engine(CE). The main functions of the TA are: (i) Validating the user, (ii)Issuing public key for encryption, (iii) Performing decryption and (iv) Providing classification result back to the user. The role of the CE are (i) Feature Selection, (ii) Classification (Anomaly detection) and (iii) Return Analysis Report.

The cloud environment consists of the TA and the CE. The user sends a request for the public key to the job. The public key is used to encrypt the data for the secure transmission of data to the cloud. The TA generates the key pair(Pp, Pr) for a job, where, Pp and Pr are Public keys and Private key respectively. These keys are used for encryption and decryption purposes. TA validates the user by using the credentials supplied by the user and provide the public key(Pp) to the user. The credentials are the username and the password. The user encrypts the data with a Pp key and sends the encrypted data to the TA. The user submits a ticket for Anomaly Detection to the TA. TA initiates the CE with the user request. TA gets the encrypted data from the user and decrypts it using the Pr key. After decryption, the data is provided to the CE where the optimal number of features are efficiently selected by the RFE algorithm to improve the classification accuracy. Thus the computation overhead of the system is greatly reduced. Upon selection, the anomaly detection is performed by using the LightGBM classification Algorithm. After completing the classification task, the final result is sent to the legitimate user from the computation engine through the Trusted Authority.

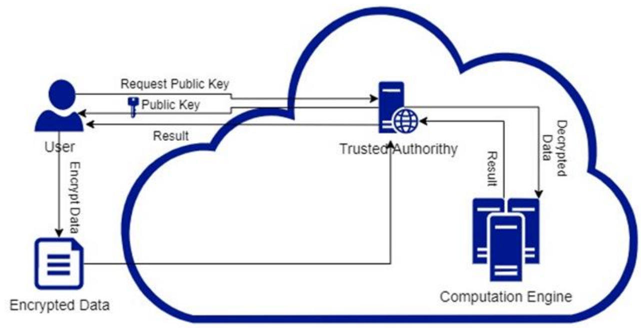

Fig 1. System Model

IV. PRIVACY PRESERVATION AND SECURITY USING THE RSA ALGORITHM

Our proposed cloud based privacy preserving model adopting the RSA scheme can provide end-to-end privacy and confidentiality. In RSA key generation, a public key is an integer value generated randomly by using the two prime numbers(p and q). With the help of the public key, the original data is well-encrypted. Algorithm 1 describes RSA key generation. The private key is used for decryption. Both the keys were generated by the TA.

Algorithm 1: RSA algorithm for key generation

Begin

Choose two large prime numbers p and q

$$n = p \times q$$

$$\phi(n) = (p-1) \bullet (q-1)$$

e= random value, such that $1 < e < \phi$(n)

Determine $d = e^{-1} \bmod \phi$(n)

Public key = (e, n) i.e. e is a public key;

private key = (d);

Stop

V. FEATURE SELECTION

Feature selection [20,21] has become essential to choose the finest and optimal features and applied in several fields such as the medical field, biology, economics, manufacturing, image processing and production. Feature selection plays a vital role in the classification task. It reduces computational time and increases classification accuracy. Recursive feature elimination (RFE) is a feature selection algorithm that selects the best features and eliminates the worst features based on the ranking of features. For ranking logistic regression method is used. RFE with logistic regression evaluates the features and select the best features by using the ranking score. The ranking of features is calculated by Logistic Regression using the eqn. 1:

$$(P(Y))/(1+P(Y))=\beta 0+\beta 1x1+ \beta 2x2+\ldots\ldots.+\beta nxn \qquad (1)$$

where, Y = Target (Dependent variable)
x1, x2,….. xn = Features(Independent variables)
β0 = Constant value
β1,… βn = Co-efficient values

The probability score value or the rank for each feature is calculated by using Y and the features x1, x2,….. xn as inputs. It can be calculated using the eqn.2

$$P=1/(1+e^\wedge(-\beta 0+\beta 1x1+\beta 2x2+\cdots+\beta nxn)) \qquad (2)$$

where P=Probability value or Rank value

Thus the rank value for every feature is assigned. The total number of features in the dataset are denoted as 'N' in fig 2. Feature Set (FS) contains all the features and Feature Rank (FR) set contains the features with rank values. The feature with the highest rank is selected as the best feature and the lowest ranking features were eliminated. The selected features provided to LightGBM for the anomaly detection process.

VI. ANOMALY DETECTION USING LIGHTGBM ALGORITHM

Light BGM [22] is a gradient boosting framework, and it is a powerful algorithm. It uses a tree based learning methodology. The computation speed is very fast for this algorithm so that it has the name light. It can able to process a large volume of data, and it requires less amount of memory. The LightGBM performs classification by using the selected features. Algorithm2 shows the LightGBM algorithm

The following are the main parameters [23,24,25] of the LightGBM which are used to implement the proposed model:

number_leaves – the leaves present in each tree.
learn_rate –learning rate of the algorithm.
maximum_depth – algorithm's maximum depth.
boosting type – it defines the type of the algorithm
minimum_data – the minimal amount of data in the leaf node
feature_fraction – the value ranges from 0 to 1. It is the ratio of the particular feature to the total number of features.

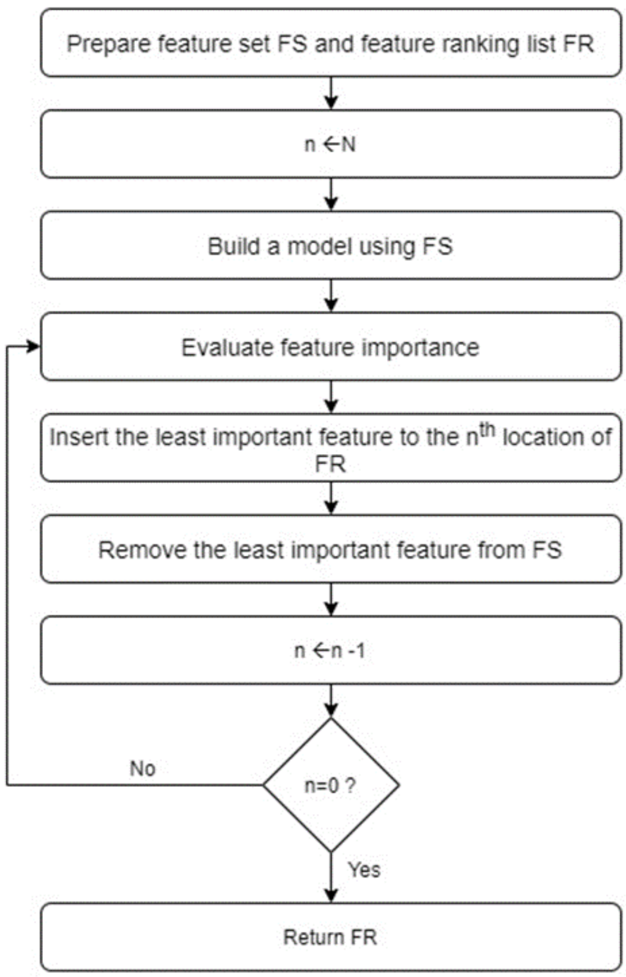

Fig. 2: Feature selection using RFE algorithm.

The parameter values for our implementation is set as follows:

learn_rate = 0.003

booster_types = 'gbdt'

objective_fn = 'binary'

metrics = 'binary_logloss'

sub_features = 0.5

number_leaves = 70

minimum_data = 50

maximum_depth = 70

Algorithm 2: LightGBM

Input: T= training data

Input: F= iterations

Input: u= sampling ratio of large gradient data

Input: v= sampling ratio of small gradient data

Input: loss_fn= loss function, L_weak= weak learner

Model ←{}, factr ←(1-u)/v

topn←u× len(T) , randn←v× len(T)

for i = 1 to F do

pred←Model.predict(T)

k← loss_fn(T,pred)

w←{1,1,… }

sort← GetSortedIndices(abs(k))

topset←sorted[1:topn]

randset←RandomPick(sorted[topn:len(T)],randn)

usedset←topset+randset

z[randset] =factr

newml ← L_weak(T[usedset],-k[usedset],z[usedset])

Model.append(newml)

VII. Results and Discussions

For experimental validation, the standard NSL-KDD dataset is used. It contains 42 features or attributes. Among these, only the important features are selected by using the RFE algorithm. For classification by LightGBM, these selected features are used by it. The performance of LightGBM is compared with the Decision Tree algorithm, and the accuracy rate of LightGBM is more than that of the Decision Tree. The metrics used for evaluation are:

i. Accuracy
ii. Precision and
iii. Recall

Accuracy

Accuracy is the measure to calculate the performance of the model. It is the ratio of correctly predicted values to the total values. The accuracy is calculated by using the eqn. 3.

$$Accuracy=(TP+TN)/(TP+TN+FP+FN) \quad (3)$$

where, TP is the Total True Positive values, TN is the Total True Negative values, FP is the Total False Positive values and FN is the Total False Negative values.

The classification accuracy of LightGBM is obtained as 0.99836, and the classification accuracy of Decision Tree is obtained as 0.986 as in fig 3.

The analysis is performed by varying the count of features selected. The overall features obtained after performing the Label and one-hot encoding schemes is 122. We performed the analysis by choosing the features ranging from 10 to 90. Based on the analysis, we found that the performance observed is very low when the number of features was very low, that is, in our case, low indicates 10 features. The best accuracy was observed when the number of features was 50. It was also observed that after the idle range of 50, the performance was not increasing and it was stable at around 0.998.

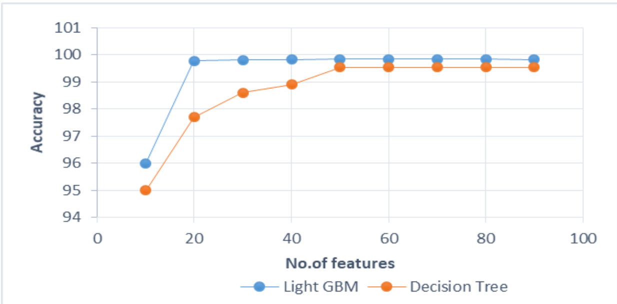

Fig.3: Accuracy value of LightGBM and Decision Tree by varying the number of features

Precision

Precision is the measure of the ratio between true positive predictions obtained and the total positive predictions available. It is calculated by using the eqn.4:

$$Precision=TP/(TP+FP) \quad (4)$$

The precision values obtained for Light GBM and Decision tree classifier in the proposed model are in fig 4. The precision value is calculated for both the algorithms by varying the number of features. It shows that Light GBM obtained more precision value than Decision Tree classifier. When the number of selected features were more than 50, then the precision value obtained for Light GBM is 0.998 and for Decision Tree is 0.992 and remains the same for the remaining number of features.

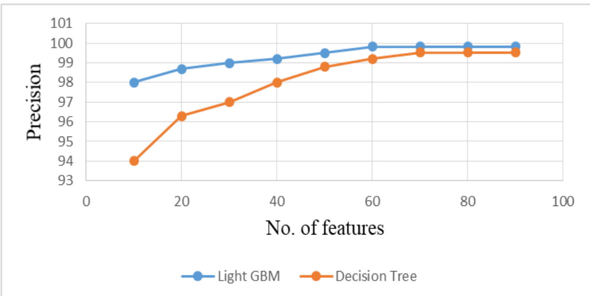

Fig. 4 Precision value of LightGBM and Decision Tree by varying the number of features

Recall

The recall is the measure of the ratio between true positive and the sum of true positive and false negative values. It is measured by using eqn.5:

$$Recall=TP/(TP+FN) \quad (5)$$

The recall values obtained for Light GBM and Decision tree classifier in the proposed model are in fig 5. The recall value is calculated for both the algorithms by varying the number of features. It shows that Light GBM obtained more recall value than the Decision Tree classifier. When the number of selected features were more than 50, then the recall value obtained for Light GBM is 0.992 and for Decision Tree is 0.98 and remains the same for the remaining number of features.

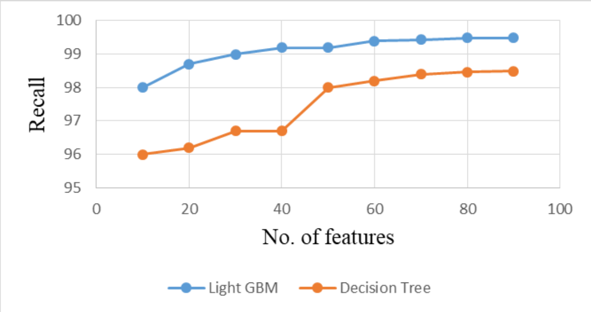

Fig. 5 Recall value of LightGBM and Decision Tree by varying the number of features

We also compared the performance of the LightGBM algorithm with the Decision Tree, and we could found that the performance of LightGBM is slightly higher than the Decision Tree. The same number of features are used in the Decision tree as that of LightGBM. The accuracy of the Decision Tree was observed as 99.53 while the performance of LightGBM was 99.83 as in fig.6. Hence the performance of LightGBM is more than that of the Decision Tree classifier.

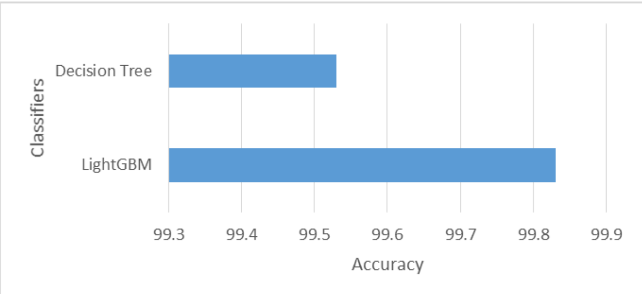

Fig.6 Comparison of LightGBM with Decision Tree classifier

VIII. Conclusion

In this paper, an anomaly detection model based on the cloud environment is proposed by using the machine learning algorithm LightGBM for classification and RFE for feature selection. Moreover, the RSA algorithm is used for privacy preservation and security of data in the cloud.

The Trusted Authority in the cloud environment is responsible for issuing the keys to the user and the computation engine. The computation engine is responsible for performing feature selection and classification tasks. The experimental validation is performed on the standard NSL-KDD dataset to analyze the performance of our work on the anomaly detection process. The performance of the LightGBM algorithm is compared with the Decision Tree algorithm with the same dataset. The proposed model provided high accuracy than the Decision Tree in detecting data anomalies.

In future, the proposed model would be evaluated with real-time datasets to work for real-time data. Also, the performance of the proposed model would be compared with various other machine learning algorithms.

References

[1] Zouhair Chiba , Noreddine Abghour, Khalid Moussaid, Amina El omri and Mohamed Rida, "New Anomaly Network Intrusion Detection System in Cloud Environment Based on Optimized Back Propagation Neural Network Using Improved Genetic Algorithm", International Journal of Communication Networks and Information Security (IJCNIS) Vol. 11, No. 1, April 2019.

[2] A. Uzma, K.K. Dewangan, D.K. Dewangan, "Distributed Denial of Service Attack Detection Using Ant Bee Colony and Artificial Neural Network in Cloud Computing," in: B. Panigrahi, M. Hoda, V. Sharma, S. Goel (Eds.), Nature Inspired Computing, Advances in Intelligent Systems and Computing, Vol. 652, Springer, Singapore, Singapore, pp. 165-175, 2018.

[3] X. Zhao, W. Zhang, "Hybrid Intrusion Detection Method Based on Improved Bisecting K-Means in Cloud Computing," 13th IEEE Web Information Systems and Applications Conference (WISA), Wuhan, China, pp. 225-230, 2016.

[4] Sahil Garg, Kuljeet Kaur, ShaliniBatra, Gagangeet Singh Aujla, Graham Morgan, Neeraj Kumar, Albert Y. Zomaya , Rajiv Ranjan," En-ABC: An ensemble artificial bee colony basedanomaly detection scheme for cloud environment",Journal of Parallel and Distributed Computing, Volume:135, Pages:219–233,2020.

[5] Eltanbouly, S., Bashendy, M., AlNaimi, N., Chkirbene, Z., & Erbad, A.. "Machine Learning Techniques for Network Anomaly Detection: A Survey". IEEE International Conference on Informatics, IoT, and Enabling Technologies (ICIoT). 2020.

[6] S. M. Mehibs, S. H. Hashim, "Proposed Network Intrusion Detection System Based on Fuzzy c Mean Algorithm in Cloud Computing Environment," Journal of University of Babylon, Vol. 26, No. 2, pp. 27-35, 2018.

[7] A. Patel, M. Taghavi, K. Bakhtiyari, J. C. JúNior, "An intrusion detection and prevention system in cloud computing: A systematic review," Journal of network and computer applications, Vol. 36, No. 1, pp. 25-41, 2013.

[8] Kaaniche, N., Laurent, M.: Data security and privacy preservation in cloud storage environments based on cryptographic mechanisms. Comput. Commun. 111, 120–141,2017.

[9] D. M. Farid, N. Harbi, and M. Z. Rahman, "Combining naive bayes and decision tree for adaptive intrusion detection," arXiv preprint, 2010.

[10] T. Huang, H. Sethu, N. Kandasamy, "A new approach to dimensionality reduction for anomaly detection in data traffic", IEEE Transactions on Network and Service Management ,651–665,2016.

[11] M. Thottan and C. Ji, "Anomaly detection in IP networks," IEEE Trans. Signal Process., vol. 51, no. 8, pp. 2191–2204, Aug. 2003.

[12] S. Garg, A. Singh, S. Batra, N. Kumar, M. S. Obaidat, "EnClass: Ensemble-Based Classification Model for Network Anomaly Detection in Massive Datasets", in: IEEE Global Communications Conference (GLOBECOM'17), Singapore, 2017.

[13] S. Xu and J. Wang, "Dynamic extreme learning machine for data stream classification," Neurocomputing, vol. 238, pp. 433–449, 2017.

[14] M. Moshtaghi, J. C. Bezdek, C. Leckie, S. Karunasekera, and M. Palaniswami, "Evolving fuzzy rules for anomaly detection in data streams," IEEE Transactions on Fuzzy Systems, vol. 23, no. 3, pp. 688–700, 2015.

[15] L. Columbus, "State Of Cloud Adoption And Security", 2017. URL: https://www.forbes.com.

[16] S. Garg, A. Singh, S. Batra, N. Kumar, L. T. Yang, "UAV-Empowered Edge Computing Environment for Cyber-Threat Detection in Smart Vehicles", IEEE Network 32 , 42–51,2018.

[17] D. Gupta, S. Garg, 375 A. Singh, S. Batra, N. Kumar, M. S. Obaidat, "ProIDS: Probabilistic Data Structures Based Intrusion Detection System for Network Traffic Monitoring", in: IEEE Global Communications Conference (GLOBECOM'17), Singapore, 2017.

[18] S. Garg, K. Kaur, N. Kumar, S. Batra, M. S. Obaidat, "HyClass: Hybrid Classification Model for Anomaly Detection in Cloud Environment",in: IEEE International Conference on Communications (ICC), Kansas City, USA, 2018.

[19] Jeon, H., & Oh, S., "Hybrid-Recursive Feature Elimination for Efficient Feature Selection". Applied Sciences, 10(9), 3211, doi:10.3390/app10093211, 2020.

[20] Bolón-Canedo, V.; Sánchez-Marono, N.; Alonso-Betanzos, A.; Benítez, J.M.; Herrera, F. “A review of microarray datasets and applied feature selection methods”. Inform. Sci., 282, 111–135,2014.

[21] Ang, J.C.; Mirzal, A.; Haron, H.; Hamed, H.N.A. "Supervised, unsupervised, and semi-supervised feature selection: A review on gene selection". IEEE/ACM Trans. Comput. Biol. Bioinform., 13, 971–989, 2015.

[22] Guolin Ke, Qi Meng, Thomas Finley," LightGBM: A Highly Efficient Gradient Boosting Decision Tree", 31st Conference on Neural Information Processing Systems (NIPS),2017.

[23] Elena-Adriana MINASTIREANU and Gabriela MESNITA (2019), "LightGBM Machine Learning Algorithm to Online Click Fraud Detection ", Journal of Information Assurance & Cyber security, Vol. 2019, Article ID 263928, DOI:10.5171/2019.263928,2019.

[24] Ma, X., Sha, J., Wang, D., Yu, Y., Yang, Q. and Niu, X.' Study on A Prediction of P2P Network Loan Default Based on the Machine Learning LightGBM and XGboost Algorithms according to Different High Dimensional Data Cleaning', Electronic Commerce Research and Applications, 31, 24 –39, 2018.

[25] Ke, G., Meng, Q., Finley, T., Wang, T., Chen, W., Ma, W., Ye, Q. and Liu, T-Y. "LightGBM: A Highly Efficient Gradient Boosting Decision Tree", Advances in Neural Information Processing Systems, 30, 2017.

An Android-based Application for Computation Offloading in Mobile Cloud Computing

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***Abstract*—Computation Offloading is a fundamental problem in mobile cloud computing in which tasks are offloaded from resource-constrained devices to some computationally rich mobile devices. In this direction, an Android-based application *ClientFramework*, is developed that offloads the client device's tasks. On the other side, an application *OffloadingServer* is developed that provides an interface between Service Provider and Service Receiver and processes the offloaded requests and sends back the results to client devices. Auction mechanism and greedy heuristics are used for resource allocation in each auction round in which tasks are allocated to available mobile devices while considering their computational and storage resources. At last, the conducted experiments verify the offloading benefits in the MCC environment.**

***Keywords*— Mobile Cloud Computing, Computational Offloading, IoT, Auction**

I. Introduction

Mobile Cloud Computing (MCC) enables the efficient offloading of applications and services from mobile devices to remote resource providers such as cloud, fog, or cloudlet [1]. In MCC, the cloud is shifted close to the mobile users for computation offloading [2]. It is like an ad-hoc cloudlet and different from static and elastic cloudlets. In MCC, there may or may not be a traditional cloud. A cloud may be formed by any ad-hoc entity close to a mobile user, whether it is a server or a combination of mobile devices, or any other infra. It is not static. In MCC, mobile (edge) devices are connected using the cloud directly without any other interleaving hop, i.e., a direct connection between the mobile edge device and cloud servers. For each application, some part of it runs on its device and some part on the cloud. Therefore, there is always a trade-off between offloading and not offloading computation to the cloud. Also, unlike traditional clouds, MCC is not based on SOA. Incorporating general and universal computing has altered the behavior of everyday objects in the presence of humans. Mobile phones, sensors, watches, and other objects are no longer limited to their simple features and upgraded to smart devices thanks to the Internet of Things (IoT) paradigm. Mobile devices will now attach to various Internet of Things (IoT) devices to sense and identify situations and make intelligent decisions [3].

Despite their many advantages, the end-user devices are characterized by limited battery and computation capacity. Consequently, running computation-intensive and delay-sensitive applications, e.g., such as face detection, fingerprint processing, voice processing, video streaming, image processing, healthcare monitoring, etc., is not always profitable. To address these issues, mobile cloud computing appears to be a promising strategy that enables the efficient offloading of applications and services from mobile devices to remote resource providers such as cloud, fog, or cloudlet.

Mobile cloud computing is a computing model that allows mobile devices to offload computationally intensive tasks to cloud computing resources for execution, thus saving battery life and enhancing the performance of mobile cloud applications. The basic concept of MCC is to offload massive and complex tasks to remote resource providers. Mobile Cloud Computing (MCC) is based on cloud computing and mobile computing principles, and it uses wireless networks to provide rich computational services to mobile users. MCC's mission is to make it possible to run rich mobile apps on various mobile devices while providing a rich user experience. Since Mobile phones have become a critical necessity for human life, Mobile cloud computing (MCC) has seen faster growth in research. Mobile clients use mobile apps or embedded browser applications to communicate with cloud service providers.

Mobile Cloud Computing (MCC) is a hybrid of mobile computing and cloud computing that uses offloading techniques to expand the capabilities of mobile devices. Computation offloading addresses the shortcomings of Mobile Devices, such as battery life, computing capacities, and storage space, by offloading the execution and workload to other resource-rich systems with better performance and resources. These systems can be mobile devices, cloudlets, or private/public clouds, having an adequate amount of computational and storage resources [4]. In this work, a client-server offloading mechanism is implemented in which mobile users who want to offload their mobile tasks to remote resources are referred to as Service Receivers who send offloading requests to the server, and mobile users with redundant resources are referred to as Service Providers. The following points illustrate our vital contribution to this work.

1. We develop an Android-based application *ClientFramework*, for placing the offloading request for a computation-intensive task and sharing the redundant

resources for offloading. A user can be a Service Provider or Service Receiver but not both at the same time.

2. We develop a Java application *OffloadingServer* to provide an interface between Service Provider and Service Receiver and offload the task requests to the selected Service Providers.
3. We adopt the greedy approach for allocating the offloading task requests to the Service Providers. The proposed algorithm takes available RAM, CPU frequency, and available time of device into consideration during allocation.

The rest of the paper is organized as follows. The system model is described in Section II. The application's functionality is demonstrated in Section III. Finally, section IV concludes the work.

II. SYSTEM MODEL

This section explains the proposed system's key components and how they perform computation offloading in the MCC environment. The device model, which abstracts the various characteristics of the proposed system, is then presented. After that, the *ClientFramework* is demonstrated in action.

