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3RD ANNUAL BRIC SYMPOSIUM 2023: ENGINEERING, SHAPING THE FUTURE

Booth Resource and Innovation Cluster (BRIC) imbibes McMaster's vision and mission of Impact, Ambition, and Transformation through Excellence, Inclusion and Community: Advancing Human and Societal Health and Well-being. Housed within the W Booth School of Engineering Practice and Technology, BRIC is a one-stop-shop for industry and community for their innovation challenges in the areas of AI/ML, Computational modeling, Biotechnology, eHealth, Environmental Excellence, Robotics, and Automation. BRIC supports collaboration, innovation, and dissemination through its symposium, bulletin, and workshops.

McMaster University

W Booth School of Engineering Practice and Technology

Editorial Note:

It is our great pleasure to introduce you to the 3rd Annual BRIC Symposium organized by Booth Research and Innovation Cluster (BRIC) at W Booth School of Engineering Practice, McMaster University Canada, on July 28th, 2023. BRIC imbibes McMaster's vision and mission of Impact, Ambition, and Transformation through Excellence, Inclusion and Community, Advancing Human and Societal Health and Well-being. Housed within the W Booth School of Engineering Practice and Technology, BRIC is a one-stop-shop for industry and community for their innovation challenges in the areas of AI/ML, Computational modelling, Biotechnology, e-Health, Environmental Excellence, Robotics, and Automation.

BRIC 2023 is a platform for engineers, academics, and industry professionals to present their research results and