A. Key Components

Mobile devices are the primary participants in the scheme we have proposed. We introduce a prototype of the architecture on the Android platform to verify the functioning of the proposed offloading mechanism on real applications. The system is based on a client-server architecture, with the client layer running in Android apps and the server running in a Java application. Mobile devices have been further categorized into two parts: Service Providers and Service Receivers.

1) Service Provider

A Service Provider is identified as a device having a lot of computing capacity but is not being used right now. As a result, it can make the most of its resources by performing the Service Receiver's computationally intensive tasks. Any device with many computing resources, such as mobile phones, computers, routers, or cloudlets, can serve as a Service Provider. However, for our purposes, mobile phones have been considered Service Providers.

2) Service Receiver

Devices with low computing capacity and battery power are classified as Service Providers. It also necessitates completing specific computationally intensive tasks that would be inefficient or impossible to complete locally on this device. To perform computationally intensive tasks requires additional computation power. For our work, we consider mobile devices as Service Receiver.

3) Offloading Server

Offloading Server provides an interface between Service Provider and Service Receiver. All Service Providers will be connected to the offloading server. And it allocates task requests from Service Receiver to Service Provider.

B. ClientFramework App

It provides an interface for users to act either as Service Provider or Service Receiver. It is an Android application written in the Java programming language. Android 9 is the minimum operating system needed to run this app.

ClientFramework uses a Wi-Fi hotspot in order to connect with Offloading Server. The J2SE Networking APIs are then used to establish a communication link. It also uses Google Vision API to perform Optical Character Recognition (OCR). The Google Cloud Vision API makes it easy for developers to incorporate vision recognition functionality into their apps.

C. System model

In MCC, task offloading is viewed as an offloading environment in which a mobile user can run an application entirely on his or her local mobile device or offload computation-intensive tasks to other computing resources in the network that share their redundant resources. Other mobile devices' local resources can also be used to replace redundant resources [5].

1) A user can send a task offloading request to the OffloadingServer if they want to offload tasks to other devices. The request includes the requested amount of computation and task completion deadline :

$$r_i = (c_i,\ d_i)$$

Where c_i denotes the necessary amount of computation for the offloading task and d_i denotes the offloading task's deadline.

2) Similarly, users who want to sell their excess resources will make a service proposal to the OffloadingServer in the network. The resource requirements are included in the service proposal.

$$s_j = (w_j, t_j, b_j)$$

Where w_j represents the processing speed of the service proposal s_j, t_j is the available time of s_j, and b_j denotes the service offer's bid.

3) Finally, the cost of task execution is calculated in terms of offloading task execution time. Assuming a large number of i task offloading requests and a large number of j devices providing offloading services, the task i execution period on system j's leased resource is :

$$T_{ij} = \frac{c_i}{w_j} + \frac{d_{in} + d_{out}}{v_{ij}}$$

Where d_{in} and d_{out} denote task i's input and output data sizes , respectively, and v_{ij} denotes bandwidth. c_i is the amount of computation needed for task i.

D. The greedy offloading mechanism

This section introduces a greedy auction algorithm for allocating task offloading requests from the Service Receiver to Service Provider's service offers. When allocating task offloading requests, the proposed algorithm takes into account the benefits of offloading in the MCC environment [5].

The proposed offloading mechanism's greedy auction can be defined as a series of auctions at discrete time intervals. Offloading requests r_i and service offers s_i arrive at random times. It sends service details to the offloading server for each s_i, including processing power, bid, and available time. For each request r_i , it contains the requested amount of computation and the user-specified task completion deadline. The greedy auction-based algorithm performs resource allocation in each auction time interval to allocate computational resources to execute task requests received from the Service Receiver.

In resource allocation, all offloading requests are placed in a queue in the order in which they were sent. The greedy auction algorithm processes the queued requests by fetching one and allocating it to available service offers depending on the task requirement and offloading benefits.

1. To process requests with extensive computation or urgent deadlines, the algorithm sorts the offloading requests in descending order of the value of c_i/d_i.
2. Similarly, service offers are sorted in ascending order based on the value of b_j/w_j, with the service with the lower bid and higher processing speed appearing first.
3. Then the algorithm takes the sorted requests and offers to start the auction process. For each sorted task request, the algorithm iterates through sorted service offers and check for the following conditions:
    a. To ensure the completion of offloading request before its deadline, the completion time of offloading request r_i on service offer s_j does not exceed the completion deadline of request r_i.
    b. To ensure the completion of offloading requests before the service offer's available time ends, the completion time of offloading request r_i on service offer s_j does not exceed the available time of service offer s_j.
    c. To ensure the offloading, the time it takes to complete offloading request r_i locally must be greater than the time it takes to complete it on service offer s_j using the offloading process.
4. After all three conditions are met, service offer s_j will be allocated to offloading request r_i and labeled as busy to other offloading requests. After all of the offloading requests have been processed, the algorithm returns the output.

III. A REAL INSIGHT

In this section, we introduce a prototype of the architecture on the Android platform to verify the functioning of the proposed offloading mechanism on real applications. The system is based on a client-server architecture, with the client layer running in Android apps and the server running in a Java application. In this section, the implementation for the client and the server is explained first, followed by the interaction between various entities of the offloading mechanism. Then some experiments are carried out on the implemented prototype using a mobile OCR application to evaluate the performance of the offloading framework.

A. Implementation of ClientFramework App

The client-side of the framework is implemented on the Android platform. The client framework is divided into three modules depending on various functionalities: a Connection module, a Resource Provider module, and an Offloading Controller module. Fig. 1 shows the starting activity of the ClientFramework App. The connection module handles communication with the offloading server as well as data encryption and decryption. All network operations in the connection module have been performed on a separate thread to provide a better user experience. The Resource Provider module submits the service offer to the offloading server and executes the offloading task requests from other mobile users. The Offloading Controller module deals with offloading tasks to the server and receives results back from the server.

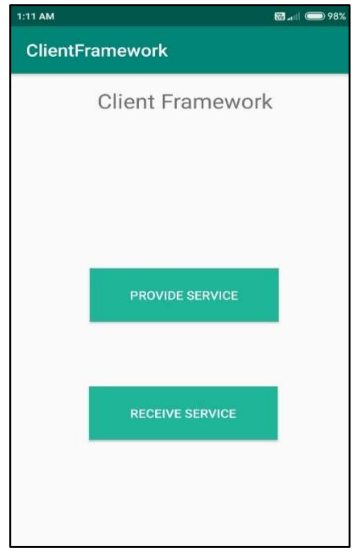


Fig. 1. Starting activity of ClientFramework App

B. Implementation of Offloading Server

The server side of the Offloading framework is implemented as a Java application on the computer. On the server-side, four modules are implemented to meet the needs of various functionalities: a Connection module, a Service Handler module, a Task Handler module, and a Resource Allocator module. The connection module deals with communication with clients. The Service Handler module keeps track of currently available service offers. The Task Handler module keeps track of available offloading task requests. The Resource Allocator module assigns offloading task requests to the available service offers using the greedy auction algorithm explained earlier.

C. Interaction between ClientFramework and OffloadingServer

This section explains the interaction between the client-side of framework (ClientFramework App) and the server-side of the framework (OffloadingServer). Since we have categorized the mobile devices into two categories earlier: Service Provider and Service Receiver. Service Provider is the device that provides or sells the resources to execute offloading task requests. Service Receiver is identified by low computing power; that is why it offloads task requests for execution. In this section, the interaction of the Service Provider with the offloading mechanism is explained first, followed by the interaction of the Service Receiver with offloading mechanism.

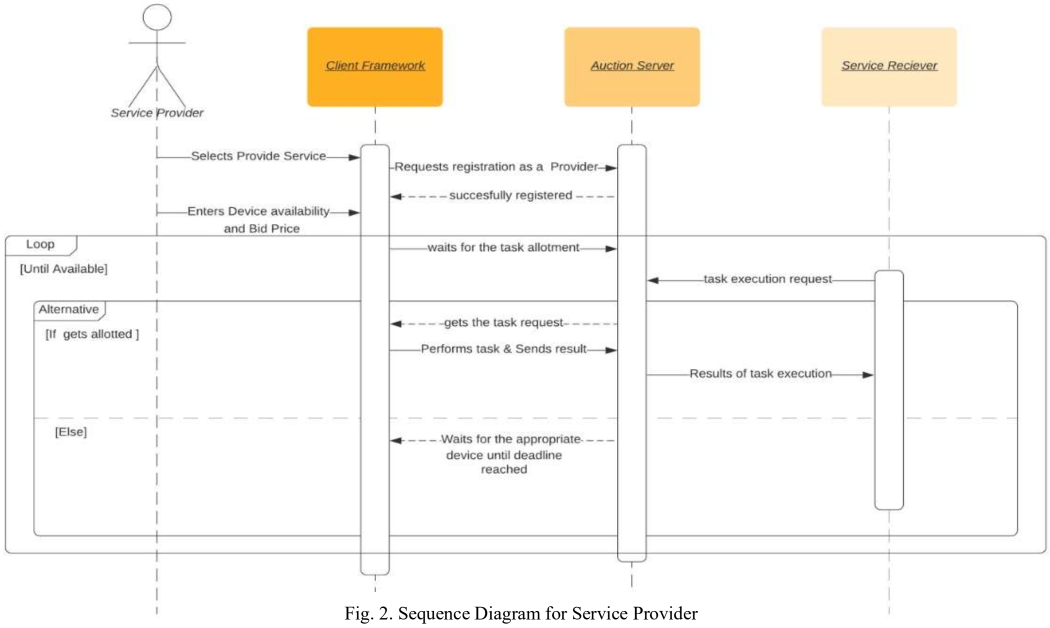


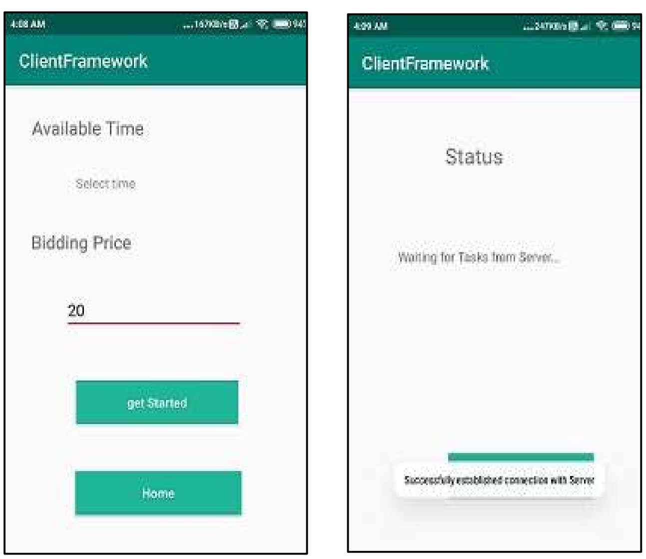
Fig. 2. Sequence Diagram for Service Provider

1) Interaction of Service Provider

Service Provider sends a service offer to the OffloadingServer through the Resource Provider module with its capacity, available time, and bid. Fig. 2 shows the Sequence diagram for the Service Provider. OffloadingServer adds it to Service Handler and sends a confirmation to the Service Provider. Fig. 3 Shows the user interface for the Service Provider. After getting the confirmation, Service Provider waits for the offloading task requests to execute. As soon as it gets assigned to any task request, the Resource Controller module executes it on shared resources. Furthermore, send back the results to the OffloadingServer. This process is repeated until its available time is over.

2) Interaction of Service Receiver

Service Receiver sends a offloading task request to OffloadingServer through Offloading Controller module with the task and its completion deadline. Fig. 5 shows the Sequence diagram for the Service Receiver. OffloadingServer adds it to the Task Handler. After each round of auction, OffloadingServer assigns offloading requests to available service offers. And sends the task to the assigned service offer. Fig.4 shows the user interface for the Service Receiver. After getting the result, OffloadingServer transmits the result to the Service Receiver and deletes the task request from the Task Handler.



(a) (b)

Fig. 3. A user interface for Service Provider

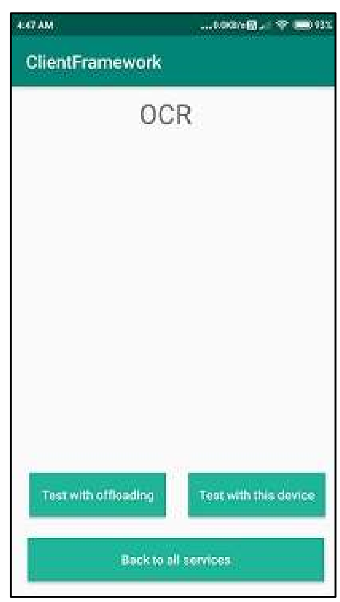


Fig. 4. A user interface for Service Receiver

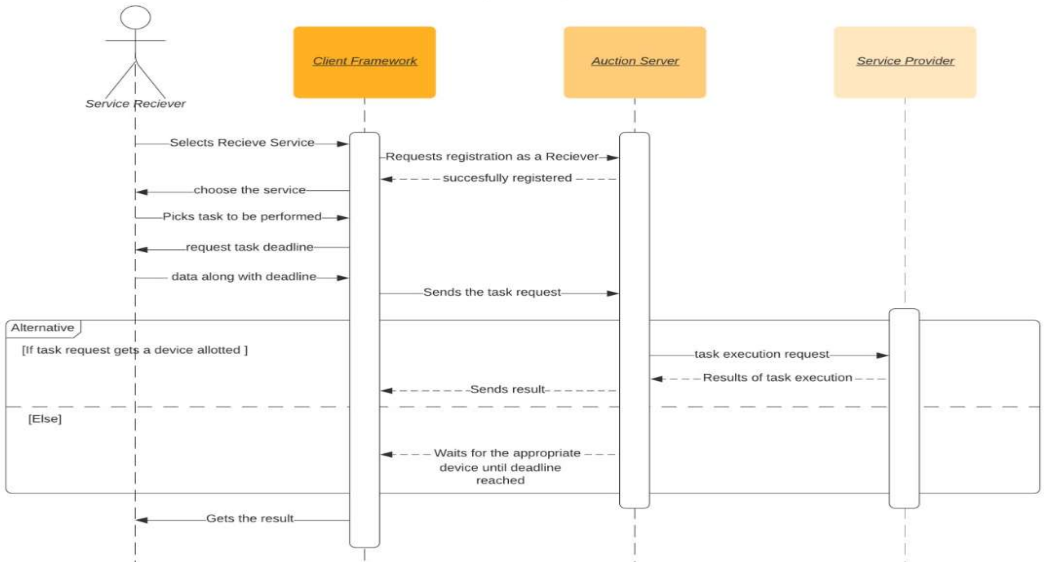


Fig. 5. Sequence Diagram for Service Receiver

D. Performance Analysis

In this section, some experiments will be carried out to test the performance of the proposed offloading mechanism. The application is developed using open-source Android OCR (Optical Character Recognition) google vision to test the framework. Using Google Vision API, it is easy to incorporate the vision features in the application. To provide better functionality of image editing for testing, we have also used the open-source uCrop library. uCrop is a library for Android that allows clip photos for later use.

We have considered three Android devices for the experiment: Vivo 1606, Redmi Note 4, and POCO M2. Vivo 1606 (2 GB RAM, 1.4 GHz) is taken as Service Receiver, Redmi Note 4 (4GB, 2 GHz), and POCO M2 (4GB, 2.32 GHz) are taken as Service Provider. All three devices will be running the android application ClientFramework. The OffloadingServer is running on a laptop. The OffloadingServer listens passively for various requests from Service Provider and Service Receiver using a server socket. Similarly, Service Provider keeps a server socket open to listening for OffloadingServer's offloading task requests.

Fig. 6 shows the interface of the Service Provider receiving the offloading task requests from OffloadingServer, executing the task, and sending back the results to OffloadingServer after successful completion of the task. Fig. 7 shows the interface of the Service Receiver sending tasks to OffloadingServer and getting back the results after successful execution. Since OCR depends upon various factors like image quality, text content, etc. So, to get meaningful and comparable results, we only consider one aspect, such as the quantity of text in the image, which means we vary the number of characters in the image. We experimented on POCO M2 with a set of 6 images with varying quantities of text. Furthermore, local runtime for both the Service Provider and the Service Receiver, as well as offloaded runtime, are measured. The Offloaded runtime of the task is calculated as the sum of local execution time for Service Provider, offloading time of the task, and auction processing time.

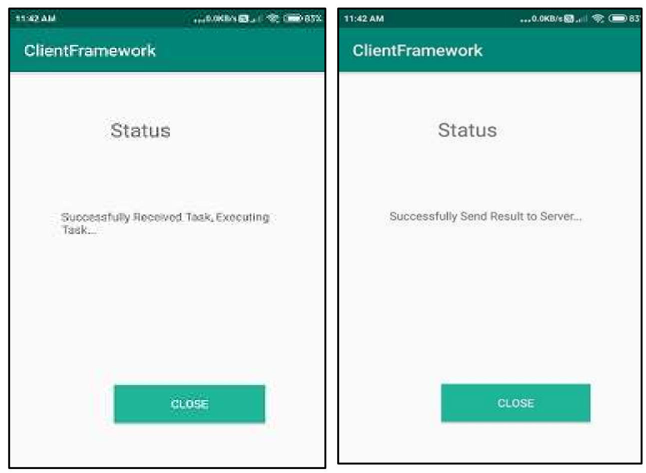


Fig 6. Service Provider receiving, executing the task, and sending back result

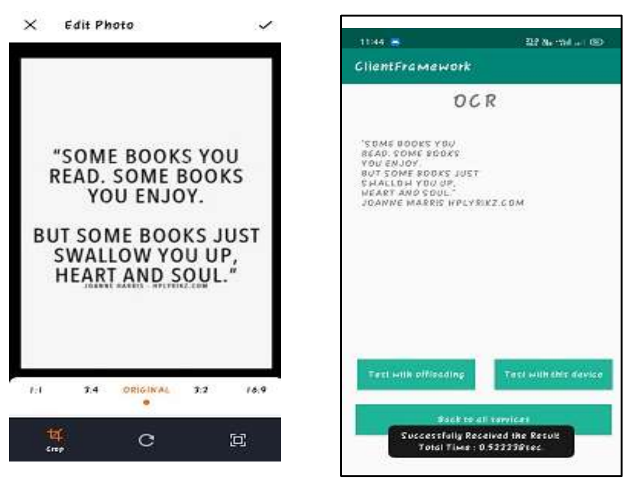


Fig 7. Service Receiver sending the task and receiving the result.

Input	Local Execution Receiver (sec.)	Local Execution Provider (sec.)	Offloaded Runtime (sec.)
Input 1	1.2405	0.0995	1.5935
Input 2	1.4510	0.1081	1.8145
Input 3	2.4101	0.1414	2.3165
Input 4	3.9017	0.2221	2.6517
Input 5	4.9582	0.2881	2.9528
Input 6	8.4118	0.5381	3.2748

Fig. 8. Task execution results

Fig. 8 shows the results of the experiment we have carried out. It shows the local execution time of the Service Receiver, the local execution time of the Service Receiver, and the total offloaded runtime. Fig. 9 shows the comparison between the local runtime of Service Receiver and offloaded runtime for image OCR. The blue bar represents the Service Receiver's local runtime, and the red bar represents the Offloaded runtime when using offloading service. As can be observed from the figure, when the quantity of text in an image is too low, the offloaded runtime is greater than the local runtime. In this case, the task offloading time becomes the major factor here. However, as we increase the text content, the execution time of the task plays the leading role after a particular stage. It shows that the proposed offloading mechanism will improve task execution time by a considerable amount.

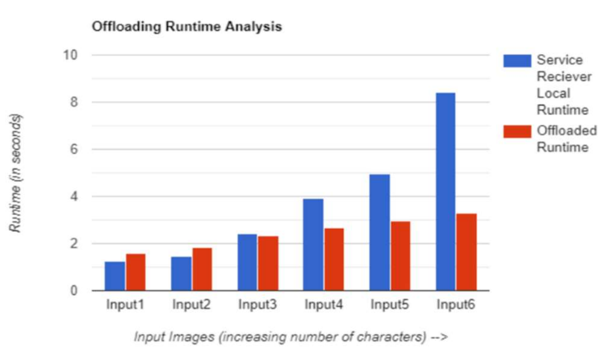


Fig. 9. Comparison of task execution between local and offloading services.

IV. Conclusions

In this paper, we present an MCC offloading mechanism that allows a device with limited computing power or battery life to offload its task request to a device with more processing power. Such mobile devices can be Service Provider or Service Receiver. Service Providers are characterized by their high processing capacity, while Service Receivers are distinguished by their low computing power or battery life. The greedy auction algorithm is then utilized, allocating Service Receiver task requests to Service Provider service offers. The greedy auction algorithm processes the offloading requests and allocates them to available service offers depending on the task requirement and offloading benefits.

Then we have presented the prototype of the proposed mechanism in which the client-side of the framework is implemented on the Android platform, and the server-side of the framework is implemented on the regular personal computer. We then divided the whole application into different modules according to their functionalities and presented the interaction between client and server modules. To assess the feasibility of the proposed mechanism, we conducted some experiments using OCR (Optical Character Recognition) as a task. The ClientFramework and OffloadingServer are available to download at https://github.com/bansalmohitwss/Mobile-cloud-offloading-framework.

References

[1] H. Flores, P. Hui, S. Tarkoma, Y. Li, S. Srirama, R. Buyya, Mobile code offloading: From concept to practice and beyond, IEEE Commun. Mag. (2015). https://doi.org/10.1109/MCOM.2015.7060486.

[2] B. Zhou, A.V. Dastjerdi, R.N. Calheiros, S.N. Srirama, R. Buyya, MCloud: A Context-Aware Offloading Framework for Heterogeneous Mobile Cloud, IEEE Trans. Serv. Comput. 10 (2017) 797–810. https://doi.org/10.1109/TSC.2015.2511002.

[3] A. Kumar, R. Yadav, G. Baranwal, NearBy-Offload: An Android based Application for Computation Offloading, in: 2021: pp. 357–362. https://doi.org/10.1109/iciis51140.2020.9342724.

[4] G. Orsini, D. Bade, W. Lamersdorf, Computing at the Mobile Edge: Designing Elastic Android Applications for Computation Offloading, in: Proc. - 2015 8th IFIP Wirel. Mob. Netw. Conf. WMNC 2015, 2016: pp. 112–119. https://doi.org/10.1109/WMNC.2015.10.

[5] B. Zhou, S.N. Srirama, R. Buyya, An auction-based incentive mechanism for heterogeneous mobile clouds, J. Syst. Softw. 152 (2019) 151–164. https://doi.org/10.1016/j.jss.2019.03.003.

Remaining Useful Life Estimation in Prognostics and Health Management using LSTM Neural Network and Vector Auto-Regression Models

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***Abstract*—Prognostics and health management (PHM) is an essential topic in the industry for asset health management and monitoring the operational availability of these assets by using their historical data, which consists of raw sensor measurements and operational settings. However, due to the lack of accurate models in most cases, there is a scope of improvement in the field of asset health management and PHM. This paper proposes a data-driven approach for prognostics using the combination of Vector Auto-Regression Model and Long Short Term Memory(LSTM) Neural Network. There is no need of any prior expertise on prognostics or signal processing due to ability of Machine Learning (ML) algorithms to efficiently model complex data, which facilitates the application of the proposed method. To demonstrate the effectiveness of the proposed approach, experiments are carried out on CMAPSS (Commercial Modular AeroPropulsion System Simulation) dataset from NASA which includes Run-to-Failure simulated data from turbofan jet engines. Experimental evaluation shows that high prognostic accuracy on the RUL estimation is achieved with proposed models.**

***Index Terms*—Prognostics and Health Management, Remaining Useful Life, Machine Learning, LSTM Neural Network, CMAPSS dataset, Vector Auto-Regression.**

I. INTRODUCTION

Prognostics and engineering maintenance plays a crucial role in many industrial areas such as aerospace, manufacturing, automotive, etc. Also, for big cyber-physical systems, like power grid, prognostics and health management (PHM) is a vital aspect and very challenging because of the added dimension of having equipment at distributed locations to maximize the operational availability, reduction of maintenance costs and improvement of system reliability and safety by monitoring the facility conditions.

Remaining useful life (RUL) is the length of time a machine is likely to operate before it requires repair or replacement. RUL can be estimated based on historical data, which consists of sensor measurements and operational settings which is very important for improving maintenance schedules to avoid engineering failures and save the resultant costs [1].

Over recent years, discovering the relationship between the monitored system historical data and determining the corresponding RUL has been receiving increasing attention in data-driven prognostics. A number of machine learning (ML) techniques have been proposed and developed to learn the mapping from the collected feature data to the associated RUL. The advantage of applying ML techniques for PHM is because of the ability of ML algorithms to efficiently model highly nonlinear, complex, multi-dimensional system without prior expertise using the system physical behaviour data.

The contribution of the proposed work in this paper is as follows:

1) Data-driven models are constructed without any prior expertise on prognostics or signal processing for predicting RUL.
2) Data-driven approach is proposed for prognostics using a combination of Vector Auto-Regression model and Long Short Term Memory (LSTM) neural network; thus, the proposed model expected to obtain higher prognostic accuracy as compared to using a single model.
3) The proposed models are capable of predicting RUL multiple cycles into the future.

To demonstrate and validate the effectiveness of the proposed work, the RUL for turbofan jet engines is estimated using the proposed models as a case study on the NASA CMAPSS (Commercial Modular Aero-Propulsion System Simulation [2]) dataset [3].

The rest of the paper is organized as follows. Related works are discussed in Section II. The proposed model are presented in Section III. Details about the dataset, pre-processing and performance measures are parts of Section IV. Results and analysis of the proposed models are discussed in Section V followed by Section VI which concludes the work presented.

II. RELATED WORK

Most of the prognostic and health management systems are designed using model-based methods [4], data-driven methods [5] and hybrid methods [6]. This paper mainly focuses on data-driven methods.

Data-driven approaches usually require historical data for training models and they do not rely on much prior expertise on prognostics and are easy to be generalized. Some of the data-driven approaches include the traditional multi-layer perceptron [7] approach for modeling the RUL of the laboratory-tested bearings which reported the prediction results superior to the reliability-based approaches. Neural network (NN) [8] approach for modeling RUL from degradation signals because

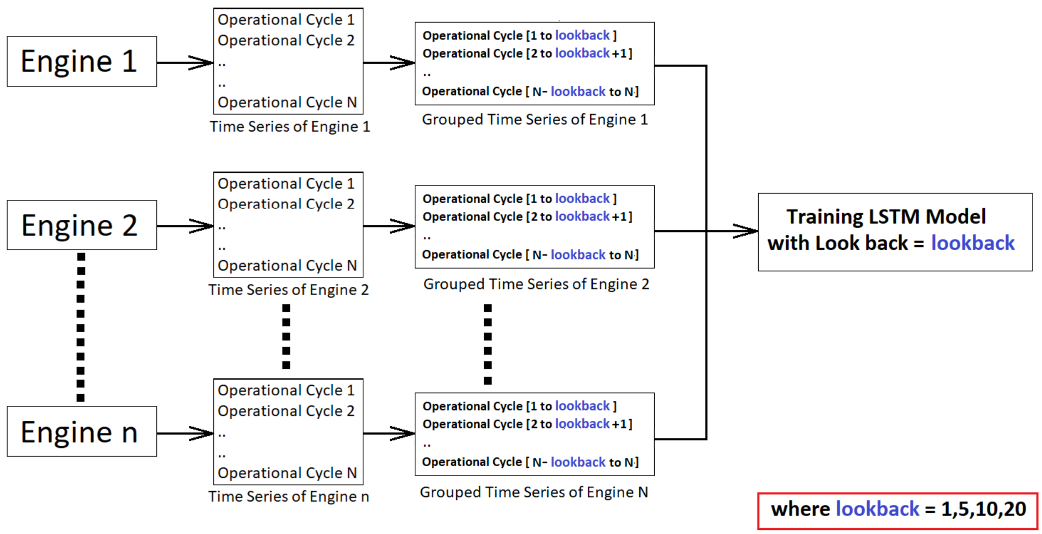

Fig. 1. Flow diagram for training LSTM Model.

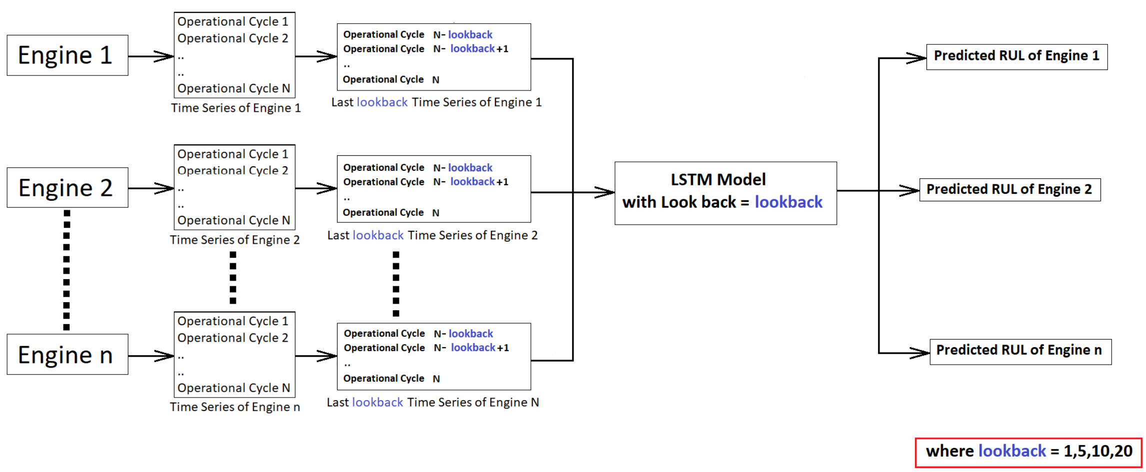

Fig. 2. Flow diagram of LSTM Model for RUL Prediction.

of vibrations and validation using real-world vibration monitoring data collected from pump bearings in the field which achieved more accurate RUL predictions. In [9] support vector machine (SVM) approach to predict RUL of bearings using the isometric feature mapping reduction technique (ISOMAP) is proposed. Support vector regression (SVR) and effectively modeled the evolution of the degradation, fault diagnosis and RUL estimation using LSTM neural network which diagnoses and predicted performance in the cases of complicated operations, hybrid faults and strong noises, is presented in [10]. Deep Convolution Neural Networks (DCNN) for RUL prediction is proposed in [11]. The hidden Markov model is proposed in [12] by developing a statistical modelling methodology for performing both diagnosis and prognosis in a unified framework based on segmental hidden semi-Markov models (HSMMs) for health monitoring of hydraulic pumps.

Most of the research work done towards developing data-driven models for RUL prediction mentioned above demonstrated RUL prediction only for one cycle into the future. Whereas the models proposed in this work are capable of predicting RUL multiple cycles into the future.

III. PROPOSED MODELS

A. Regression Model

Regression-based models are easy to implement [13] and provide a rough lower bound on the performance for models like LSTM neural network and VAR model which are later used in the proposed work to improve the performance.

Regression-based models implemented in this paper include linear regression, logistic regression and random forest regression and they are constructed as follows:

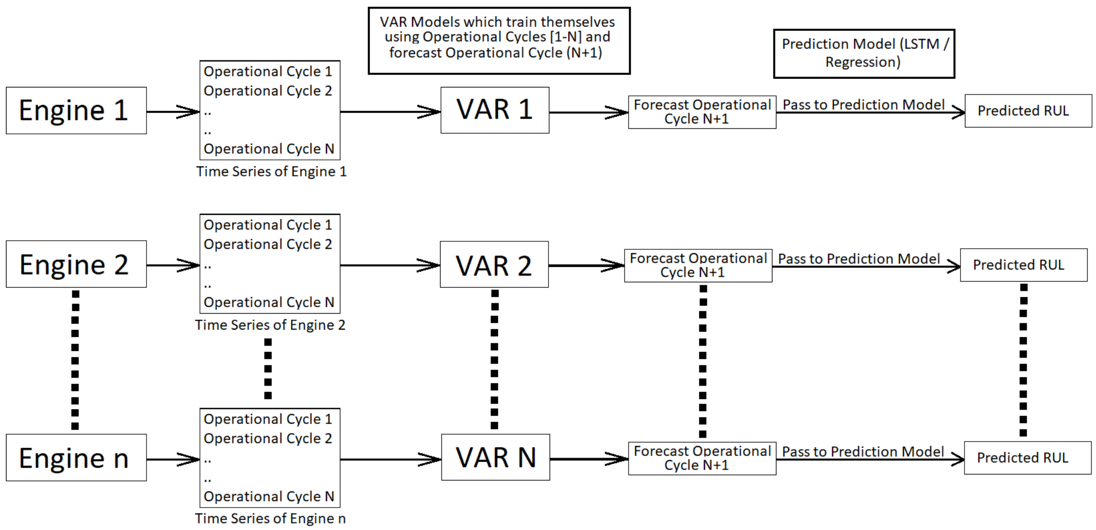

Fig. 3. Flow diagram of Vector Autoregression (VAR) model for RUL prediction.

TABLE I
LSTM MODEL ARCHITECTURE.

Layer	Input shape	Output shape
LSTM	Columns x Lookback	128
LSTM	128	64
Dense	64	16
Dense	16	1

1) Training data and test data are pre-processed as discussed in IV-B.
2) Regression models are trained using time-series of all the engines from training data all at once.
3) Time-series of each engine from the test data is passed to trained models one by one.
4) Final predicted RUL for an engine is taken as mean of all the predicted RULs of entire time-series of that engine.

B. LSTM (Long Short Term Memory) Model

LSTM [14] networks are well suited in time-series forecasting [15] which is an advantage over previously discussed regression models.

1) Model Architecture: LSTM Models used in the proposed work consists of two LSTM layers followed by two dense layers. Multiple LSTM layers are not added to prevent overfitting caused by larger-scale parameters in deeper LSTM networks [16].

The LSTM model architecture details are given in the Table I, where number of columns = number of features in the dataset, and lookback = 1,5,10,20.

Lookback of LSTM cannot be increased beyond 20 because lookback should be less than maximum number of cycles of any engine runs for, and it is observed that minimum of maximum cycles of any engine is 31. Also, increasing lookback leads to slower computation.

Following are the steps for RUL prediction using the LSTM model :

1) Training data and test data are passed through preprocessing modules discussed in IV-B.
2) Time-series of each engine in the training data is grouped according to the lookback and are then used to train the LSTM model.
3) Pre-processed time-series from the test data are grouped according to the corresponding lookback of LSTM.
4) RUL for each engine is predicted by using the last group of (1,5,10 or 20 which are lookback for LSTM) time-series of that engine.

Training of LSTM Model and RUL prediction using LSTM model is shown in Fig. 1 and Fig. 2 respectively.

C. VAR (Vector Autoregression) Model

Vector auto-regression (VAR) is a statistical model used to capture the relationship between multiple quantities as they change over time. VAR generalizes an autoregressive model for multivariate time-series and is used for data description, forecasting, structural inference, policy analysis, etc [17].

For the prediction module, RUL is required to be predicted for the immediate next cycle based on the given past time-series of every engine. Each engine has its own VAR model; therefore, the number of VAR models is equal to the number of engines present in the dataset.

Following are the steps for RUL prediction using the VAR model :

1) Training and test data are passed through pre-processing modules discussed in IV-B and pre-processed training data is used to train LSTM and regression models.

2) Time-series of each engine from the test data is passed to corresponding VAR model which forecasted future time-series one cycle ahead.
3) The forecasted time-series by VAR model is passed to trained regression or LSTM model which calculates RUL and compares it to actual RUL from the dataset.

VAR Model architecture is shown in Fig. 3.

IV. EXPERIMENTAL SETUP

A. Dataset

The NASA CMAPSS(Commercial Modular Aero-Propulsion System Simulation) dataset [3] is used to validate the effectiveness of the proposed models. This dataset consists of time-series of turbofan jet engines along with their remaining useful life. Each time-series consists of the engine ID, current operational cycle, three operational settings and 21 sensor measurements.

Engines start with unknown initial condition and evolve with the progression of their time-series. The engine develops a fault at some point during the series. In the training set, the fault grows in magnitude until system failure. In the test set, the time-series ends some time prior to system failure, and the goal is to estimate the number of operational cycle remaining (RUL) before the system failure.

B. Pre-processing

Pre-processing is divided into two phases, viz, pre-processing datasets and generating RULs for training data which will be used to train the models.

1) Pre-processing datasets: Following are the steps for involved in data pre-processing :

1) **Data Analysis** : To analyse the various statistics like minimum, maximum, standard deviation, etc.
2) **Normalization** : Done using MinMaxScaler.
3) **Noise removal** : PowerTransform is used to remove noise and also shift the distribution of dataset to Gaussian distribution.

It is observed that when both MinMaxScaler and PowerTransform, are used for data pre-processing, supervised machine learning leads to better results [18].

2) Generating RULs for training data: To obtain RUL for the training data :

- In the training set, every engine with a unique Machine ID runs for a particular number of cycles and the engine fails at the end of all these cycles.
- So RUL for every cycle of an engine is defined as: (total number of cycle Engine runs for) - (current operational cycle)

C. Performance Measures

Performance measures used to evaluate various models in this work are Mean Squared Error (MSE), Root Mean Squared Error (RMSE) and Mean Absolute Error (MAE) as shown below: [19].

$$RMSE = \sqrt{(\frac{1}{n})\sum_{i=1}^{n}(y_i - x_i)^2} \tag{1}$$

$$MSE = (\frac{1}{n})\sum_{i=1}^{n}(y_i - x_i)^2 \tag{2}$$

$$MAE = (\frac{1}{n})\sum_{i=1}^{n}|(y_i - x_i)| \tag{3}$$

N = number of data points
y_i = actual observations of time-series
x_i = estimated time-series

V. RESULTS AND ANALYSIS

A. Regression Models

The results obtained by regression models are presented in Table II.

TABLE II
RESULTS OF VARIOUS REGRESSION MODELS.

Regression Model	MSE	RMSE	MAE
Random Forest	3179.90	56.39	49.34
Linear	2747.63	52.41	44.35
Logistic	2454.39	49.54	40.50

Regression models cannot learn from their past inputs. Since the dataset used for this experiment consists of time-series data, results obtained by regression models are not optimal enough.

However, the results obtained by regression models provide a boundary for the performance of LSTM and VAR models. Also, logistic regression in combination with VAR showed better results as compared to logistic regression alone.

B. LSTM Models

The results obtained by LSTM models are presented in Table III and comparison of predicted vs actual RUL for LSTM with lookback of 1,5,10,20 is shown in Fig 4, Fig 5, Fig 6, Fig 7 respectively.

TABLE III
RESULTS OBTAINED BY LSTM MODEL.

Lookback	MSE	RMSE	MAE
1	1082.23	32.89	26.39
5	1854.72	43.06	33.38
10	1694.33	41.16	32.39
20	1629.12	40.36	31.48

It is not possible to create a different model for every engine as LSTM requires a long historical database of measurements [20]. However, number of cycles every engine runs is very short (between 200-250) which is insufficient to train different LSTM model separately for every engine.

Lookback can not be increased beyond a certain value, and thereby LSTM models cannot take full advantage of the entire

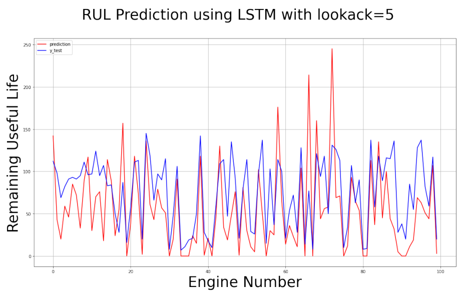

Fig. 4. LSTM results with Lookback=1.

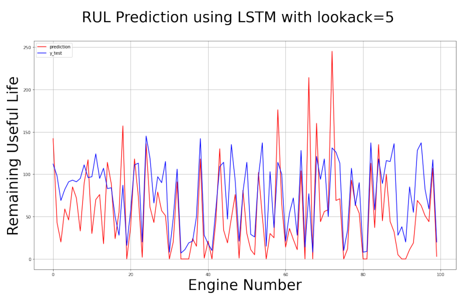

Fig. 5. LSTM results with Lookback=5.

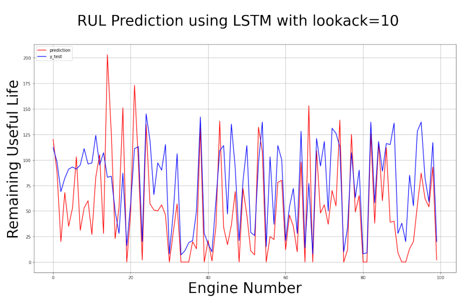

Fig. 6. LSTM results with Lookback=10.

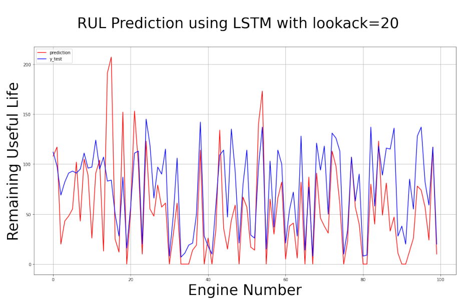

Fig. 7. LSTM results with Lookback=20.

time-series of an engine from the test dataset. RUL for an engine from the test dataset is only based on its last 1,5,10 or 20 time-series. This problem is resolved by using the VAR model which have modifiable order.

Performance of LSTM can be further improved by adding dropout [21] and employing feature optimization techniques such as genetic algorithm [22].

C. VAR Models

The results obtained using VAR models are presented in Table IV and comparison of predicted vs actual RUL for VAR with logistic regression and VAR with LSTM is shown in Fig 8 and 9 respectively.

TABLE IV
RESULTS OBTAINED BY VAR.

Model used to Predict RUL	MSE	RMSE	MAE
Logistic Regression	1262.74	35.53	28.68
LSTM(lookback=1)	861.63	29.35	22.91

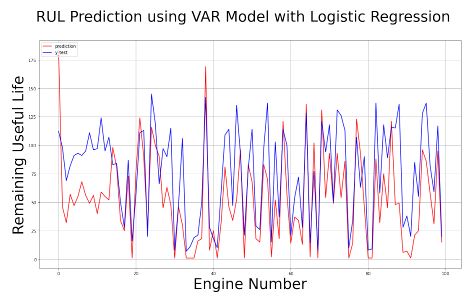

Fig. 8. VAR results with Logistic Regression for RUL Prediction.

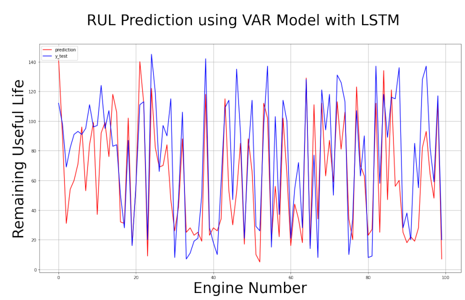

Fig. 9. VAR results with LSTM(lookback=1) for RUL Prediction.

Previously discussed LSTM models suffered the problem of increasing lookback beyond a certain value and thereby LSTM models cannot take full advantage of the entire time-series of an engine from the test dataset. This problem is solved by using autoregressive models which have dynamic order.

VAR model is used along with logistic regression and LSTM with lookback=1 since logistic regression showed better results compared to other regression models and LSTM with lookback=1 showed better results compared to LSTM with lookback=5,10,20.

Lookback=1 for LSTM is compatible with VAR for predicting RUL one cycle into the future based on the past time-series of an engine. LSTM models with greater lookback can be used with VAR if RUL is to be predicted further into the future.

As it can be clearly seen from the above results, VAR performed better as compared to LSTM and regression models alone because of the following reasons :

1) Unlike LSTM, VAR model only requires at least 50 but preferably more than 100 observations [23] for training

and are implemented individually for each engine, as each engine in the dataset has more than 150 observations.

2) Order of a particular VAR for a certain engine depends on the number of cycles that engine has been operating for, unlike LSTM where lookback can not be increased beyond 20.
3) Entire time-series of an engine from test dataset is used in estimating RUL unlike LSTM, where only last 1,5,10 or 20 time-series were used in RUL prediction.

VI. Conclusions

The main motive of this paper was to develop a robust data-driven approach in prognostics and health management for RUL prediction. Various machine learning and neural network models for RUL prediction are implemented and compared. Experiments are carried out on the popular CMAPSS dataset to show the effectiveness of the proposed models. The goal is to estimate the remaining useful life of turbofan-jet-engine units.

With data normalization using MinMaxScaler and noise removal using PowerTransform which shifts the distribution of the dataset to Gaussian distribution, good prognostic performance is achieved by combining VAR with LSTM for RUL prediction method.

Results of linear regression, logistic regression, random forest regression, LSTM with lookback of 1,5,10,20, VAR models in combination with logistic regression and LSTM (lookback=1) are compared. The results of VAR combined with LSTM (lookback=1) has shown better results. The proposed VAR with LSTM for RUL prediction model can also be used to predict RUL multiple cycles into the future by increasing the steps of VAR model. Comparison of performance measures of these models is shown in Fig. 10, Fig. 11 and Fig. 12.

While good experimental results have been obtained by the VAR with LSTM, further architecture optimization is still necessary. Efforts will be made to enhance model performance by using feature optimization techniques such as Genetic Algorithm [22], by adding dropout to LSTM models which had shown to increase model performance [21] and by using scoring function as a performance metric which has been proposed by many researchers [24], [25], [26]. In PHM late prediction are more dangerous than early prediction, which is because late prediction usually leads to more severe consequences in many fields such as aerospace industries. Scoring function takes this asymmetry of late vs. early predictions into account, and penalizes late predictions.

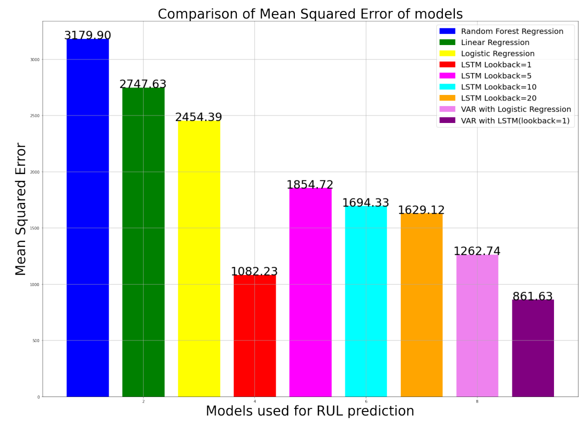

Fig. 10. Comparison of Mean Squared Error of various models.

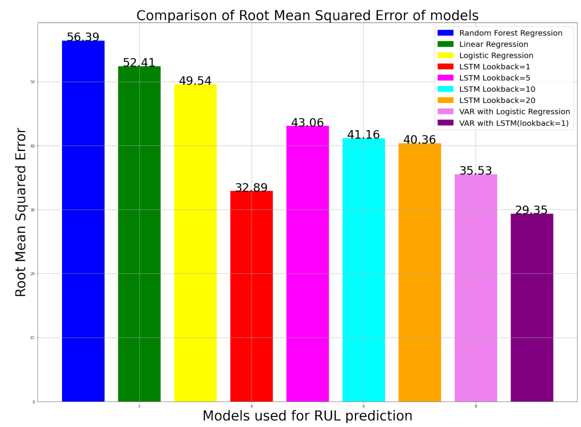

Fig. 11. Comparison of Root Mean Squared Error of various models.

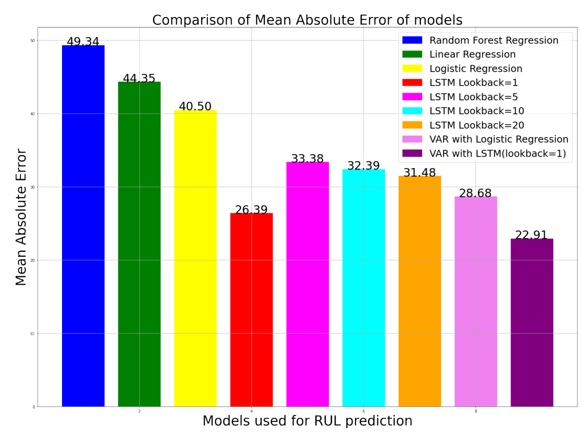

Fig. 12. Comparison of Mean Absolute Error of various models.

References

[1] J. Lee, F. Wu, W. Zhao, M. Ghaffari, L. Liao, and D. Siegel, "Prognostics and health management design for rotary machinery systems—reviews, methodology and applications," *Mechanical Systems and Signal Processing*, vol. 42, no. 1, pp. 314–334, 2014. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0888327013002860

[2] D. K. Frederick, J. A. DeCastro, and J. S. Litt, "User's guide for the commercial modular aero-propulsion system simulation (c-mapss)," 2007.

[3] A. Saxena, K. Goebel, D. Simon, and N. Eklund, "Damage propagation modeling for aircraft engine run-to-failure simulation," in *2008 International Conference on Prognostics and Health Management*, 2008, pp. 1–9.

[4] M. Pecht and J. Gu, "Physics-of-failure-based prognostics for electronic products," *Transactions of the Institute of Measurement and Control*, vol. 31, no. 3-4, pp. 309–322, 2009. [Online]. Available: https://doi.org/10.1177/0142331208092031

[5] F. O. Heimes, "Recurrent neural networks for remaining useful life

estimation," in *2008 International Conference on Prognostics and Health Management*, 2008, pp. 1–6.
[6] A. Heng, S. Zhang, A. C. Tan, and J. Mathew, "Rotating machinery prognostics: State of the art, challenges and opportunities," *Mechanical Systems and Signal Processing*, vol. 23, no. 3, pp. 724–739, 2009. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0888327008001489
[7] R. Huang, L. Xi, X. Li, C. Richard Liu, H. Qiu, and J. Lee, "Residual life predictions for ball bearings based on self-organizing map and back propagation neural network methods," *Mechanical Systems and Signal Processing*, vol. 21, no. 1, pp. 193–207, 2007. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0888327005002165
[8] N. Gebraeel, M. Lawley, R. Liu, and V. Parmeshwaran, "Residual life predictions from vibration-based degradation signals: a neural network approach," *IEEE Transactions on Industrial Electronics*, vol. 51, no. 3, pp. 694–700, 2004.
[9] T. Benkedjouh, K. Medjaher, N. Zerhouni, and S. Rechak, "Remaining useful life estimation based on nonlinear feature reduction and support vector regression," *Engineering Applications of Artificial Intelligence*, vol. 26, no. 7, pp. 1751–1760, 2013. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0952197613000365
[10] M. Yuan, Y. Wu, and L. Lin, "Fault diagnosis and remaining useful life estimation of aero engine using lstm neural network," in *2016 IEEE International Conference on Aircraft Utility Systems (AUS)*, 2016, pp. 135–140.
[11] X. Li, Q. Ding, and J.-Q. Sun, "Remaining useful life estimation in prognostics using deep convolution neural networks," *Reliability Engineering System Safety*, vol. 172, pp. 1–11, 2018. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0951832017307779
[12] M. Dong and D. He, "A segmental hidden semi-markov model (hsmm)-based diagnostics and prognostics framework and methodology," *Mechanical Systems and Signal Processing*, vol. 21, no. 5, pp. 2248–2266, 2007. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0888327006002214
[13] K.-Y. Lee, K.-H. Kim, J.-J. Kang, S.-J. Choi, Y.-S. Im, Y.-D. Lee, and Y.-S. Lim, "Comparison and analysis of linear regression artificial neural network," *International Journal of Applied Engineering Research*, vol. 12, pp. 9820–9825, 01 2017.
[14] R. C. Staudemeyer and E. R. Morris, "Understanding lstm–a tutorial into long short-term memory recurrent neural networks," *arXiv preprint arXiv:1909.09586*, 2019.
[15] S. Siami-Namini, N. Tavakoli, and A. Siami Namin, "A comparison of arima and lstm in forecasting time series," in *2018 17th IEEE International Conference on Machine Learning and Applications (ICMLA)*, 2018, pp. 1394–1401.
[16] K. Xu, H. Wang, and P. Tang, "Image captioning with deep lstm based on sequential residual," in *2017 IEEE International Conference on Multimedia and Expo (ICME)*, 2017, pp. 361–366.
[17] J. H. Stock and M. W. Watson, "Vector autoregressions," *Journal of Economic perspectives*, vol. 15, no. 4, pp. 101–115, 2001.
[18] V. N. G. Raju, K. P. Lakshmi, V. M. Jain, A. Kalidindi, and V. Padma, "Study the influence of normalization/transformation process on the accuracy of supervised classification," in *2020 Third International Conference on Smart Systems and Inventive Technology (ICSSIT)*, 2020, pp. 729–735.
[19] C. J. Willmott, "Some comments on the evaluation of model performance," *Bulletin of the American Meteorological Society*, vol. 63, no. 11, pp. 1309 – 1313, 01 Nov. 1982. [Online]. Available: https://journals.ametsoc.org/view/journals/bams/63/11/1520-0477_1982_063_1309_scoteo_2_0_co_2.xml
[20] T. Boulmaiz, M. Guermoui, and H. Boutaghane, "Impact of training data size on the lstm performances for rainfall runoff modeling," *Modeling Earth Systems and Environment*, vol. 6, no. 4, pp. 2153–2164, Dec 2020. [Online]. Available: https://doi.org/10.1007/s40808-020-00830-w
[21] W. Zaremba, I. Sutskever, and O. Vinyals, "Recurrent neural network regularization," 2015.
[22] P. Ghamisi and J. A. Benediktsson, "Feature selection based on hybridization of genetic algorithm and particle swarm optimization," *IEEE Geoscience and Remote Sensing Letters*, vol. 12, no. 2, pp. 309–313, 2015.
[23] G. E. P. Box and G. C. Tiao, "Intervention analysis with applications to economic and environmental problems," *Journal of the American Statistical Association*, vol. 70, no. 349, pp. 70–79, 1975. [Online]. Available: https://amstat.tandfonline.com/doi/abs/10.1080/01621459.1975.10480264
[24] Z. Zhao, Bin Liang, X. Wang, and W. Lu, "Remaining useful life prediction of aircraft engine based on degradation pattern learning," *Reliability Engineering System Safety*, vol. 164, pp. 74–83, 2017. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0951832017302454
[25] J. B. Coble and J. W. Hines, "Prognostic algorithm categorization with phm challenge application," in *2008 International Conference on Prognostics and Health Management*, 2008, pp. 1–11.
[26] P. Wang, B. D. Youn, and C. Hu, "A generic probabilistic framework for structural health prognostics and uncertainty management," *Mechanical Systems and Signal Processing*, vol. 28, pp. 622–637, 2012.

Sound Sensor to Control Traffic System for Emergency Vehicles

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Abstract - Traffic Congestion is a serious issue in many densely populated cities. Especially during the passage of emergency vehicles in such congestions. This work mainly aims on providing a solution for the emergency faced by the ambulance during such traffic blocking. The implementation needs the usage of sound sensors and monitoring the ambulance to pass traffic signal lanes using Xbee protocol. Fire disaster management prevention can also be the further application of sound detecting sensors.

Index Terms - sound detector, sensors, traffic congestion, Xbee.

I. INTRODUCTION

The increase in human population is an important cause for the drastic increase in the usage of vehicles for transportation, which ultimately started being a reason for the hectic traffic jams in many of the densely populated cities. This congestion causes a delay for the transportation, which increases waiting time. When it comes to overcrowded cities these waiting times become comparatively higher, such higher waiting time for emergency vehicles causes a great impact. Hence, this idea proposes the smart traffic system by clearing jams for emergency vehicles like ambulances by providing green signals on the lane during heavy traffic. This method involves using two sensors for sound detection like Arduino UNO along with the LM393 platform and then uses Xbee protocol (which is a wireless communication protocol) like wi-fi, Bluetooth. The frequency of incoming ambulances is detected with the help of sensors, i.e. frequency of around 700Hz-900Hz. The sensors detect the threshold value of sound in decibels. Once and a while the frequency exceeds the threshold value, which indicates detection of ambulances, and the respective lane is made green providing the necessary delay for the passage of ambulances on the lane completely.

The rest of the paper is followed by related works, which describe the other work done on the traffic control system. Accompanied by a brief explanation of sound detector sensor, which is part of the implementation, and pattern recognition approach to the siren detection clearly explains the working principle of pattern recognition. The proposed work mentions the core functionality followed by implementations representing the execution of the idea. Pin configuration gives the digital design followed by concluding the idea proposed and mentioned the source referred to under references.

II. RELATED WORKS

Detecting the traffic and identifying the presence of emergency vehicles is made available, here the camera plays a major role in detecting the count of vehicles passing. Similarly, camera placement is a crucial step that involves the usage of certain calculations to find the suitable angle for fixing the camera and the optimum height of 25feet. These angles are calculated so that a certain distance is covered and a clear-cut threshold line visible.

Formulas for Calibration of camera:

- Base angle=7° and rise=7.62
- Diagonal=7.62/sin(7)
- Top angle=(90°-7°)=83°
- Base= 7.62/tan(7)

Using image subtraction, the video is compared and finds moving blobs. Then these blobs are analyzed followed by tracking and counting the number of vehicles. If the count exceeds the threshold level the traffic density is estimated. For ambulance detection, the Bluetooth of the ambulance driver is connected which transmits data to the traffic signal and makes the lane green.

IR sensors are used to detect Traffic blocking, by placing them on the roads that find the length of the vehicle and duration of the signal to make way for emergency vehicles. The vehicle drivers are sent with necessary data and instructed to take alternate paths using GSM[7]. The IR sensor notices the volume and density of the traffic, which is controlled by the microcontroller named PIC also alters the transition slot. The magnitude of the emitted light the output voltage varies, IR radiation emitted by the LED travels towards the photodiode[8].

III. SOUND DETECTOR SENSOR

Detection of ambulances can be done in many instance methods the first idea is placing a special transmitter on each emergency vehicle to allow priority passage through intersections. The traffic light controllers at each intersection should be equipped with a receiver and these receivers receive the signal from the transmitter and thereupon regulates the flow of traffic. This method is relatively expensive, and manually actuating vehicles is needed.

The other method is using detectors to detect flashing lights on the traffic light controllers. This technique exhibits some cost and utility advantages since emergency vehicles are normally equipped with flashing lights that are actuated in emergencies. The cost becomes a disadvantage if the special light is detected with a traffic signal controller. There may be a case of false detection since any non-emergency vehicle has no restriction in the use of flashing lights. Hence those private vehicles may be actuated with flashlights. The other scenario also exists where the flashing lights are used in advertising, commercial window displays which may result in false triggers.

The better approach is utilizing the siren sound produced by the emergency vehicle. The cost advantage is conventional since these sirens are equipped in emergency vehicles. These sirens are not embedded in non-emergency vehicles and also these sirens are actuated only during emergency scenarios.

IV. PATTERN RECOGNITION APPROACH TO THE SIREN DETECTION

There exists a periodic alteration of frequency for the siren signal, which is characterized by a modulated-frequency waveform. The lower frequency spectral is dominant among many numbers of the harmonic spectral components. The periodic alteration of the frequency of this dominant component is visualized as a curve based on current frequency and time. Thus the curve generated is called FCC that is Frequency Characteristic Curve. The fig 1 and fig 2 represents the frequency characteristic curve of the siren and a filter-bank placed inside the dominant frequency range of a siren respectively[9].

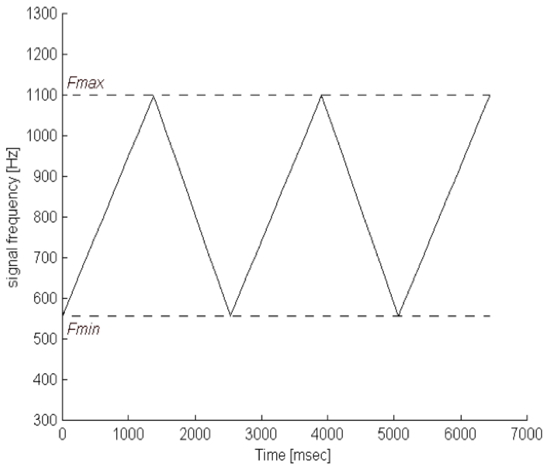

Fig.1 Frequency characteristic curve of the siren.

To identify the siren signal, few points that represent roughly on the frequency characteristic curve, are more than sufficient. Digital filter-bank of narrow band-pass filters is used to obtain those points. With the obtained points whose center frequencies are distributed in the spectral range from Fmin to Fmax.

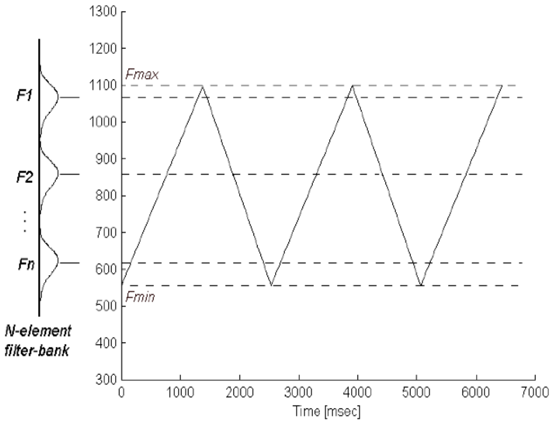

Fig.2 A filter-bank placed inside the dominant frequency range of a siren.

V. PROPOSED WORKS

This implementation of this system uses a sample of four cases where finding the solution ambulance passes through the two ways. The sensor 1 is placed at a distance of 100mts away from the traffic signal and the sensor2 is placed near the traffic lights.
If any ambulance gets detected, State 1 indicates that the ambulance is detected . If no ambulance is detected within the range, State 2 indicates that no ambulance is detected.

Table 1: Four cases for providing the solution for an ambulance heading towards the traffic signal for two ways

Sensor-1 state	**Sensor-2 state**	**Action**
0	0	No ambulance detected and normal traffic operation continues
1	0	An ambulance is detected at sensor1, make the signal green for 150s
0	1	An ambulance is detected at sensor2, continue the lane to be green for 5s
1	1	An ambulance is detected at both sensor1 and sensor2.

Table.1 Four cases involved in the process

VI. IMPLEMENTATION

The implementation includes two sound detecting sensors to detect the frequency of the heading ambulance. These two sensors are connected to an Arduino, hence two Arduino is connected to the sensors and Xbee, a wireless communication protocol is used to relate these two sensors. The first sensor is placed at a distance of 100mts away from the traffic signal and the second sensor is placed at traffic signals. Normal traffic lights operations continue when no ambulance is detected in Sensor1 and Sensor2.

When sensor1 is detected with an ambulance, the respective lane in which it is traveling is made green for a duration of 150 sec for the ambulance to reach sensor 2 which is placed at a traffic signal, and the remaining lane signals are made red. If an ambulance is detected at sensor 2, the green signal for the respective lane where the ambulance is detected is continued with a delay of 5sec for the ambulance to pass the lane completely and the rest of the lanes remains red. When an ambulance is detected in both sensor1 and sensor 2 at the same time, the respective lane is made to green signal for a duration of 5 sec plus an extra 150 sec to make the ambulances pass the lane completely. After the ambulance passes the lane completely the traffic signal resumes its normal operations.

VII. PIN CONFIGURATION

Two Arduino boards are connected with the sensor 1 and sensor 2 respectively. The sensor has three pins namely Vcc pin which is connected to 5V supply of Arduino, ground pin connected to the ground terminal on the Arduino board, and pin 3 and 4 on Arduino 1 and Arduino 2 are connected to an output pin.

Pin 0 and 1 in the Arduino are connected to Xbee transceivers with the Tx and Rx terminal respectively. 3.3V supply of Xbee is given to the 5V supply of Arduino and the ground terminal is connected to the ground terminal of the Arduino board.The fig.3 and fig 4 shows the pin configuration of xbee protocol and arduino uno respectively[10].

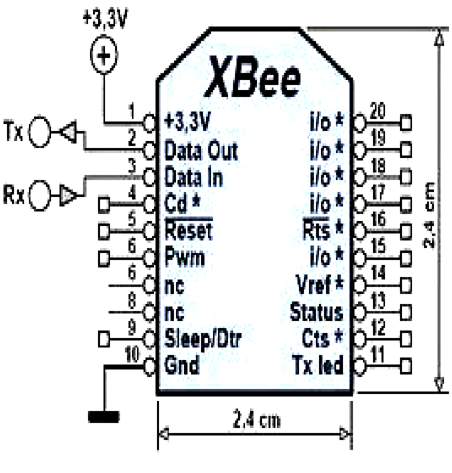

Fig.3 Xbee Pin configuration

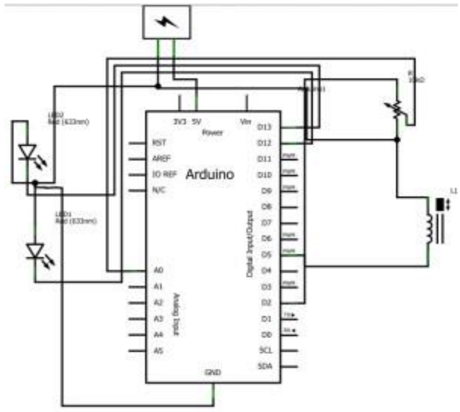

Fig.4 Arduino Pin configuration

VIII. CONCLUSION

The two sensors and Xbee protocol used in this method finds a solution for the existing problem, that is it avoids the waiting time for emergency vehicles in the traffic signals. This model serves as a better option when compared to the usage of other ambulance detecting methodologies, which are either expensive or not accurate in detecting the ambulance on the roads. Hence the utilization of the sound detectors is found to be more actuated since these siren sounds are used only during an emergency situation. The proposed system in the future may be improved and adds many emergency vehicles along with ambulances like a fire truck, police patrol, disaster management, etc and implementation of this system on many lanes of the traffic signal.

IX. REFERENCE

[1] "The Effect of IoT New Features on Security and Privacy: New Threats, Existing Solutions, and Challenges Yet to be Solved". IEEE Internet of Things Journal. **6** (2): 1606–1616 Zhou, Wei; Jia, Yan; Peng, Anni; Zhang, Liu, Peng (2019).

[2] Acharjya, D.P.; Ahmed, N.S.S. (2017).Recognizing Attacks in Wireless Sensor Network in View of IoT". In Acharjya, D.P.; Geetha, M.K. (eds.). Internet of Things: Novel Advances

and Envisioned Applications. Springer. pp. 149–50.

[3] Ujaley, Mohd (25 July 2018).”Cisco to Invest in Fiber Grid, Internet of Things, Smart Cities in Andhra Pradesh”.

[4] Kushalnagar, N.; Montenegro, G.; Schumacher, C. (August 2007). IPv6 over Low-Power Wireless Personal Area Networks (6LoWPANs): Overview, Assumptions, and Goals.

[5] "San Jose Implements Intel Technology for a Smarter City". *Intel Newsroom*. Retrieved 11 July 2014.

[6] M. Wijerathna Basnayaka, Chathuranga. "Internet of Things for Smart Cities".

[7] Shilpa S. Chavan, Dr. R. S. Deshpande & J. G. Rana (2009), Design of Intelligent Traffic Light Controller Using Embedded System Second International Conference on Emerging Trends in Engineering and Technology, pp 1086-1091.

[8] Bilal Ghazal, Khaled EIKhatib, Khaled Chahine, Mohamad Kherfan, Smart Traffic Light Control System, Third International Conference on Electrical, Electronics, Computer engineering and their Applications,2016.

[9] A Siren Detection System based on Mechanical Resonant Filters by Dimitris K. Fragoulis andJohn N. Avaritsiotis

[10] Xbee and Arduino, “Building Wireless Sensor Networks: with ZigBee, XBee, Arduino, and Processing 1st Edition”, by Robert Faludi.

Internet of Things: A Review on Machine Learning-based Intrusion Detection System

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Abstract—**The Internet of Things (IoT) connects billions of interconnected devices that can exchange information with each other with minimal user intervention. The goal of IoT to become accessible to anyone, anytime, and anywhere. IoT has engaged in multiple fields, including education, healthcare, businesses, and smart home. Security and privacy issues have been significant obstacles to the widespread adoption of IoT. IoT devices cannot be entirely secure from threats; detecting attacks in real-time is essential for securing devices. In the real-time communication domain and especially in IoT, security and protection are the major issues. The resource-constrained nature of IoT devices makes traditional security techniques difficult. In this paper, the research work carried out in IoT Intrusion Detection System is presented. The Machine learning methods are explored to provide an effective security solution for IoT Intrusion Detection systems. Then discussed the advantages and disadvantages of the selected methodology. Further, the datasets used in IoT security are also discussed. Finally, the examination of the open issues and directions for future trends are also provided.**

Keywords—***Machine Learning, Deep Learning, Intrusion Detection, Internet of Things, Network Security.***

I. Introduction

With the exponential growth of IoT applications, approximately 20.4 billion devices online in 2020, and the number expected to increase by 75 billion by the end of 2025. Different sensors embedded in IoT systems allow them to acquire and process data remotely in real-time. The data obtained from the sensors help them to make intelligent decision-making systems and handle IoT environments effectively [3]. Users can control their devices from anywhere, anytime, which leads to the vulnerability of multiple threats. Security threats that are harmful to Users are (1) Unauthorized access to personal information and misuse of it; (2) endorsing attacks on other systems; and (3) growing security risks [1]. IDSs are required to keep the IoT networks protected and available to detect intruders. IoT devices have limited computation and power resources (bandwidth, battery, memory, and computation), so a complex Intrusion Detection System (IDS) cannot be implemented.

It is becoming imperative to improve research in this field of detecting intrusion in computer networks. Denial of service (DoS) is an acute devastating attack that blocks legitimate customers from accessing the resources they have paid [4], which breaches the terms of the Service Level Agreement (SLA), which results in enormous monetary damages for businesses and organizations. Besides, DoS also impacts small networks, such as smart houses, intelligent healthcare systems, intelligent agriculture systems, etc. [2]. DoS attacks that affect vital, intelligent applications such as healthcare can also lead to human death, as regular services are delayed. IoT gadgets (e.g., air conditioners, smart refrigerators, and smart televisions) are easily targeted by attackers who manipulate their flaws to carry out DoS attacks [4]. Thus, one of the essential issues for researchers today is to protect these devices. Intrusion detection is investigated worldwide to resolve this issue. Based on the detection, IDS are divided into signature-based, Specification-based, and anomaly-based.

In signature-based methods, when the device or network activity analyze an attack based on the signature stored in the internal IDS databases, IDSs attack detected. A warning will be activated if some device or network operation correlates with stored patterns/signatures. In identifying identified threats, this method is reliable and very successful, and its mechanism is simple to understand. However, to classify new attacks and discrepancy of existing threats, this strategy is unsuccessful since a corresponding signature is still unknown for such attacks [3, 4].

Anomaly-based IDS measures a system's operations to a standard behavior profile and produces an alarm if a normal behavior variance crosses a threshold. However, it seems that it does not adhere to a normal pattern to classify an intrusion, and understanding the full spectrum of normal behavior is not a straightforward process. This method is useful in identifying new threats. Typically, therefore this approach has false-positive rates very high [3-5].

The specification-based method is a collection of rules and thresholds that describe network modules such as routing tables, protocol, and nodes as expected behavior. Intrusions are observed by specification-based methods as network activity deviates from specifications definitions. Therefore, the same goal of anomaly detection is given to specification-based detection: to recognize anomalies from behavior normal. However, one crucial distinction between these methods is in the specification-based technique; each specification's rules should be specified by a human expert manually [1-5]. Compared with anomaly-based identification, manually defined parameters typically have lower false-positive rates. Specification-based detection systems, however, do not need a training process because they can start operating directly after setting up the specification [4].

In a popular application for detecting network attacks like IoT networks, ML/DL-related techniques have recently acquired a reputation. So, in IoT environments, ML/DL-based approaches can monitor benign and anomalous activity.

Network traffic was collected and investigated to understand regular patterns used in IoT devices. To detect abnormal behavior, any divergence from these normal trained behaviors can be used to forecast zero-day or new attacks by ML/DL-based approaches that have been studied. This paper focuses on various strategies to detect anomaly-based intrusion detection by ML/DL techniques.

The remaining study is structured as follows. Section 2. Discussion about the research work that uses the traditional and new ML/DLtechnique to IoT networks and discusses relevant literature-related contributions to IoT IDS methods. Section 3. presents some datasets that are widely used. Section 4. illustrates the discussion on an open challenge and future challenge to IoT security. Finally, Section 5 states conclusions for research in IoT security.

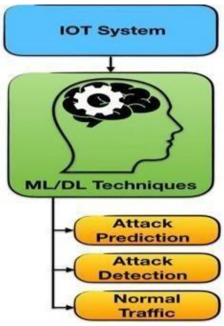

Fig 1. Role of ML/DL based IDS for IoT System

A. Motivation

Recently, a lot of work has been done related to IoT devices and gained attention that makes human activities easier, also use in the academic field and even within the industry. IoT is a possible option for improving people's quality of life (e.g., a smartwatch that tracks health through its sensors, smart home), and a variety of innovations have become desired with the drop in sensor costs, due to the remote storage facilities, and significant data IoT devices become popular. Simple access to such services explicitly reinforces IoT by integrating devices with various resources to a network, thereby leading to new applications [3]. A price has appeared less, so there is a need for security. Besides, there is doubt about the degree of trust in the data collected from IoT products, and how or when this knowledge can be used is one of the reasons for research [5].

Different surveys have presented numerous techniques for modeling IDS for IoT applications; however, several surveys have not comprehensively addressed ML / DL methods implementation to detect IoT intrusion. The main objective of this analysis is to compile recent works and discuss various methodologies.

II. RELATED WORK

This module has introduced a literature survey that uses modern and conventional algorithms focused on ML/DL algorithms to cope with IoT environments' security problems. The so-called "Systematic Review Literature" (SRL) was followed in the context of collecting the work considered in this survey. Methods can be defined, analyzed, and interpreted meaningfully using SRL methodology.

The use of ML to promote defense and identification in IoT systems has become increasingly necessary in recent years to tackle the previously mentioned challenges. In terms of security problems in IoT-based systems, overlooked too many works that used the ML and DL algorithm. In the last few years, the DL algorithm has also gained tremendous interest. DL algorithm is relevant to intrusion detection in networks.

A. ML Techniques for IDS

In this section, a summary of the various ML approaches used in IoT-based IDS environments is discussed. Table 1 presents a concise overview of the ML approaches, their benefits, and drawbacks. Fig 2 describes the ML methodologies used for detecting IDSs in an IoT environment.

K-Nearest Neighbour (KNN) is a nonparametric approach. The Euclidean distance is used as the distance metric by the KNN classifier. KNN method is used to detect new sample data into various categories based on the number of closest maximum neighbours from each class. A significant step in deciding the optimum value of k for a taken dataset is to evaluate various k values at the cross-validation time. Even though the KNN classifier is a basic algorithm for classification and efficient for the large training dataset, obtaining the feasible value of k may be a difficult and time is taken process. In [6] author suggested a model for the identification of R2L and U2R threats.

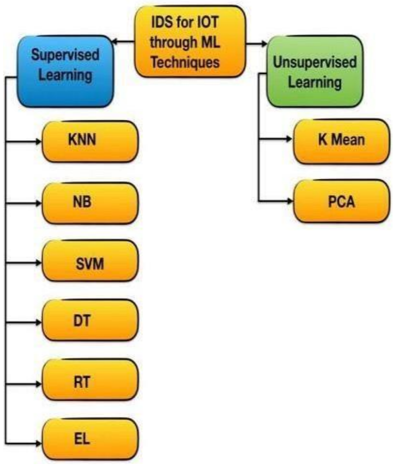

Fig.2.ML Methodologies for IoT based IDSs

The algorithm decreased the dimensionality of the features to improve reliability by using two feature reduction levels and then added a two-tier classification model using NB and KNN classifiers; this model showed promising results for detecting attacks.

Naïve Bayes (NB) classifier uses Bayes' theorem to estimate an occurrence based on prior observations of related events. This can be used in ML scenarios to distinguish normal and unusual behaviors based on previous findings in the supervised learning model. NB estimates the later likelihood, and a labeling determination to mark unlabeled traffic as normal or anomalous is taken based on that. An independent collection of observed traffic features such as status flags, protocol, and latency are used To estimate the possibility of traffic being regular [10]. Different IDS have used the NB method to classify abnormal traffic as it is quick and fast to incorporate an algorithm. In [7] author suggests that DoS threat identification is correlated with traffic information from the network. It needs relatively few training samples and can be categorized into both binary and multi-label classifications. NB classifiers are unable to capture valuable information from the associations and interactions between characteristics.

Interactions between characteristics can be critical for precise classification in complex samples. Inter-relation between characteristics can substantially help the method increase its ability to distinguish between classes.

Support Vector Machine (SVM) is another classifier method that operates on two or more classes' features through the formation of a hyperplane. SVMs are useful for use when classes with a broad set of features need to be categorized based on smaller data samples. SVM can create a hyperplane that delivers optimum margin. The strengths of SVMs are their flexibility and their ability to detect intrusions in real-time and change training patterns. However, it is essential to explore the output of SVM with large databases and datasets that are generated in multiple conditions and scenarios [8]. Another gain of using SVM is its lower memory/storage consumption. In separate research studies [9], the use of SVM in IDSs in an IoT method was tested, where SVM gives more precise results in comparison to other ML classification methods, including NB and RT. However, it remains a challenge to obtain the necessary classification using the ideal kernel function used in SVM to isolate the data sample, which is not linearly separable.

Decision Trees (DTs) collects sample characteristics from a dataset and arranges a tree based on feature value. Each of the features is classified by a tree node, and the branches from a node denote subsequent values. The tree's root node is known to be any function node that optimally splits the tree into two. Various metrics are used to define the origin node, which separates training datasets such as the Gini index and Information Gain optimally [10]. DTs have the ability to be used as classifiers in the field of intrusion detection. However, attention must be given to elements of more significant storage needs and computing complexity. An analysis reported in [10] in the IoT environment has used DT to classify DDoS attacks by evaluating network traffic to identify abnormal sources.

Random Forest (RF) is used to predict more precise and error-tolerant classification outcomes; an RF is constructed using multiple DTs. Randomly built DTs are trained on voting-based performance classification. Although DT can be viewed as RF, there are different algorithms for classification since RF creates a rule- subset using all member DTs, unlike DT, which constructs a rule through training to classify new data points. This result is a more stable and precise performance that tackles the overfitting and requires considerably fewer inputs, and does not need the feature selection process [12]. RF is ideal for intrusion detection in IoT networks, as suggested by several studies. Another research [13] has shown that RF in IoT networks is giving better results than KNN and SVM in DDoS classification because it needs fewer inputs. However, in particular, in real-time detection in which the necessary training dataset is large, the use of RF could be inefficient because RF requires the development of many DTs.

Ensemble Learning (EL) combines all the outputs of various simple classification methods to generate a combined output and enhance classification efficiency. To achieve a final answer, the EL goal to merge different or same multi-classifiers [11]. However, since EL contains multiple classifiers, the computation of an EL-based system is more than that of a single classifier-based system, leading to an increase in time complexity. For anomaly-based intrusion detection and malware detection [11-13], EL was used effectively. A previous study [13] shows that it is possible to reduce the time complexity of models to make it acceptable for devices with minimal hardware resources in IoT devices. Different experiments have tested the effectiveness of EL for intrusion detection.

K- Mean Clustering is an unsupervised algorithm focuses on the identification of k cluster in datasets. Each class of sample data is allocated to a specific cluster according to its characteristics. Data points are distributed on k clusters based on their behavior using the squared Euclidean distance. The recomputation of the centroids is then done by calculating the mean of the data points assigned to that cluster. The method proceeds iteratively until no improvements can be made to the clusters [14]. The specification of k and presumption are taken value is that the dataset will be spread uniformly on the k clusters serve as drawbacks for this algorithm. Recent research discussed in [14] indicates the use of a k-means clustering algorithm to detect anomalies by measuring the similarity of features.

Principle Component Analysis (PCA) is a feature selection or feature reduction technique used to convert a large dataset of features into a minimal set to retain much of the details in the dataset and is not an anomaly detection technique. After reduction, the identified feature can be used with specific other ML classifiers to identify anomalies on the IoT network [14-15].

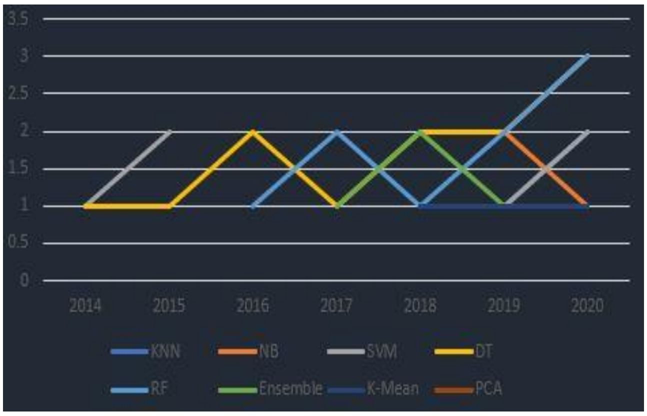

Fig.3. Machine Learning based IDS publication in IoT over years

Fig.3 shows statistical results on different ML algorithms-based publication in IoT IDS up to December 2020 which is still increasing.

B. DL Techniques for IDS

The implementation of the DL algorithm in IoT devices has recently been an essential focus of research [42]. It gives good performance in massive datasets is the most significant benefit of DL over conventional ML. Many IoT systems generate a vast volume of real-time data; hence, DL methods are sufficient for such systems [16, 17]. Various DL-based strategies used for constructing an IDS are described in this section. Table 2 shows a research study using different DL-based approaches to develop IDS. In the respective sub-sections below, details about research work are explained with the several DL methodology.

Convolutional Neural Network (CNN) is used to reduce the amount of sample data inputs needed for a traditional neural network using equal representation, sparse interaction, and parameter sharing [16]. CNN consists of a three-layer convolutional layer, pooling layer, and activation unit. For convoluting data inputs, the convolutionary layers use separate kernels [18].

Samples are reduced by the pooling layers, minimizing the sizes of successive layers through Max pooling and average pooling. CNN is applied for extracting highly effective and fast features from raw data, but CNN needs high computing capacity at the same time. Using CNN in resource-constrained IoT systems is therefore incredibly difficult for their security. In prior research published in [16- 18], malware detection and use in IoT environment protection were addressed.

Recurrent Neural Networks (RNNs) is also DL based discriminative algorithm that is ideally designed for a system where sequential processing of sample data is necessary. Unlike other neural networks, instead of forwarding propagation, its performance depends on backpropagation [19]. In the IDS design, long short-term memory (LSTM) network systems are used for RNN. The primary attribute of this is that information survives for later network use. This purpose makes them ideal for conducting temporal data analysis that varies over time. LSTM is also solved time-series sequence data related to anomaly detection. Various types of RNNs, including LSTM-based RNNs, were used by researchers in [20] intrusion detection in IoT networks. Although RNNs have shown encouraging results in forecasting time series data, it is still challenging to identify anomalous traffic using these predictions.

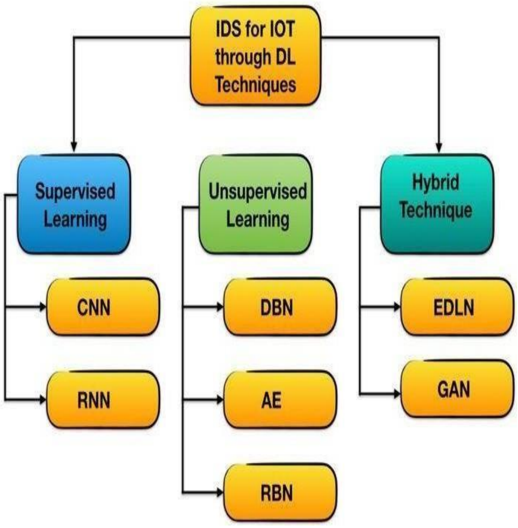

Fig 4. Taxonomy of DL techniques for IoT IDS

Deep Autoencoders is an unsupervised algorithm designed to replicate its input samples to its output through a function, and a code contains hidden layer descriptions used for input presentation [21]. In an Autoencoders (AE) neural network, the other function is known as the encoder function. It is defined for translating the information represented into code where reconstruction errors should be reduced during preparation [22]. Feature extraction from the datasets is one use case for AE. These suffer from the need for high computing capacity. It gives better accuracy than SVM and KNN for detecting network malware [22].

Restricted Boltzmann Machine (RBM) generates a generative, undirected model. In every layer of an RBM, there are no two nodes that have any relation with each other. The two kinds of layers that compose an RBM are visible and hidden layers. The predetermined input parameters are found in the visible layer, while multiple layers comprising the hidden layer are included in the possible unknown variables. Features derived from a dataset are then moved on to the next layer. A survey [23] shows that RBN is used to detect Intrusion detection in IoT networks. RBN requires high computing resources, so it is challenging to implement in IoT devices.

Deep Belief Network (DBN) is an unsupervised learning-based generative algorithm that can be formed by stacking two or more RBNs. In the pre-training process for each layer, initial features are extracted, then a fine-tuning step where the implementation of the softmax function layer is performed on top of the layer. It consists basically of two layers, namely the visible layer and the hidden layer. At the same time, the research in [24] addressed the detection of malicious attacks

using DBN and gave better results than most of the ML algorithms. The Generative Adversarial Network (GAN) uses generative and discriminatory models for training [17]. The generative model learns and generates data samples from the distribution of data, and the discriminative model estimates the probability that an input sample is generated from the training dataset rather than the generative model. The goal of training this model to increase the likelihood that the discriminative model misclassifies the sample. The discriminative output model lets the generative model boost the input samples produced for the previous iteration. The research published in [25] addressed the GAN algorithm's effectiveness to detect suspicious behavior in IoT systems with positive findings due to their potential to counter zero-day attacks by producing samples that imitate zero-day attacks, then enabling the discriminator to train various scenarios of attacks. The difficulty of using GAN, however, is that its preparation is challenging and creates unpredictable outcomes. Ensemble of DL Networks (EDLN) is a collection of DL algorithms that can perform better than algorithms applied independently.

It is possible to obtain EDLNs by combining generative, discriminatory, or hybrid ones. Further studies and analysis are necessary to use the EDLN to IoT security to determine the likelihood of enhancing the IoT system's efficiency and accuracy to resolve a challenge due to computation complexity [16-25].

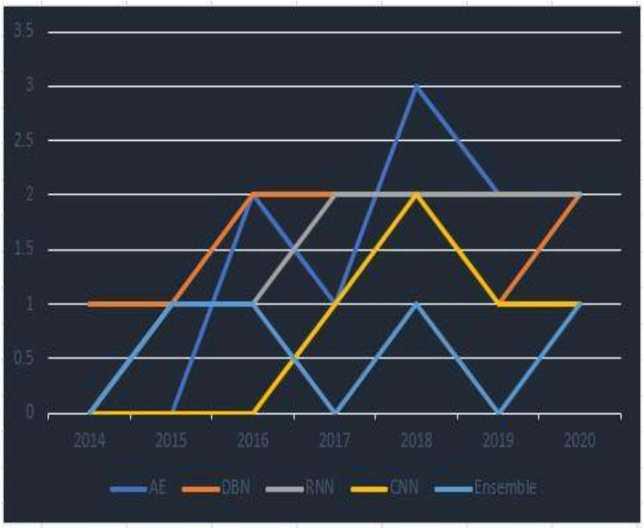

Fig.5. Deep Learning based IDS publication in IoT over years

Fig.5 shows statistical results on different DL algorithms-based publication in IoT IDS up to December 2020 which is still increasing.

Table.1 ML-BASED TECHNIQUE FOR IOT IDS

ML Methods	Attack Type	Advantages	Disadvantages
NB[7,10]	HTTP attacks (Shell attacks, Buffer overflow), Probe, DoS, R2L	• Fewer samples are required for training. • Classify both multi-label and binary classification. • For irrelevant features, it shows the robustness	• It fails when the features are interdependent, which affects its accuracy.
KNN[6]	U2R, R2L, Flooding attacks, DoS, DDoS	• Easy to use.	• Determining the best K value and finding missed nodes are challenging problems.
DT[10]	DDoS, U2R, R2L	• Simple and easy to use.	• It requires extensive storage and computationally complex • It is easy to use only if fewer DTs are constructed.
SVM[8,9]	Scan, DDoS (TCP, UDP flood), smurf, port sweep	• SVMs are incredibly versatile so that they can handle real-time tasks like anomaly-based intrusion detection and online learning. • SVMs are thought to be appropriate for data with a broad range of feature attributes. • SVMs consume fewer resources and storage.	• Achieving the desired classification using the optimum kernel function in SVM, which is used to separate data when it is not linearly separable, remains a problem. • SVM-based models are difficult to understand and analyze.
RF[12,13]	DoS, U2R, Probe, R2L	• It generates a more reliable and precise output that is less prone to overfitting. • It needs much fewer inputs and does not necessarily require the feature selection process.	• • Since RF produces several DTs, it can be inefficient to use in real-time applications that require a large dataset.
K-Mean[14]	DoS, Probe, U2R, R2L	• Labeled data are not required in k-Mean.	• It is less effective than supervised learning methods at predicting known threats.
PCA[14-15]	It combines with another classifier to detect Dos attack	• PCA is appropriate when the dataset contains a large number of variables since it reduces the number of features without compromising any details.	• Reduces the complicated amount of data. • It isn't a process for analyzing abnormalities. It must be associated with other machine learning approaches to construct a security model.

Table.2 DL BASED TECHNIQUE FOR IOT IDSs

DL Techniques	Attack Types	Advantages	Disadvantages
RNN[19,20]	R2L, DoS, U2R, and Probe and predict the anomalies in time-series data	Best suited in a scenario where data is to be processed sequentially. The IoT device environment can generate sequential data in certain situations. As a result, RNNs are appropriate for IoT protection.	The most challenging aspect of using RNNs is dealing with vanishing or exploding gradients, which makes it challenging to learn long data sequences difficult.
CNN[18]	Malware attacks	CNN is ideally suited for extracting highly effective and fast features from raw data. CNN can learn behavior automatically from raw network security data, and they may be useful in IoT security.	CNN takes a lot of processing capacity, so using it for authentication on resource-constrained IoT devices is difficult.
Deep Autoencoders[21,22]	Malware attacks Botnet attacks	AEs have been used to extract features and reduce dimensionality with incredible results.	AEs are computationally powerful. and does not yield desired effects if the training dataset is not similar to the testing dataset
RBM [23]	R2L, DoS, U2R and Probe	RBMs' feedback feature makes it easier to retrieve essential attributes, which are then used to capture IoT traffic behavior.	RBMs require a lot of computational power, and they can be implemented on low-power IoT devices. A single RBM is incapable of representing features.
DBN[24]	R2L, DoS, U2R and Probe	With training on unlabeled data, it's ideal for extracting critical features.	DBNs require high computational costs.
GAN[25]	Botnet (Mirai, Bashlite), Scanning, MiTM	Detection of unknown threats.	It produces unstable results, and training is difficult
EDLN[16-25]	Malware, DoS, Botnet, MiTM	EDLNs perform better in an unpredictable scenario with prominent features, so an ensemble of DL classifiers will improve model efficiency.	EDLNs are computationally heavy and complex.

III. DATASET

This section discusses frequently used datasets in IoT networks for IDS are KDDCUP99, UNSW-NB15, and NSL-KDD. Table 3 gives an overview of the advantage and disadvantages of the most common datasets for the IDS evaluation. Then Fig.6 and Fig.7 shows the accuracy of the ML/DL Model on the NSL-KDD dataset.

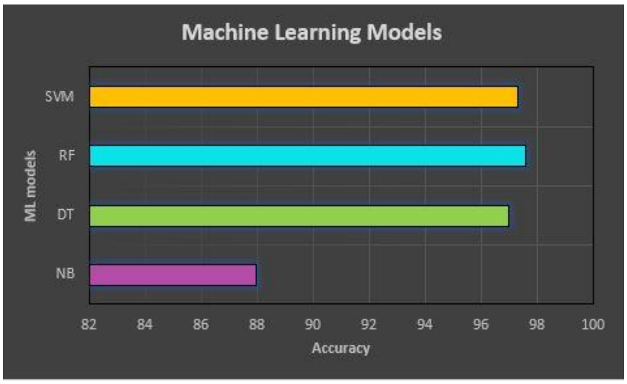

Fig.6. accuracy of the ML Model

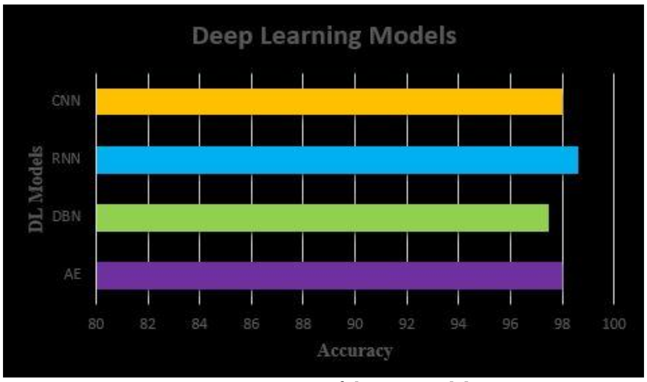

Fig.7. accuracy of the DL Model

The comparative study applied on the NSL-KDD dataset on binary classification, which had 41 attributes and one class attribute. The four categories of attacks are Denial of Service (DoS), Probe, Remote to Local (R2L). User to Root (U2R).

Table.3 IOT DATASET USED FOR IDS

DATASETS	ADVANTAGES	DISADVANTAGES
KDDCUP 99[26]	The dataset contains Labelled data. Based on 41 features for each connection, along with the class label. Implements Probing attacks, Denial of Service, User to Root, and Remote to User,	KDD99 suffers from unbalanced classification methods. Dataset does not contain updated attacks.
NSL-KDD [26]	Better than KDDCUP99 Overcome KDDCUP99 limitations	Lack of modern attack
UNSW-NB15[26]	Generate network traffic CSV files and (PCAP). It consists of nine types of attack, namely, Analysis, Fuzzers Backdoors, Dos, Reconnaissance, Exploit, Worms, Generic, and shellcode	It is complex than the KDD99 dataset due to the modern attack's similar behaviors and normal network traffic.

IV. CHALLENGES AND FUTURE SCOPE

Concerns regarding data security vulnerabilities are increasing with the development of IoT. The problem is that no standard framework exists that ensures the validation of the proposed systems. The research work primarily illustrates the estimation of their methods that has been presented in IoT systems based on their implemented datasets and discusses one particular issue that does not work on actual data in the real world and the presence of the other problems. It is challenging to develop an IDS that covers most of the essential aspects of an IDS, i.e., it is deployable, flexible, online, operates efficiently on actual data, and meets all stakeholders' specifications. Instead, much of the published literature shares the assessment test findings based on the constructed datasets, covers some or fixed parts of the method, and uses biased criteria to display results.

The most recent intrusion detection problems that occur in IoT networks are discussed:

It is demanding to create a real-time detection system for anomaly detection for IoT networks. This is because such an IDS will involve understanding normal behavior to predict suspicious or abnormal behavior first. The learning process implies no external attack or attack traffic that cannot be assured during this time. Such an IDS will produce high false alarms if these issues are not dealt with.

The various stages required in the designing and executing IDS, such as feature reduction, data preprocessing, and model preparation and implementation, in particular, ML/DL-based techniques for IDS, increase computation complexity. Constructing an effective IDS that is lightweight on computational requirements is another problem and field for future study.

To minimize future risks, it is considered that the need for further research that relies on threat detection becomes a reality in that sense and that their security issues, such as privacy and confidentiality, have been recognized and must be resolved and prevented.

V. CONCLUSION

The Internet of Things (IoT) has the ability to transform the future and get global things into our hands. Therefore, to improve security with time and increasing popularity, complexities, and security, IoT has become a widely explored area that needs to be resolved with new solutions and innovative strategic strategies for unpredictable attacks in the near future. This paper discussed various machine learning and deep learning methodologies for intrusion detection and their advantage and disadvantage, and the study showed that intrusion detection in the IoT is still having a problem. Most techniques can reduce the false positive rate so that training and the classification time increase. On the other hand, specific strategies execute the opposite method, i.e., if the false positive rate is stable, but the expense of a high statistical burden on training and research. Such a problem is of interest to intrusion prevention, where real-time detection is a relevant aspect. This study aims to give researchers a detailed summary of different security issues currently facing IoT systems and potential solutions, with an emphasis on intrusion prevention, focusing on ML/DL-based approaches.

REFERENCES

[1] Tabassum, Kahkashan, Ahmed Ibrahim, and Sahar A. El Rahman. "Security issues and challenges in IoT." In 2019 International Conference on Computer and Information Sciences (ICCIS), pp. 1-5. IEEE, 2019.

[2] Zarpelão, Bruno Bogaz, Rodrigo Sanches Miani, Cláudio Toshio Kawakani, and Sean Carlisto de Alvarenga. "A survey of intrusion detection in Internet of Things." Journal of Network and Computer Applications 84 (2017), pp. 25-37.

[3] Tahsien, Syeda Manjia, Hadis Karimipour, and Petros Spachos. "Machine learning-based solutions for the security of Internet of Things (IoT): A survey." Journal of Network and Computer Applications (2020), p.102630.

[4] Hussain, Fatima, Rasheed Hussain, Syed Ali Hassan, and Ekram Hossain. "Machine learning in IoT security: Current solutions and future challenges." IEEE Communications Surveys & Tutorials 22, no. 3 (2020), p.1686-1721.

[5] Hajiheidari, Somayye, Karzan Wakil, Maryam Badri, and Nima Jafari Navimipour. "Intrusion detection systems in the Internet of things: A comprehensive investigation." Computer Networks 160 (2019), pp.165-191.

[6] Pajouh HH, Javidan R, Khayami R, Dehghantanha A, Choo KK "A two-layer dimension reduction and two-tier classification model for anomaly-based intrusion detection in IoT backbone networks." IEEE Transactions on Emerging Topics in Computing. 2016 Nov 29;7(2), pp.314-23.

[7] Swarnkar, Mayank, and Neminath Hubballi. "OCPAD: One class Naive Bayes classifier for payload based anomaly detection." Expert Systems with Applications 64 (2016), pp.330-339.

[8] Bhati, Bhoopesh Singh, and C. S. Rai. "Analysis of support vector machine-based intrusion detection techniques." Arabian Journal for Science and Engineering 45, no. 4 (2020): 2371-2383.

[9] Y. Liu and D. Pi, "A Novel Kernel SVM Algorithm with Game Theory for Network Intrusion Detection," KSII Transactions on Internet & Information Systems, vol. 11, no. 8, 2017

[10] Goeschel, Kathleen. "Reducing false positives in intrusion detection systems using data-mining techniques utilizing support vector machines, decision trees, and naive Bayes for off-line analysis." In SoutheastCon 2016, pp. 1-6. IEEE, 2016.

[11] Doshi R, Apthorpe N, Feamster N. "Machine learning DDoS detection for consumer internet of things devices," In2018 IEEE Security and Privacy Workshops (SPW) 2018 May 24 (pp. 29-35). IEEE.

[12] Gaikwad DP, Thool RC. "Intrusion detection system using bagging ensemble method of machine learning." In2015 International Conference on Computing Communication Control and Automation 2015 Feb 26 (pp. 291-295). IEEE.

[13] Gao, Xianwei, Chun Shan, Changzhen Hu, Zequn Niu, and Zhen Liu. "An adaptive ensemble machine learning model for intrusion detection." IEEE Access 7 (2019) pp.82512-82521.

[14] Chandrasekhar, A. M., and K. Raghuveer. "Intrusion detection technique by using k-means, fuzzy neural network and SVM classifiers." In 2013 International Conference on Computer Communication and Informatics, pp. 1-7. IEEE, 2013.

[15] Zhao, Shengchu, Wei Li, Tanveer Zia, and Albert Y. Zomaya. "A dimension reduction model and classifier for anomaly-based intrusion detection in the internet of things." In 2017 IEEE 15th Intl Conf on Dependable, Autonomic and Secure Computing, 15th Intl Conf on Pervasive Intelligence and Computing, 3rd Intl Conf on Big Data Intelligence and Computing and Cyber Science and Technology Congress (DASC/PiCom/DataCom/CyberSciTech), pp. 836-843. IEEE, 2017.

[16] Li, He, Kaoru Ota, and Mianxiong Dong. "Learning IoT in edge: Deep learning for the Internet of Things with edge computing." IEEE network 32, no. 1 (2018), pp. 96-101.

[17] Fadlullah, Zubair Md, Fengxiao Tang, Bomin Mao, Nei Kato, Osamu Akashi, Takeru Inoue, and Kimihiro Mizutani. "State-of-the-art deep learning: Evolving machine intelligence toward tomorrow's intelligent network traffic control systems." IEEE Communications Surveys & Tutorials 19, no. 4 (2017): 2432-2455.

[18] Vinayakumar, R., K. P. Soman, and Prabaharan Poornachandran. "Applying convolutional neural network for network intrusion detection." In 2017 International Conference on Advances in Computing, Communications and Informatics (ICACCI), pp. 1222- 1228. IEEE, 2017.

[19] Torres, Pablo, Carlos Catania, Sebastian Garcia, and Carlos Garcia Garino. "An analysis of recurrent neural networks for botnet detection behavior." In 2016 IEEE biennial congress of Argentina (ARGENCON), pp. 1-6. IEEE, 2016.

[20] Almiani, Muder, Alia AbuGhazleh, Amer Al-Rahayfeh, Saleh Atiewi, and Abdul Razaque. "Deep recurrent neural network for IoT intrusion detection system." Simulation Modelling Practice and Theory 101 (2020): 102031.

[21] Mirsky, Yisroel, Tomer Doitshman, Yuval Elovici, and Asaf Shabtai. "Kitsune: an ensemble of autoencoders for online network intrusion detection." arXiv preprint arXiv:1802.09089 (2018).

[22] Al-Qatf, Majjed, Yu Lasheng, Mohammed Al-Habib, and Kamal Al-Sabahi. "Deep learning approach combining sparse autoencoder with SVM for network intrusion detection." IEEE Access 6 (2018): 52843- 52856.

[23] Mayuranathan, M., M. Murugan, and V. Dhanakoti. "Best features- based intrusion detection system by RBM model for detecting DDoS in cloud environment." Journal of Ambient Intelligence and Humanized Computing (2019), pp. 1-11.

[24] Li, Yuancheng, Rong Ma, and Runhai Jiao. "A hybrid malicious code detection method based on deep learning." International Journal of Security and Its Applications 9.5 (2015), pp. 205-216.

[25] Li, Dan, Dacheng Chen, Jonathan Goh, and See-kiong Ng. "Anomaly detection with generative adversarial networks for multivariate time series." arXiv preprint arXiv:1809.04758 (2018).

[26] Choudhary, Sarika, and Nishtha Kesswani. "Analysis of KDD-Cup'99, NSL-KDD and UNSW-NB15 Datasets using Deep Learning in IoT." Procedia Computer Science 167 (2020): 1561-1573.

A Review of Deep Learning Application in Cryptography

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***Abstract*—Deep Learning-based cryptosystem is an emerging field of cryptography with less computational overhead and improved accuracy. 'Deep Learning in Cryptography' is an attempt to study various Deep Learning applications in the field of cryptography. Transforming plaintext into ciphertext requires complex mathematical calculations and an algorithmic approach for making the system more difficult and secure. This additional overhead can be minimized using the concept of data science such as Artificial Intelligence, Machine Learning and Deep Learning. The complex network structure in neural networks makes the system more secure. Deep Learning-based model predictions can be applicable for malware classification, intrusion detection, and multichannel attacks. The efficient feature extraction process can produce an accurate result from the given set of input data. The featured input structure passes through various layered architecture and produces better classification output with good accuracy.**

***Index Terms*—Cryptography,Privacy Preserving,Deep Learning,Intrusion Detection,Artificial Intelligence.**

I. Introduction

Artificial intelligence is an emerging field of computer science capable of performing intelligence tasks as like as human brain. Machine learning and deep learning are a broad category of Artificial intelligence. Machine learning requires structured data as input while deep learning requires layers of a neural network for processing inputs. The Deep Learning approach can be used for model prediction such as image classification, speech recognition, natural language processing and malware detection. The problems which are difficult for human and statistical standards can be solvable by Artificial Neural Networks. Deep learning is the subfield of machine learning and also belongs to the family of Artificial Neural Networks. Artificial neural network receives mathematically designed patterns and images as inputs for processing and produces output in the form of prediction or classification. The observed inputs pass through multiple layers of neural networks and until the attainment of the final output. The applications of stochastic algorithms such as artificial neural network algorithms can be used for encryption and cryptanalysis in the field of neural cryptography. Artificial neural network provides various approaches for data encryption and testing the strength of encryption data. Deep Learning models can be employed in the field of image encryption using Cycle-GAN network[12].

Deep learning approaches can be applied for the detection of multichannel attacks in social networks. Deep learning plays an important role in cryptography. Deep Learning can be applied in the field of cryptography for cryptographic applications such as encryption, malware detection and classification. Deep learning and cryptanalysis are more common than of cryptography and DL. DNA cryptography is the branch of cryptography which employs deep learning approaches for key generation using genetic algorithms with a neural network algorithm [1]. Nowadays, cyber attacks become difficult to detect in a variety of fields such as industry, national defense, and healthcare. Deep learning-based intrusion detection is an alternative solution instead of traditional intrusion detection systems[11] through a deep neural network. Attackers can be able to pretend to be normal users by bypassing known signatures. Deep learning is an alternative to solving these issues. Deep learning extracts intrusion features through training input data. Known signature based attack detection and anomaly detection based on normal use patterns are the two types of intrusion detection system.

The neural network model composed of artificial neurons and nodes in a circuit manner. Artificial Neural Networks and Deep Learning methods are powerful AI techniques for solving complex problems. In Deep Learning approach, the input data passes through various complicated hidden layers and produces a target output. The meaningful results can be produced by efficient feature extraction methods introduced in Deep Learning algorithms. Nowadays, Cryptography and cryptanalysis are the emerging trends of deep learning. Deep learning based cryptosystem, attacks classification, privacy preservation[10] and encryption algorithm analysis are the various research areas in deep learning based cryptosystem. Deep learning based cryptanalysis can be applied in the field of light weight block ciphers.

II. Related works

In [3] introduced chaotic based algorithms to provide secure storage and transmission of images. Encryption algorithm is controlled by the newly introduced heterogeneous

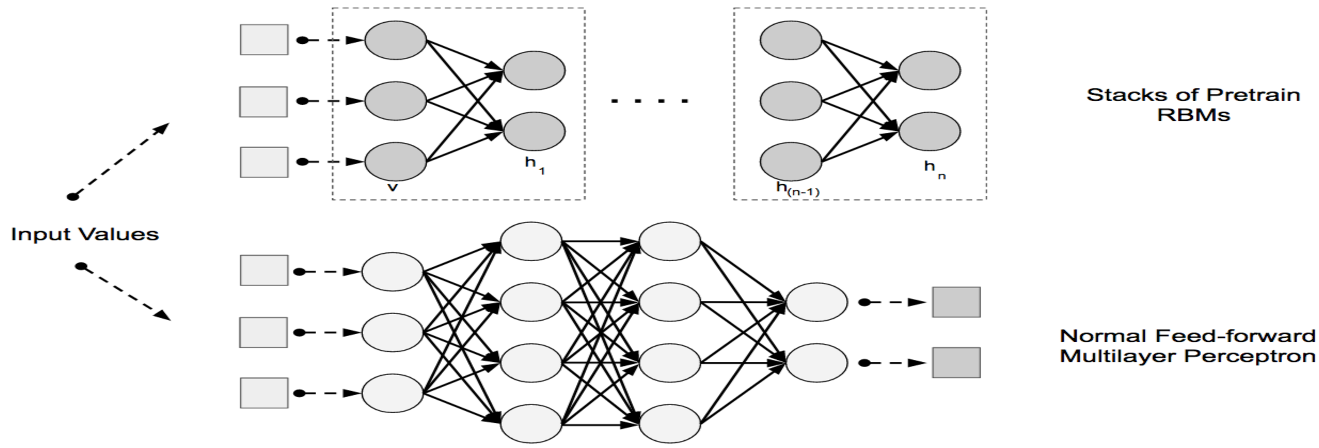

Fig. 1. Deep Learning Layered Architecture.

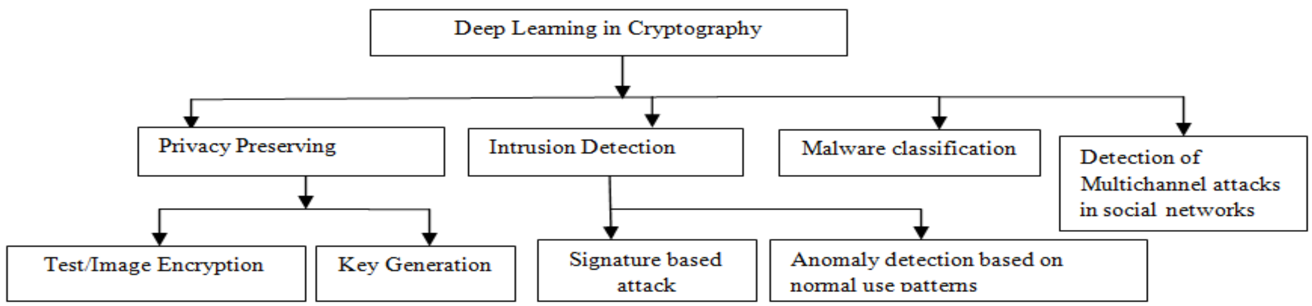

Fig. 2. An Overview of Deep Learning in Cryptography.

chaotic neural network generator. Chaotic generator as input for the operations of DNA based bit substitution and permutations. Degree of randomness is tested based on auto correlation, cross correlation, I/O balance and NIST test. The generation of chaotic sequence depended on the number of neurons in the output layer. Logistic Chaotic Map, Piece Wise Linear Chaotic Map and Logistic-Tent system are introduced in Neural Network layers. The proposed system performs I/O balance on 10 orders best. Histogram analysis is performed by taking 100 encrypted images as input and obtaining the average pixel intensity of 127.46. The ideal value was 127.5. The system provides a better entropy value for encrypted images. The entropy value is compared with other similar works and achieved a high cryptographic quality.

In [2] proposed an integrative approach for DNA cryptography with Deep Learning. Natural selection process of the genetic algorithm for key generation is mixed with Needleman Wunsch algorithm which is capable of finding dissimilarity in DNA strands. The deep learning algorithm generates a complex cryptosystem based on biological operations and human behaviour by using the input key and DNA cryptography [1]. This method increases the security and reduces the mathematical complexity for the formulation of the algorithm. The DNA computing follows symmetric encryption and decryption. The encoded nucleotides are encrypted with a key which is generated through genetic algorithms. The complexity of the algorithm makes the process more secure.

In [4] introduced a deep learning based cryptosystem following auto-encoder neural network for symmetric encryption and decryption. Replicative capability of the auto-encoder forms the key of the sequence of seed values for a symmetric system. This is a pseudorandom process. After the fine tuning process, the sender and receiver can exchange keys. This system proposed an efficient and secure cryptographic algorithm. A sparse auto-encoder is used for encryption and decryption and the learning process is done by a key generator. This encryption process can be applied to multimedia files in the future. In [5] introduced a novel network intrusion detection system based on the Deep Learning model which offers more feasibility and sustainability. This application uses asymmetric stacked deep autoencoder for unsupervised feature learning which is combined with a random forest algorithm. This system was implemented with GPU based TensorFlow, and experimented using the KDD data set. This model offers average accuracy of 95% which is greater than the performance and accuracy of existing techniques.

TABLE I
VARIOUS DEEP LEARNING METHODS IN CRYPTOGRAPHY

Article	Outline of the study	Focused Domain	Learning Architectures
Aldweesh et al.(2019) [8]	Classification for Deep learning based IDS, Compared the performance of the proposed methods through descriptive analysis.	Intrusion Detection(IDS)	AE,RBM,DBN, RNN,CNN
Kalsi, S et al.(2018) [2]	DNA cryptography with Deep Learning for encryption and decryption	Data security	DNN
Tran et al.(2020) [6]	Data privacy among users is implemented, Introduced a secure decentralized training framework.	Privacy preserving	CNN and LSTM centralize
Warit Sirichotedumrong et.al(2019)[9]	A novel approach to pixel based image encryption without key management. Provides protection for visual information.	Privacy preserving	Deep Residual network , DNN
Shone et.al (2019) [5]	Unsupervised feature learning with a non symmetric auto-deep encoder is implemented, which improves the accuracy and performance of the existing techniques.	Network Intrusion Detection.	Deep Auto-Encoders, RF-ensemble learning method.
Francisco Quinga-Socasi et.al (2020)[4]	Symmetric encryption key combines RNN and Deep Learning approaches. The system is evaluated with different cryptographic algorithms.	Symmetric Key Cryptography based on Deep Learning Technique.	ANN
Gururaj Maddodi et.al(2018) [3]	Secure transmission and storage of images based on chaotic encryption algorithm and Chaotic pseudo-random generator based on neural network is introduced.	Deep Learning based Symmetric key cryptosystem.	ANN

In [6] introduces a new well-organized deep learning model framework named Secure Decentralized Training Framework (SDTF) for privacy-preserving. This model provides privacy for local data and also capable of working decentralized network setting without a trusted third-party server.This system proposes an Efficient Secure Sum Protocol (ESSP) which is capable of enabling a large group of parties to jointly compute a sum of private inputs and cryptographically strong. This protocol assurance high privacy with lesser communication costs. The framework is based on two input datasets such as balance class image datasets (MNIST) and unbalance class text data set (UCI SMS spam) and obtained a very high-accuracy of 97

In [8] discusses the role of deep learning in intrusion detection and provides a novel categorical approach of the deep learning-based IDSs with respect to different features, including input data, detection, deployment, and evaluation strategies. The features are again classified according to different criteria. The various intrusion detection methods are compared in terms of feature learning, classification technique, testing methodology and efficiency. This study ensures that Deep Learning-based anomaly detection achieves a high accuracy with the use of different deep learning architectures using benchmark datasets, KDD99 and NSLKDD.

In [9] proposed encrypting images by using different encryption keys. All clients are able to utilize independent keys for training and testing a model. Hence, there is no need to use key management techniques. The independent key performs high classification performance and vigorous against DNN based attacks. Data augmentation is also introduced in the encrypted domain. The system evaluates its performance in terms of accuracy and robustness against DNN-based attacks.

This study provides a theoretical framework describing Deep Learning in the field of cryptography. The neural network approach can be applicable for various cryptographic techniques such as encryption, cryptanalysis, steganograhy, intrusion detection, malware classification [7], social network attacks detection and privacy preserving. The integrative approach of deep learning methods and DNA cryptography plays an important role in data security.

III. Conclusion

The objective of this study is to evaluate the various applications of Deep Learning in the field of cryptography. This study provides an integrative research scope in the field of Deep Learning based cryptosystem. As comparing with traditional methods, the Deep Learning approach reduces the mathematical complexity of algorithms and computational cost. TensorFlow supports CPU and GPU based computation which provides better accuracy. The Deep Learning technique overcomes the security problems in traditional cipher by using Deep Neural Network System approach.

References

[1] Mondal M, Ray KS. Review on DNA cryptography. arXiv preprint arXiv:1904.05528. 2019 Mar 15.

[2] Kalsi S, Kaur H, Chang V. DNA cryptography and deep learning using genetic algorithm with NW algorithm for key generation. Journal of medical systems. 2018 Jan;42(1):1-2.

[3] Maddodi G, Awad A, Awad D, Awad M, Lee B. A new image encryption algorithm based on heterogeneous chaotic neural network generator and dna encoding. Multimedia Tools and Applications. 2018 Oct;77(19):24701-25.

[4] Quinga-Socasi F, Zhinin-Vera L, Chang O. A Deep Learning Approach for Symmetric-Key Cryptography System. InProceedings of the Future Technologies Conference 2020 Nov 5 (pp. 539-552). Springer, Cham.

[5] Shone N, Ngoc TN, Phai VD, Shi Q. A deep learning approach to network intrusion detection. IEEE transactions on emerging topics in computational intelligence. 2018 Jan 22;2(1):41-50.

[6] Tran AT, Luong TD, Karnjana J, Huynh VN. An efficient approach for privacy preserving decentralized deep learning models based on secure multi-party computation. Neurocomputing. 2021 Jan;422:245-62.

[7] Vinayakumar R, Alazab M, Soman KP, Poornachandran P, Venkatraman S. Robust intelligent malware detection using deep learning. IEEE Access. 2019 Apr 3;7:46717-38.

[8] Aldweesh A, Derhab A, Emam AZ. Deep learning approaches for anomaly-based intrusion detection systems: A survey, taxonomy, and open issues. Knowledge-Based Systems. 2020 Feb 15;189:105124.

[9] Sirichotedumrong W, Kinoshita Y, Kiya H. Pixel-based image encryption without key management for privacy-preserving deep neural networks. IEEE Access. 2019 Dec 12;7:177844-55.

[10] Tanuwidjaja HC, Choi R, Baek S, Kim K. Privacy-Preserving Deep Learning on Machine Learning as a Service—a Comprehensive Survey. IEEE Access. 2020 Sep 10;8:167425-47.

[11] Roy SS, Mallik A, Gulati R, Obaidat MS, Krishna PV. A deep learning based artificial neural network approach for intrusion detection. InInternational Conference on Mathematics and Computing 2017 Jan 17 (pp. 44-53). Springer, Singapore.

[12] Sirichotedumrong W, Kiya H. A gan-based image transformation scheme for privacy-preserving deep neural networks. In2020 28th European Signal Processing Conference (EUSIPCO) 2021 Jan 18 (pp. 745-749). IEEE.

Number Plate Recognition Using CNN For Identification Of Theft In Toll Collection System

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Abstract—An electronic toll collection system is a technology that enables automatic toll fee collection through online or offline mode from the user in a secure way. Using the image processing technique here we identify the number plate of a particular vehicle. The details of the vehicle owner (i.e vehicle number, name, phone number) will be stored in the database for paying toll fees and identifying theft at toll. Initially, we will scan the object (vehicle) using the camera placed in the toll booth it will change the captured image of a vehicle into black and white using binarization. Then the number plate is detected using CRF algorithm and the text is extracted from number plate using OCR algorithm. The data is matched with the database automatically and bill is generated without any delay. This approach also identify the theft of vehicles and real-time alert is given to the concerned persons for necessary action.

Keywords—Fixed Thresholding, Binarization, Number Plate Detection, Text Extraction, CRF algorithm, OTP Verification.

I. INTRODUCTION

Motor vehicle registration for a new number plate is done with government authority. The purpose of motor vehicle registration creates a link between the vehicle and the owner of the vehicle. This link might be used for crime detection in the case of theft and the taxation purpose in the toll booth or paying a fine for violating the traffic rules. License plate detection is used in many real-time applications such as parking systems, toll collecting systems, and security systems. It still faces many issues while using the digital camera such as in traffic detecting multiple plates, ambiguous signs, detecting other objects in the frame, and obscure images taken in bad climate or night time. These variations result in false positivity in the number plate detection and provide poor accuracy.

In our day today's life image processing techniques are used in many applications. Here, we use this technique to detect the theft vehicle in the toll booth. The surveillance camera in the toll booth captures the video and detects the vehicle in each frame of the video. Each frame will be converted into the black and white image by using the binarization technique and from that image, the vehicle object is detected. Bag of words are created from the number plate by using the conditional random field algorithm.

To solve the problems in the existing system, we propose an efficient way of license plate recognition by using Optical Character Recognition(OCR) which has a more positive rate in the result and here CNN is used for training the data for good accuracy in the result. In the OCR it consists of six steps that should be done for extracting the text from the number plate such as Image Acquisition, Pre-Processing, Segmentation, Feature Extraction, Training a Neural Network and Post-Processing. The text extracted from the number plate is matched with the database and it sends the OTP to the user for identifying the theft. Using OCR, we achieve 99% of character recognition accuracy. This method shows high performance and accuracy when compared with the traditional number plate recognition system.

a) Image Processing

Image processing is a field of study that involves the processing of images coupled with the mathematical operations. In image processing technique, input may be image or a series of images or a video. The output may be the set of characteristics or the definite attributes pertained to that image. This technique is applied to various fields like: 1. Digital Image Processing, 2. Optical Image processing, 3. Analog Image Processing. Most of the images are processed in a two-dimensional signal processing technique. Recent technologies such as computer graphics and computer vision are closely related to image processing. In computer graphics, the images are taken manually. The images are from physical models of objects, lighting, environment, and natural scenes or some animated movies captured only through devices such as cameras or computers. Computer graphics is one of the sub-field of computer science which involves in the process of digitally synthesizing and manipulating visual content. Using computer graphics we can easily process in Two Dimensional and Three Dimensional graphics. Computer graphics are made up of pixels. Pixel is the unit of the graphical picture. Computer vision is playing a major role in the field of Artificial Intelligence. Artificial intelligence is defined as the process making a machine to think and act like a human. Simply stated as simulating a human brain. Using Deep Learning, it is easily capable for a network site to learn an environment using unsupervised learing technique from unlabeled data. Using Digital Images from videos or cameras and applying deep learning models, machines can easily identify and understand the visual world. Image Analysis is the process of extraction of Information from the digital Images using image processing techniques.The Image analysis tasks also includes reading the bar-coded tags which is analogous to identifying a person using the face. Recent advancements in image processing technology paved the way for analyzing huge amount of data. Using the human visual cortex, we can extract higher-level information and give excellent image analysis. It includes medicine, security, or some remote sensing process. It is difficult to replace human analysis by computers. The edge detectors and neural networks are image analysis tools that are inspired by perception models. In Image editing, the images in digital photographs or traditional photographs are modified. Every aspect of an Image can be altered. This Image editing technique is similar to the traditional photo retouching using basic tools such as airbrush. By this we can modify the images or apply editing illustrations with any art medium. Graphic software programs are also used to alter, modify or enhance the Images with special tools. Most images are extracted from various editing programs with the use of rendering computer art built from the scratch. Raster Images contains the picture in the form of grid elements or pixels from the computer. These type of pixels contains only Images and brightness information. The pixels can be changed as a group or Individually by only sophisticated algorithms from image editors. Many graphical applications are capable of merging one or more Individual Images into a single file. When using Raster Image which is otherwise called silhouetting is not rectangular, it separates the edges from the background. The process of clipping paths is used to add silhouetted Images or Raster Images to vector graphics. From selecting the Edges by raster tracing or consisting a path to a silhouetted selection. Once the image is selected means, it may be copied and pasted into another section of the same file or separate file. Using Transparent layers composite images are created and Using the Image layer mask, the parts of various images are merged in the background layer.

a)Steps of Image Processing:

i)Image Acquisition

It is the initial and basic step in image processing. It is a simple process in image processing because the given image is already in digital form so the process can be done easily. Generally, this process involves preprocessing such as scaling, cropping ,etc.,

ii)Image Enhancement

It is the most simple and appealing step in image processing where the given digital image became more sharpen after completing this step. The main idea behind the step is to highlight certain features in the image such as contrast, brightness, etc.,

iii)Image Restoration

Image Restoration is used for improving the appearance of an image. This step is different from the image enhancement step wherein enhancement is subjective but the image restoration is objective. The image restoration technique is purely based on the mathematical model of image degradation.

iv)Color Image Processing

It is an important process because of the increase in use of digital images over the internet. It includes color modeling and processing in the digital domain.

v)Wavelets and Multiresolution Processing

Wavelets are used to represent the image in various degrees of resolution. For data compression, images are successively subdivided into smaller regions. It is a technique to reduce the size of image or bandwidth to transmit. Bandwidth is important, because it uses the internet. It is also important to compress the size of an image.

vi)Morphological Processing

It is a tool that is used to extract the image components which is helpful in the representation and description of shape

vii)Segmentation

In which the image will be partitioned into its constituent parts or objects. One of the difficult tasks in digital image processing is autonomous segmentation. For identifying the individual objects in the image, we can use a rugged segmentation procedure which is a successful solution for the imaging problem.

viii)Representation and Description

It follows the output of a segmentation stage which is raw pixel data it will either represent all the region or the boundary of a region. Representation is a part of a solution for transforming the raw data into a form of subsequent computer processing. Description deals with extracting the attributes and that result in one class of object from another.

ix)Object Recognition

It is the process of assigning a label for the object based on the descriptors.

x)Knowledge Base

It is a simple process, where it details the regions of image. While performing the search operation it is highly preferred to give only a limited set of attributes. It became quite complex to interrelate the major possible defects in materials or an image database containing a high-resolution satellite image of a region in connection with change-detection applications.

II. RELATED WORK

In recent years, many traffic applications like: smart security systems, smart traffic systems, smart parking systems etc., uses License Plate Recognition technology. Technological advancements enables Licence Plate Recognition (LPR) to play a major role in the development of smart cities. This LPR facilitate the surveillance system for vehicle management, investigation of theft vehicles, and traffic monitoring in smart cities. Cheng-Hung Lin et al. [1] has proposed an approach for efficient hierarchical license plate recognition system. In this approach they used YOLOv2 model , SVM, LPRCNN model in order to capture and detect the character in the license plate but this approach has an flaw where it doesn’t detect the theft. Gibrael-Elamin [2] proposed an system for localizing vehicle plate number inside plane images in this technique they use multi-window-size binarization and semi-hybrid genetic algorithm using the technique Substitution operator but it will be depends on the shape and color. G. L. Corneto [3] have proposed an approach for a new method for automatic vehicle license plate detection using the HAAR Cascade classifier technique but this approach is only identifies the number plate and do nothing to it. Safaa S. Omran [4] has proposed an approach in application software for the recognition of car license plate is designed by using the technique Optical character recognition (OCR) but in this approach it has Irrelevant features extraction. Neha Rana [5] proposed an approach called Localization Techniques in ANPR Systems by using Signature Analysis technique but it has flaw which is Improper illumination and blurring. Hossein Ziaei Nafchi [6] has proposed an approach for CorrC2G: Color to Gray Conversion by Correlation using the Decolorization method in order to detect the number plate but it doesn’t work for every image. Rajshekhar Mukherjee [7] proposed a robust algorithm for morphological, spatial image-filtering, and character feature extraction and mapping employed in order to detect the vehicle number plate recognition using fuzzy logic and template matching technique. Hui Li [8] has proposed towards end-to-end car license plates detection and recognition with deep neural networks using the technique called Linear Discriminant Analysis (LDA) but it need more processing time. Ihsan Ullah [9] have proposed an approach of locating Korean vehicle license plate based on Mathematical Morphology and Geometrical Features in this approach they use Mathematical morphology technique this approach is affected from low location rate. Animesh Chandra Roy [10] has proposed License Plate Detection and Character Recognition System for Commercial Vehicles based on Morphological Approach and Template Matching using Boundary based contour algorithm but this approach need more training data.

This paper is organized as follows: The algorithm used to implement the LPR system is described in section III and Experimental results are described in section VI. Finally, Conclusions are summarized in Section V.

III. THEFT DETECTION IN THE TOLL BOOTH USING VEHICLE NUMBER PLATE

Each vehicle will be provided by license plate number containing a unique ID. The license plate number is captured using the camera placed in the toll booth. Then, the vehicle object is converted as a black and white image using the binarization algorithm and the condition random field(CRF). The algorithm detects the number in the vehicle which should be already trained by using the convolution neural network(CNN). For extracting the text from the detected number plate optimal character recognition(OCR) algorithm is used. The text which is extracted from the number plate act as a primary key in the database and started to see a match for data in stored database. The user will get an one-time password(OTP) in his registered mobile number which is stored in database for a particular number plate. If the given OTP is not matched with the admin side then it is a theft vehicle and the alert message will be sent to the concerned police officer. If the OTP is matched then the user can pay the toll fee either online or offline mode. In this theft detection approach in toll booth using vehicle number plate offers many advantages: 1. It save time, 2. It provides real-time alert system, 3. It maintains the records in the database for further references.

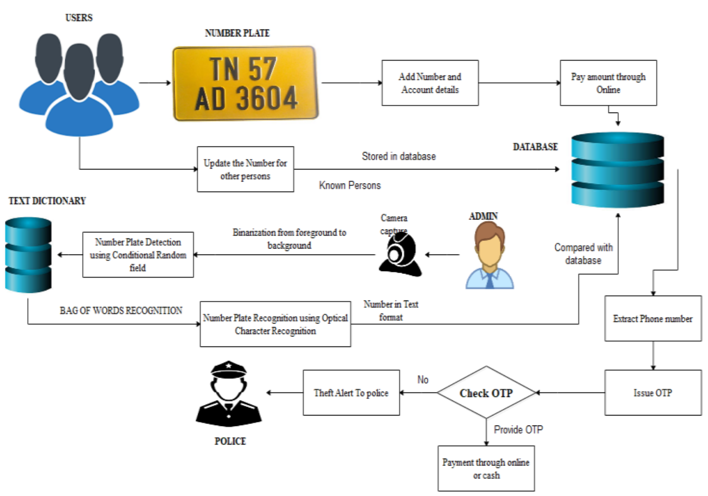


Fig 1.Theft detection in toll booth using vehicle number plate

a) Binarization

In this Fixed Thresholding binarization method, the fixed threshold value is used to assign 0's and 1's for all pixel positions in a given image. The basic method of fixed binarization is described below.

$$g(x,y) = \begin{cases} 1 \ if \ f(x,y) >= T \\ 0 \ otherwise \end{cases}$$

Fig 2. Fixed binarization

Where T shows the global threshold value. The threshold is a way of exacting the useful information from the given image and it will be encoded into pixels by reducing the background noise. It can be archived by a feedback loop to optimize the threshold value before converting the black and white image to binary. Here the ultimate objective is to separate the image into two parts foreground and background. Initially, we select the threshold value and split the image into two different parts. For background, the pixel value should be less than or equal to the threshold and for foreground the pixel value should be greater than the threshold value. After that, the mean average is calculated for two new images and the threshold is calculated by finding the average of two mean values. If the previous threshold value and the new threshold value are below a specific limit then the threshold process is completed. Otherwise apply a new threshold to the image and keep trying the same by repeating the entire process.

b) Conditional Random Field

A CRF is an undirected probabilistic graphical model, it represents the relationship among different variables. The structure of the CRF model is used to determine the unobserved one to observed one. CRF assigns a word tree by using the probability of occurrence of each character. The correct sequence of characters with high probability path is selected in forming the word. By using the conditional random field, it helps us to detect the features of an image using the pixels and filtering concept. In our case, the conditional random field is used to detect the number plate and text strokes from the number plate. It stores the details in text dictionary where it passes the bag of the words for fetching the users details to identify the theft in the toll booth.

c) Optimal Character Recognition

In the OCR technique, it extracts the text from the given input image before that the image acquisition should be done then the noise should be removed from the given input image by preprocessing after that image segmentation is done for grouping the characters into meaning full chunks and the text should be trained by using CNN. Initially, it differentiates the word contours associated with the input image then it will differentiate the letter contours associated with the word contours and the letter contours are detected using the feature detection concepts that means if two horizontal lines and one vertical line connected then it detects the character as A. After that, it will preprocess the letter image according to the trained OCR input. Consolidating ConvNet predictions of characters to text. By using the OCR technique the accuracy will be higher it has 95% accuracy and a 5% error rate in most cases.

d)Modules and Its Description

Some of the important modules which are used inour system namely Framework Construction, Image Acquisition, Text Detection, and Recognition, Membership Access, Payment With Alert.

i) Framework Construction

By using the electronic toll collection system our goal is to reduce the delay by using the smart way for collecting the toll which is proposed in our system and this kind of technology should be introduced and improved so that it will save time. This is a module where the user can register their name, phone number, and other details. Where the number plate is captured and the details of the number plate will be stored in the database and from the admin end all the user details can be maintained in the single database.

ii) Image Acquisition

In this module from the admin end by using the digital camera they will capture the image. Binarization is the most important pre-processing step in image processing. Then the binarization technique is implemented to detect and separate the foreground and background from the detected image. Where every pixel has its threshold value if the pixel is white in the image then the threshold value will be 0 else the threshold value will be 255. By using threshold binarization the accuracy of the image will be higher.

iii) Text Detection and Recognition

In this module, after processing of Binarization technique, the number detection approach would be obtained based on text strokes. A strokes value is the process of defining the values as minimum and maximum in the order of obtaining in the number plate based on styles and fonts. The strokes value removes other identified objects which have very small or very large objects, it will be removed and in the range of outside the threshold. The objects are successfully passed from the predefined threshold to the training process. After the text detection process, the text strokes in the number plate detected were recognized by the Conditional Random Field Algorithm.

Using the Conditional Random Field technique, the detected texts are assigned as bounding box and then the bounding box text will be recognized by using Optical Character Recognition. This algorithm which is Optical Character Recognition was recognized the detected text. Optical Character Recognition is a software that was used to converts images and printed text into a digitized form of the process using capturing the image with the help of a webcam. The process can be manipulated by machine only. OCR is one of the complex problems because of the different languages, variety of fonts and different styles, and the complex rules of languages.

iv) Membership Access

In this module, After the Optical Character Recognition technique, the detected text will be checked from the databases. The databases stored some user data's which is name, phone number, address, and other details during the registration process of buying a vehicle. The user data are stored in the databases which collect user information for identifying the vehicle which is the user's or not. This process may be held by the admin side. The process of admin was checking the output of number plate detection using the Optical Character Recognition technique and the database's information which was user data.

Users can also update new numbers for future verification due to if the vehicle was driven by the user's neighbor means how he manages to admin. So, it was very useful to the user may update their neighbor number. The admin can store the details in the system which was who drives the vehicle and to license number plate, vehicle types, amount, date of arriving, and vehicle images with the help of a webcam. The admin can easily get the information day by day in the toll plaza in the system. The user can set the source and destination in the system only after checking tolls in the system to calculating the number of tolls and easily pay the amount online directly.

v) Payment With Alert System

In this module, After completing the verification process of user data using databases which were given by the user. If there is nothing problem with the verification process means, it sends the OTP to the user's mobile number. Using this OTP users can pay the amount simply either online or offline mode. At the same time, if the OTP can't be submitted within seconds from the user means, it automatically considers as a theft vehicle and it sends an alert immediately to the police number. An OTP is a secure one then a static password. So, it can't be hacked the OTP number which was more secure. The user can updates the new number in the login authentication due to the purpose of when the friends or neighbors can use the user vehicle. For this situation, the user may have an additional number to update in the system authentication. Due to this update, there is nothing problem to the user and the admin side also and easily identified by the admin so it can't take time to process and the queue may not be formed, the time will be saved.

IV. EXPERIMENTAL RESULT

Experiments have been performed to test the proposed system, the recognition of sample images and to measure the accuracy of the proposed system. It is designed using python using the library openCV for recognition of license plate. The measurement of accuracy is given in Table I.

TABLE I.
MEASUREMENT OF ACCURACY

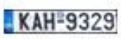
Units of License Plate Recognition	Number of Accuracy	Percentage of Accuracy
Extraction of plate region	35/40	87.5%
Extraction of character from plate region	32/35	95%

For extracting the plate region from the 40 images which are stored in the database, only the 35 images extract the number plate correctly from the test images. The reason for not extract the number plate for the remaining 5 images is due to the unclear image will wipe out some important information so it causes the incorrect crop of the license plate has occurred.

For extracting the character from the number plate region on the 35 images which are stored in the database, among 3 images are correctly extracted the license plate but the text extraction from the license plate is not proper because it detects some noise or extra object in the number plate.

The results of the number plate recognition in the different scenarios for some of the cars are given in Table II.

TABLE II.
RESULT OF NUMBER PLATE RECOGNITION

License Plate variation	Original image	License Plate Image	Result with proposed method	Accuracy with proposed method
1)Image with multiple license plate				95%
2) Image with blur				96%
3)Image taken at night				97.18%
4)Image with rotation				96.89%

V. CONCLUSION

In this paper, we have proposed an efficient license plate recognition in the toll booth for identifying theft of vehicles. This detection technique uses OTP verification from the user end to the admin end. The fixed threshold binarization can identify vehicle object in the image to avoid multiple detections or different objects in the given input image. Conditional Random Field is used to detect the number plate from the given vehicle object with high accuracy. In addition to that, for text extraction from the number plate Optimal Character Recognition is used which gives high accuracy in text detection from the given image. Here, the vehicle number is matched with database repository and OTP is sent to the user end and admin end. OTP verified with the admin end and user is allowed to pay toll fee either in online/offline mode provided the OTP is authenticated else an alert message is sent to the police officer as the vehicle is stolen. Experimental results shows the superiority of the proposed approach in terms of accuracy and performance.

REFERENCES

[1] Lin, Cheng-Hung, Yong-Sin Lin, and Wei-Chen Liu. "An efficient license plate recognition system using convolution neural networks." In *2018 IEEE International Conference on Applied System Invention (ICASI)*, pp. 224-227. IEEE, 2018.

[2] Abo-Samra, Gibrael-Elamin. "Application independent localisation of vehicle plate number using multi-window-size binarisation and semi-hybrid genetic algorithm." *The Journal of Engineering* 2018, no. 2 (2018): 104-116.

[3] Corneto, Guilherme Lofrano, Francisco Assis da Silva, Danillo Roberto Pereira, Leandro Luis de Almeida, Almir Olivete Artero, Joao Paulo Papa, Victor Hugo Costa de Albuquerque, and Helton Molina Sapia. "A new method for automatic vehicle license plate detection." *IEEE Latin America Transactions* 15, no. 1 (2017): 75-80.

[4] Omran, Safaa S., and Jumana A. Jarallah. "Iraqi car license plate recognition using OCR." In *2017 annual conference on new trends in information & communications technology applications (NTICT)*, pp. 298-303. IEEE, 2017.

[5] Rana, Neha, and Pawan Kumar Dahiya. "Localization techniques in ANPR systems: A-state-of-art." *International Journal of Advanced Research in Computer Science and Software Engineering* 7, no. 5 (2017).

[6] Nafchi, Hossein Ziaei, Atena Shahkolaei, Rachid Hedjam, and Mohamed Cheriet. "CorrC2G: Color to gray conversion by correlation." *IEEE Signal Processing Letters* 24, no. 11 (2017): 1651-1655.

[7] Mukherjee, Rajshekhar, Amit Pundir, Dharmendra Mahato, Gaurav Bhandari, and Geetika Jain Saxena. "A robust algorithm for morphological, spatial image-filtering and character feature extraction and mapping employed for vehicle number plate recognition." In *2017 International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET)*, pp. 864-869. IEEE, 2017.

[8] Li, Hui, Peng Wang, and Chunhua Shen. "Toward end-to-end car license plate detection and recognition with deep neural networks." *IEEE Transactions on Intelligent Transportation Systems* 20, no. 3 (2018): 1126-1136.

[9] Ullah, Ihsan, and Hyo Jong Lee. "An approach of locating Korean vehicle license plate based on mathematical morphology and geometrical features." In *2016 International Conference on Computational Science and Computational Intelligence (CSCI)*, pp. 836-840. IEEE, 2016.

[10] Roy, Animesh Chandra, Muhammad Kamal Hossen, and Debashis Nag. "License plate detection and character recognition system for commercial vehicles based on morphological approach and template matching." In *2016 3rd International Conference on Electrical Engineering and Information Communication Technology (ICEEICT)*, pp. 1-6. IEEE, 2016..

Security Issues in Public Clouds

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***Abstract*—Cloud Computing delivers hosted cloud services over the internet. Computational services are usually limited but can be extended by purchasing, maintaining and updating the provided equipment. These services are accessed via HTTP(S) protocols. They can be established within a shorter time with high throughput. Costs depend on service providers. Technology advancements over the past few years have increased the security of users in the public cloud. Still, the public clouds are not 100 percent secured. More robust challenges are still underlying these public cloud accounts. This paper focuses on providing a review of different public cloud security issues and immediate remedies to date.**

I. Introduction

Majority of the Information Technology Industries directly or indirectly uses cloud services. In day-to-day life, an employee uses Gmail / Microsoft Outlook to send emails to other people in their organisation. Gmail and Microsoft Outlook are Software as a Service (SaaS) applications. Such SaaS application provides services to the end-users over the internet with some handling fee based on the account type. These SaaS applications are deployed in the cloud and use Simple Mail Transfer Protocol (SMTP) to deliver emails.

Constructing and maintaining computational resources in an IT Industry is a costly effort. It requires a lot of human effort, capital and space. IT Industry outsources its needs to public cloud computing services.[1] These are relatively cheaper and effective compared to the traditional services. Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS) are three commonly categorized cloud delivery services in the market.

A. Infrastructure as a Service

Infrastructure as a Service is an instant computing infrastructure, provided and managed over the internet. In IaaS, the service provider provides support to users to manage their Operating System, Middleware applications, Runtime and Application Data. Virtualization, Servers, storage and networking will be controlled by the service provider. Amazon Web Services (AWS) offer IaaS solutions to the users. These resources are monitored for billing purposes.

B. Platform as a Service

Platform as a service provides the platform to users. Users develop, run, and manage their applications without maintaining the infrastructure. The service provider provides the Runtime, Middleware software, Operating System, Virtualization, Servers, Storage and Networking to the users. Users can control their applications and maintain them on the platform. Google Cloud Platform (GCP) offer PaaS solutions to the users.

C. Software as a Service

Software as a Service provides software to the end-users. Users don't need to run, maintain the application. Users can use software for their activities. Application, Data, Runtime, Middleware software, Operating System, Virtualization, Servers, Storage and Networking control will be in the hands of the service provider. All Cloud hosted application software comes under this delivery model. Gmail / Microsoft Outlook comes under SaaS delivery.

Users are free to adopt any delivery model to outsource their work. Each delivery model has its pros and cons but our scope is limited to cons here under security. Data / Program we insert in the cloud service providers are encrypted. Data Encryption doesn't mean that our data is completely safe. It is just a lock to make original data invisible. Once the lock is opened with a valid key, the data is visible to everyone.

As long as data is made publicly available on the internet relevant measures have to be taken care of before permitting users to see the data. Data Access Control Strategies are increasing day-by-day starting from a secured authentication systems to IP address-based authentication systems. These systems are very complex and hard to construct but are being improved to a greater extent because of the increase in number of attacks. The further sections in the paper are categorized as follows.

II. Data Security in Public Cloud

Cloud computing uses multiple technologies including but not limited to networking, databases, resource scheduling, virtualization, transaction management, load balancing, concurrency control, operating systems and memory management

In a high level there are 6 major areas where we encounter security issues in public cloud [2]

Cryptographic Encryptions can secure the data at rest as well as data in transit. But the data encryption time becomes overhead. User Authentication and Integrity protection mechanisms ensure data availability to the customer requested. These are equally important as the data is handled over the internet.

Cloud providers prefer Virtual Machines and Hypervisor to separate the cloud users. Each cloud user must have their legal and regulatory experts to inspect cloud provider's policies and practices for ensuring their adequacy. Automated notifications

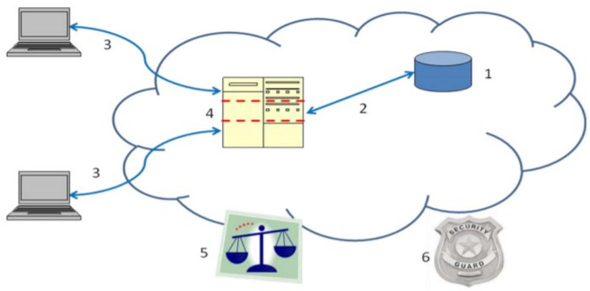

Fig. 1. 1. Data at rest, 2. Data in transit, 3. Authentication, 4. Separation between customers, 5. Cloud legal and regulatory issues and 6. Incident response.

help to inform the cloud users regarding the incident to handle the security breach.[3]

Security issues in cloud computing are dynamic. Some of the security issues are addressed below.

A. Privileged User Data Access

The customer data present in the cloud can be accessed by other cloud users in unauthorized ways. It is similar to hacking a OTP from a bank account to perform a transaction by a bank employee. These Privileged users can present inside or outside of your cloud environment but they have access to the data to manipulate.

It is one of the major issues in any database implementation. This problem was faced earlier by Apple and Google. They have mitigated this issue by the separation of duties. They have ensured that the activities of privileged third parties are monitored by your staff and fraudulent activity will make a notification to the higher authorities.[4]

B. Data Location and Segregation

Public Cloud Service providers offer multiple locations to the customer to store data. Amazon Web Services has around 100 data centers spread across 15 cities in 9 countries. Without knowing the presence of the data location, the provision of the data protection act for some region might be severely affected and violated. This also possess a risk of data along with other customers' information[5]. Segregation methods like Encryption and Digital Signatures might help to save the data.

C. Data Loss

Data in the cloud is distributed. If one data center failed to retrieve your data, another data center can access and get your data. Data loss is referred to when valuable or sensitive information on a computer is compromised due to theft, human error, viruses, malware, or power failure. User authorization and time-to-time resource monitoring can help to mitigate data loss. Swim-lane isolation is a popularly known technique that can help to avoid data loss in public clouds.[6]

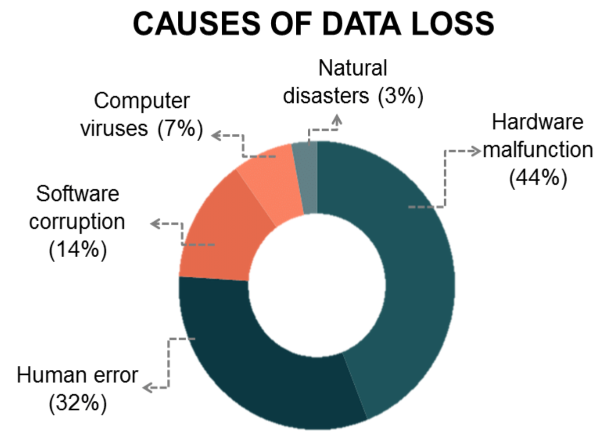

Fig. 2. Causes of Data Loss[6]

D. Data Disposal

Data Disposal refers to the deletion of user data in the cloud environment. This issue arises due to the dynamic allocation of hardware resources to cloud users. The cloud providers need to ensure that all backup, logs data must be removed alongside the user data in the cloud. Formatting the data disk drives would be an ideal option but necessary care has to be taken to make sure that other customers' data won't be affected. Improper disposal leads to side-channel attacks.

E. Protective Monitoring

Cloud users have to be monitored to protect other users data. Many privacy issues will arise but it is as important as protecting security to other users. Customers may not invoke their protective mechanisms as they are a bit costly to handle and some cloud providers don't provide service to the customer level.

III. Network Security in Public Clouds

Cloud services are offered using Networking Protocols. Cloud Service providers need to ensure a low data loss during the data transfer from local machines to the cloud environment.[7] To ensure data loss, we can use strong encryption techniques such as Secure Socket Layer (SSL) and Transport Layer Security(TSL). AWS protects users from several network attacks like Man-In-The-Middle (MITM) attack, port scanning, IP spoofing..,

A. Virtual Private Networks

A single vendor organisation can experience lower data transfer rates. Virtual Security Gateways and multiple vendors can be incorporated for high data transfer rates. This provides customer-controlled security. A private infrastructure can be established where the cloud control lies within the organization.[8]

B. Network Accessibility

Data in the public cloud can be accessed by most of the users. Eg: A public AWS EC2 server can be called in a web browser with the IPv4 address provided. A server administrator can use his security key and instance key (.pem file) to login into the server from Command Line Interface(CLI). Complex and secured User Authentication systems can help cloud users to protect the data leak. System administrators must limit the instance login access from the IP address as well. This can be performed under the security groups of AWS EC2.

C. Data Latency

Low data latency should be maintained to avoid attacks during the data transfer. Data transfer won't be continuous and consistent in the case of Metropolitan Area Networks(MAN) and Wide Area Networks(WAN) compared to LAN(Local Area Network). More number of intermediate network components affect the data latency.[9] This issue can be mitigated by invoking optimized routes to route the data from the local machine to the data center.

IV. Recent Threats in Public Clouds

Majority of the security threats arises due to the vulnerable design of cloud architecture. Poor architecture causes data loss to cloud customers. Four major security threats identified in recent times are discussed below

A. Compromised Credentials

User Credentials in public clouds compromises. It happens involuntarily a lot. For Eg: In Amazon Web Services, an email notification will be sent to the root account if a Identity and Access Management (IAM) access and secret keys are exposed publicly in the internet. It happens when we push the code into public repositories like Github, BitBucket..., Majority of the attackers get access to credentials here. A good practice is to make these credentials invalidate if the accounts are not being used. One more practice is that to provide limited access and restricted scope to these credentials.[10]

B. Data Breach

Data Breach is referred to when confidential information is stolen/used by unauthorized personnel. Data Breach can be avoided by restricting access to the information as soon as possible before the confidential information is out. It is always advised to maintain confidential data restricted to a specific set of users in the organisation. Known and trusted parties should have access to the information in the cloud. Alert systems should trigger in time of data breach.

C. Hacked Application Protocol Interfaces(API)

Nowadays, API's are vividly used to pass data between different heterogeneous devices. These API's can be tampered creating a business loss to the organisation. To mitigate that we can encrypt the API Key and should be decrypted only at the server environment. Age limit should be set to these API keys and make users update their API Keys time-to-time. Real-Time API monitoring also helps to prevent the hacking of API.

D. Permanent Data Loss

Data in the cloud will be dynamic. These data should have a backup copy secured at different servers other than the running instance. This helps to restore the system state at the time of vulnerability. These backups are costly and the cost varies among providers. Maintaining a restricted set of users to perform activities in cloud environments helps to reduce the data attacks in the organisation.

V. Best Practises in Public Clouds

The security issues in public cloud services are increasing day-b-day[11]. 95% of the organizations are considering data security in public clouds. Here are few best practices to employ a secured and reliable cloud application in public clouds.

A. Access Management and Control

It is advised to provide access to a trusted and restricted set of users in the organisation. These access credentials should be timely changed to avoid data breaches. Email Triggers and Log Information should be recorded when an event happens with these credentials in the public service.

B. Vulnerability shielding

The Organisation must check the vulnerability of their cloud services utilized frequently. Timely updating the services reduce the risk of an attack of the cloud by the hackers[12]

C. Cloud Architecture

Cloud Architecture employs a major role in reducing attacks. Resources should be distributed and follow strict access control to unauthorized users. New Software / Packages updates for these resources should be properly inspected before updating. Resources should be properly managed to meet the organisation needs. Adaptation, run-time models, continuous development and deployment are some of the highly adopted principles to employ a better cloud architecture[13].

D. Data Backup

Data in the public cloud should be backed up safely to restore the system to a particular point. These Backups as aforementioned are costly and the cost varies from provider to provider. A best practice is to store the backup in a different server which is only accessed by restricted users. Some organisations prefer to save copies of data either in local or standalone computers.

E. Organisation Policies

Newly formed or established organisation must ensure that the employees are abiding with the data policies imposed and need to provide regular training on Data Importance, Case Study analysis which could mitigate future havoc.

VI. Conclusion

Cloud Computing is a revolutionized technology in the Information Technology Domain. These services are employed directly (or) indirectly by almost all IT organisations. Cloud services should be properly allocated and used. Newer Security concerns were constantly raised day-by-day in public clouds compared to other cloud delivery models. Effective practices should be lined up to keep the stored data safe from vulnerabilities. With the increase of attacks, we can't employ a one-stop solution to security challenges. The methods aforementioned will minimize threats to an extent. Reviewing the security policies and procedures helps to protect the data and its privacy.

Acknowledgment

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References

[1] A. Heydari, M. Tavakoli, and M. Riazi, "An overview of public cloud security issues," *International Journal of Management Excellence*, vol. 3, 06 2014.

[2] T. C. Group, "Cloud Computing and Security – A Natural Match," Tech. Rep., 04 2010.

[3] J. Sen, *Security and Privacy Issues in Cloud Computing*, 09 2013, vol. 3, pp. 1– 45.

[4] D. Teneyuca, "Internet cloud security: The illusion of inclusion," *Information Security Technical Report*, vol. 16, no. 3, pp. 102–107, 2011, cloud Security. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S1363412711000501

[5] M. Ahmed and M. Hossain, "Cloud computing and security issues in the cloud," *International Journal of Network Security and Its Applications*, vol. 6, pp. 25–36, 01 2014.

[6] A. Yeang, Z. Zaaba, and N. Samsudin, "Reviews on security issues and challenges in cloud computing," *IOP Conference Series: Materials Science and Engineering*, vol. 160, p. 012106, 11 2016.

[7] N. Sehgal, Y. Xiong, W. Mulia, S. Sohoni, D. Fritz, and J. Acken, "A cross section of the issues and research activities related to both information security and cloud computing," *IETE Technical Review*, vol. 28, p. 279, 07 2011.

[8] K. S. S. Bulusu, "A study on cloud computing security challenges," Master's Thesis, Blekinge Institute of Technology, 2013.

[9] D. D. M. A. Viswanadham, "Security issues in cloud computing and associated mitigation techniques," *INTERNATIONAL JOURNAL OF ENGINEERING RESEARCH TECHNOLOGY*, vol. 13, 2015.

[10] R. Jathanna and D. Jagli, "Cloud computing and security issues," *International Journal of Engineering Research and Applications*, vol. 07, pp. 31–38, 06 2017.

[11] P. Mell and T. Grance, "The nist definition of cloud computing," 2011-09-28 2011.

[12] Y. Z. An, Z. F. Zaaba, and N. F. Samsudin, "Reviews on security issues and challenges in cloud computing," *IOP Conference Series: Materials Science and Engineering*, vol. 160, p. 012106, nov 2016. [Online]. Available: https://doi.org/10.1088/1757-899x/160/1/012106

[13] C. Pahl, P. Jamshidi, and O. Zimmermann, "Architectural principles for cloud software," *ACM Transactions on Internet Technology*, vol. 18, 06 2017.

Proof of Quality in Organic Farm Produce using Distributed Ledger Technology.

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***Abstract*—With the increase in population, the goal to feed all is a high hill task. The excessive use of pesticides can improve the yield extensively for shorter gain but has long-term effects on the neuro system. As a result, governments are issuing laws to keep a check on the farm produce. Thus a decentralized, transparent system is need of an hour, which will rejuvenate the faith of the end buyer on farm produce. Our system uses proof of quality witha user-rank approach for creating credits of different users associated with farming. Thus our system suggests End-Buyers about suitable suppliers. Also, it punishes suppliers with non-ethical standards through our system.**

***Index Terms*—Proof of Quality,Distributed Ledger Technology, User-Rank, Supply Chain**

I. Introduction

Food security and traceability have received the most significant attention now and in the future. According to a study by the University of Oxford [1], by 2023, the world's population is expected to exceed 8 billion. This poses a challenge to the current agricultural system in high hill task, meeting the demand of 8 billion both in terms of quantity and quantity. Farmers use large amounts of fertilizers and pesticides on their farms to increase yields, which has proven harmful to the land and production consumers. Therefore, most consumers of the middle class and above have begun to develop health awareness about the consumption of their agricultural products. As a result, consumers now rely on credible agencies responsible for verifying their product's fertilizer and pesticide content, building trust among consumers. The health awareness of most societies for current agricultural consumption is generating new demands for organic agriculture. In organic farming practice, fertilizer, Pesticides, etc., are obtained from plants and animal products. The standard fertilizer that is still in use since the last century is cow dung fertilizer. Cow Dung manure is an excellent fertilizer that is highly rich in organic matter. Due to increased health awareness , the value of India's organic food market will reach US$849.5 million in 2020. With the support of the government's support plan, the organic-farm market expects to achieve a compound annual growth rate of 20.5% CAGR during [2] the forecast period 2021-2026. By 2026, the organic-farm market is hoping to reach 2.601 billion US dollars.

Therefore, active research is needed to track people's current quality and quantity demands (consumers) and farmers (producers) in capital and consumables. The sole purpose of this article is to introduce the supply chain between farmers and end-users. Our supply chain can track the origin of food in terms of quality and quantity. The use of blockchain in managing the supply chain has become a common trend. Blockchain technology provides security, traceability, and reliability to the supply chain, an indispensable part of the supply chain.

The paper is divided into the introduction section, working methodology section, and conclusion section. We provide a brief introduction to distributed ledger technology.

A. Distributed Ledger Technology

A ledger is a set of records that cannot be modified once it is written to a file/database (for example, a land-record database is an excellent example of a ledger description. Here, when a new entry is created for land, all previous entries remain intact, and the latest entry is inserted to the top, so over time, the stack of all transactions will remain on a specific land, with the new entry at the top of the stack. Distributed ledgers [3] are system-wide rather than using simple data storage applications in multiple locations. It manages users, policies and policies used to maintain records in the system. Typically distributed ledger consists of four parts: nodes, consensus algorithms, cryptography and shared ledger.

A node [3] is a system responsible for inserting and verifying transactions in the ledger between users. Management organizations usually maintain nodes. (For example: in the case of a land record system, the node is organized by

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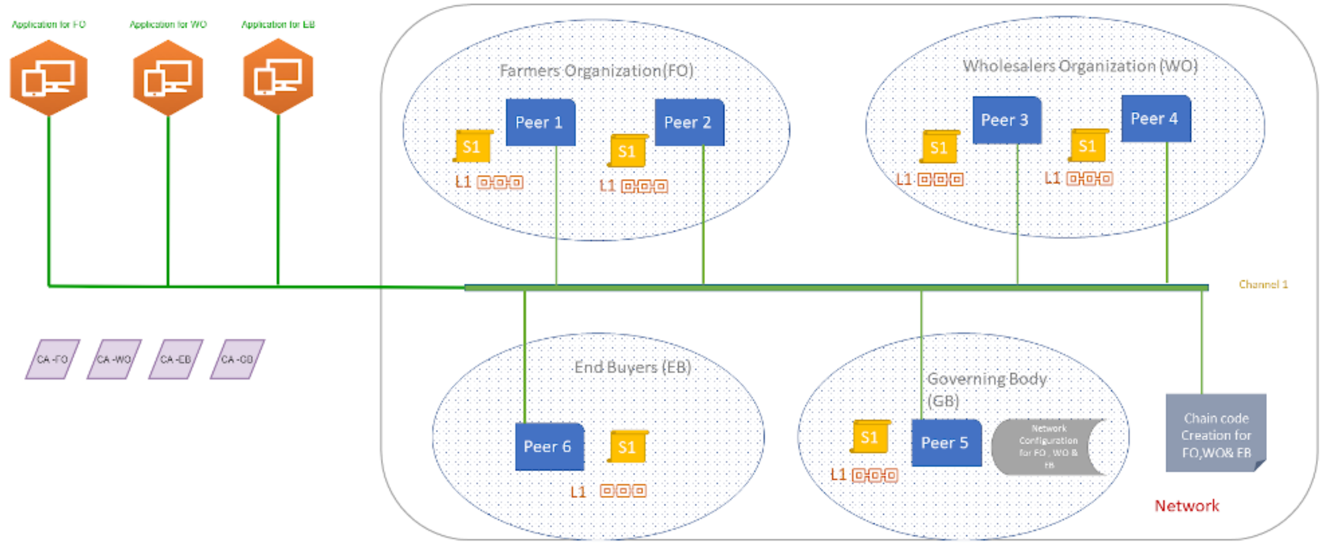

Fig. 1. Organic Farming Distributed Ledger Framework

a government organization responsible for maintaining land records). The concept of nodes varies from system to system, depending on the type of ledger used by the application. If all users in the network can participate in transaction verification, the ledger can be a public-ledger. In this case, the user behaves like a node because each user has a separate copy of the ledger, managed by them individually. For a private network, users with privileges can participate in the validation of transactions in the ledger. Therefore, duplicating the ledger on a large number of systems is an ideal solution for maintaining the ledger. Not all users participate in the verification process, so the system under a privileged user can act as a network node. The node definition is also affected by the network consensus definition.

A consensus algorithm is a decision-making sequence for approving transactions between the users. In general, a consensus consists of a validation process and updating the transactions over the ledgers. The consensus process may significantly depend on the type of data structure used in the trades, such as blockchain or directed graph with topological ordering.

Cryptography enables [4] the users to identify themselves and other users in the network securely. Digital certificates with SHA256 are mostly applied in the process of authentication. These certificates are also used in the process of validation of transactions between the users. Maintaining the same state of ledgers among all replicas is an uphill task. Thus replicas are mostly maintained using state databases that use key-value pair systems for recording transactions.

B. Supply Chain

Supply chain management is a process of transferring and transforming goods from the chain of users. It involves managing business in supply from senders to the receiver to maximize customer satisfaction and gain market capital. A supply chain consists of five parts.
1. Plan for developing a business module.
2. Supplier of raw ingredients.
3. Process of making final Product.
4. tracing of product from manufacturing outlets to the end buyers.
5. A feedback system for improving the business plan.

Our system's focus is to develop a good tracing strategy of farm products from farmers to the end buyers responsible for generating a broader income source for farmers in organic farming. Distributed Ledger can act as a business-friendly source of developing this system. [5] [6]The advantages of using Distributed Ledgers over other systems can be identified in terms of Anonymity and privacy, Auditability, Decentralized database, Immutability , Traceability, Transparency.

Tracing of Farm products can be done in various steps such as Traders, Farm-Organizations, Retailers. Pesticide residue levels of farm products can be tested at each step. High-performance liquid chromatography (HPLC), spectrometric analysis, thin layer chromatography are used to determine the level of arsenic in the products. [7]HPCL method is used to separate, identify, and quantify each component in a mixture. Total arsenic is extracted using Microwave-assisted extraction, Water-Based Extraction.

Spectrophotometry [8] is a method to measure how much a chemical substance absorbs light by measuring light intensity as a beam of light passes through the sample solution. Glyphosate herbicide residue can be determined using the spectrography method by studying effects on regents concentration and ph levels.

II. Methodology

A. Proposed Framework

We are currently developing a distributed ledger application on Hyperledger fabric shown in figure 1, responsible for

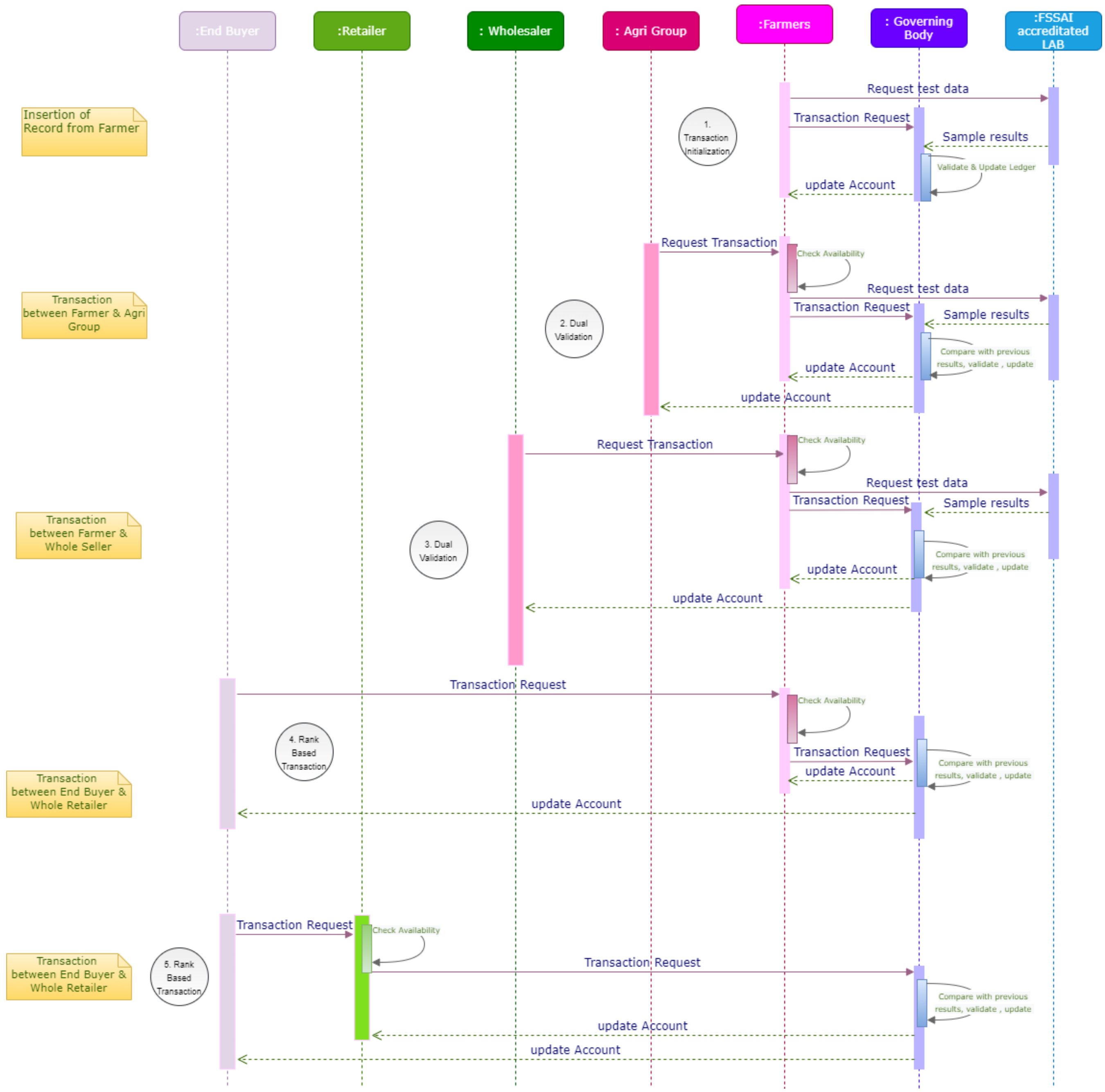

Fig. 2. User Based Transaction Flowchart

tracking and validating organic products. Our network consists of organizations, network-administrator, and transaction Chanel. An Organization consists of users who either perform transactions between the same or different organizations. Each organization manages a certificate authority that issues a certificate to the users of the organization. i.e., certificate authority for farmers organization (CA-FO) issues a digital certificate to a registered farmer under farmers organization.

Digital certificates issued by the organization identify users over the network. A farmer with a digital certificate can be seen by other farmers, traders, and end buyers while performing transactions. Each organization maintains a structure for storing copies of ledgers(L). The system for storing and maintaining a ledger is called peer. A peer can be a system privately used by the end-users of the organization or the computing structure created during the organization's creation. Farmers are using Peer1 and Peer 2 for storing and maintaining the records.

The network administrator (governing body) describes network policies for the transaction channel and sets administrative rights to the participating organization. Here governing body set rules for Farmers Organization and Traders Organization. Channel is a mode of communication between different organizations. A quorum of organizations uses a channel to perform transactions over a common cause. The governing body forms a quorum of farmers, traders, and end buyers for the supply of grains like wheat and rice.

Smart contracts(S) are used for writing conditions of the insertion of records in the ledger. Our system allows transactions between farmers and traders as well as transactions between farmers and end buyers. Thus a single ledger is maintained by all three organizations. Updation of ledger needs smart contracts. To maintain the ledgers associated with the peer, every peer stores the logic of smart contracts in its system. Farmers, Traders, and End-users use the application provided by their respective organizations for performing transactions. The application's functionalities provided through the user interface ultimately trigger the smart contracts for performing ledger operations. Our framework uses one direction transactions to present the supply chain of farm produce. i.e., Farmers can sell farm produce to traders and end-buyers. Also, traders can sell goods to end-buyers, but the reverse is not possible. To achieve this, Policies are made during the creation of organizations that ultimately prohibits reverse transactions.

B. Transaction Flow

We have established three organizations: a farmers organization(FO), a wholesale organization(WO), and a governing body(GB) organization. Farmer's organization is composed of individual farmers or small agricultural groups. The farmers initiate the transaction by adding the record to the ledger of the agricultural products that the farmer is currently harvesting. For the product to be organic, according to the Food Safety Standards Agency of India (FSSAI) 2017 regulations[], pesticide residues in organic food must meet the stricter non-organic food limit of 5%. The average amount of metal containment, naturally occurring toxic substances, Insecticides and Pesticides as given in [Appendix A] are computed and verified in FSSAI-certified laboratories before inserting entries in the ledger, forming general validation about the farm product as shown in 1st part of transaction flow . Farmers also provide parameters such as seed type, harvest date, sowing date, seed count with 14% moisture level in 100gm, manure quality, quantity, area of crop to justify agricultural products price. These are important indicators for agricultural product's life cycle to prove the quality and quantity of agricultural products. The target user can only view the published record. In other words, users in a country/region can only view transactions that meet the maximum residue limit (MRL) set by the country/region. For example, the Indian government has set the MRL of metallic cadmium in wheat products to 0.2 ppm. Therefore, all records that meet the above restrictions are visible to Indian users.

As part of the supply chain, Farmers can sell farm produce to Farm Organizations, Wholesalers, Retailers, or End-buyers. Farm organizations, Wholesalers, retailers initiate transactions by placing an order request against the records published by farmers in the ledger. If the Available quantity matches against the requested quantity provided from the buyer's side, the seller initiates a transaction on the ledger. At this point, the buyer also sends the test samples to FSSAI accredited test laboratories to detect pesticide residues in the samples. The test results are returned to the governing body, where previous results are compared with current test results. Here the governing body re-validates the record previously available from the farmer's side, defining proof of quality for the record shown in 2nd and 3rd part of the transaction flow. Our system repeats the process for the succeeding transactions between Farm organization and Wholesaler, Wholesaler and Retailer, Retailer and End-Buyer for the same set of farm produce broadcasted from farmers side for sale. More transactions on the same set of farm produce indicate sound Proof of Quality.

III. Challenges and Solutions to Proof of Quality.

For any transactions between the End buyer and all other types of users, trust on validation of the last transaction is the only available option as the end buyer does not send the products for testing. Here other users (Farmers, Traders, Retailers, Farm Organizations) may send different products than the one tested. Our system uses a rank-based system [9] that generates rank for the users based on the transactions to overcome this situation. Group, Traders, Retailers receive rewards for each valid transaction. For an invalid transaction, the sender of the transaction receives punishment. Reward increases the rank of a user, while punishment decreases the rank of a user. When a transaction is processed between Farmers and other users such as traders, farm organizations, and retailers, the difference between residue levels and grain count per 100gm is computed as a part of dual verification. If the difference varies more than 10% with the previous result, the transaction is considered invalid. This is an ideal case when users apart from the end-buyer can send different products than the ledger's product. As a part of the punishment, users are marked, and their mean value is set to the highest mean value available for that type of user. For instance, if a farmer's transaction is computed as invalid during the dual validation process, then the farmer's mean value is set to the highest mean value available amongst all farmers. This process is also applicable for Framgroups, Traders.

A farmer's rank [10] is computed based on the mean residual difference available in [appendix A]. The system awards farmer with the lowest mean value with the first rank. If two farmers have the same mean value, then the system considers no transactions he has performed in overall transactions. The more no of the transaction indicates that the system has recommended the farmer for the transaction. Also, he has performed those transactions ethically. In case of an invalid transaction, the farmer's stake in his previous transactions is reduced by 50%. In the situation of having two farmers with equal no transactions, the farmer with more no transactions in 1 standard deviation is to be considered first. The above process is also applicable to Framgroups, Traders.

TABLE I
OPPORTUNITIES AND CHALLENGES

Stake holders	Opportunities	Challenges
Farmers	1.To sell the product at own decided price. 2. To introduce its own produce at a wider platform with new potential customers.	1.To keep the level of inorganic residuals as low as possible. 2. To incorporate ethical practices used in organic farming.
Traders	1.To get access to desirable products at a touch of fingers. 2. . Able to negotiate with farmers on their own terms.	1. Keeping produce in storage according to the norms of government.
Governing Body(FSSAI)	1.To collaborate with certified labs for providing testing services and generating revenue. 2. To generate a dataset of residual tests for further analysis.	1. To create a large no of testing facilities and collaborations for timely test results. 2. To reduce the cost of testing up to a level that is affordable for farmers.
Smart Startups	1. A potential market is developing, which uses applications based on sensors, Artificial Intelligence, and Blockchain technology for the crop life cycle.	1. The cost of using these technologies is greater than the production itself, thus creating the hesitation in farmers' minds.
Research Institutes	1. To get access to datasets available for finding consumer's pattern over farm produce. 2.To detect upcoming trends in farm produce.	1. To obtain a verified dataset from farmers, such as date of sowing, date of harvesting. 2.To obtain the actual amount and type of fertilizer applied from farmer's side.

For considering rank system amongst retailers parameters such as seed count and near vicinity are considered.

IV. Conclusion and Future Scope

Proof of quality provides a transparent and tamper distributed ledger system for the Organic farm industry. It encourages the users to have ethical practices and, at the same time, it disrupts the users with malpractices. The critical observations about opportunities and challenges for the vital role players such as Farmer, Traders, Governing bodies, Research Institutes are discussed in table I.

As a researcher, we will work on a separate distributed ledger system to trace the farmer's supplements using IoT, purchase order. Finally, we will integrate the current ledger system with the above system to form a complete Organic Farming solution.

References

[1] M. LLC. (2021) MS Windows NT kernel description. [Online]. Available: https://ourworldindata.org/grapher/global-demand-for-education-world-population-and-projected-growth-to-2100-by-age-group?tab=chart&time=1950..2100&region=World

[2] ——. (2021) MS Windows NT kernel description. [Online]. Available: https://www.expertmarketresearch.com/reports/india-organic-food-market

[3] H. F. Atlam and G. B. Wills, "Intersections between iot and distributed ledger," in *Advances in Computers*. Elsevier, 2019, vol. 115, pp. 73–113.

[4] Z. Zheng, S. Xie, H. Dai, X. Chen, and H. Wang, "An overview of blockchain technology: Architecture, consensus, and future trends," in *2017 IEEE international congress on big data (BigData congress)*. IEEE, 2017, pp. 557–564.

[5] S. S. Kamble, A. Gunasekaran, and R. Sharma, "Modeling the blockchain enabled traceability in agriculture supply chain," *International Journal of Information Management*, vol. 52, p. 101967, 2020.

[6] A. Kamilaris, A. Fonts, and F. X. Prenafeta-Boldύ, "The rise of blockchain technology in agriculture and food supply chains," *Trends in Food Science & Technology*, vol. 91, pp. 640–652, 2019.

[7] G. Raber, N. Stock, P. Hanel, M. Murko, J. Navratilova, and K. A. Francesconi, "An improved hplc–icpms method for determining inorganic arsenic in food: application to rice, wheat and tuna fish," *Food chemistry*, vol. 134, no. 1, pp. 524–532, 2012.

[8] M. R. Jan, J. Shah, M. Muhammad, and B. Ara, "Glyphosate herbicide residue determination in samples of environmental importance using spectrophotometric method," *Journal of Hazardous materials*, vol. 169, no. 1-3, pp. 742–745, 2009.

[9] T. Burnham, "Public goods with punishment & payment for relative rank," *Available at SSRN 2623763*, 2015.

[10] C. W. Bauman, L. P. Tost, and M. Ong, "Blame the shepherd not the sheep: Imitating higher-ranking transgressors mitigates punishment for unethical behavior," *Organizational Behavior and Human Decision Processes*, vol. 137, pp. 123–141, 2016.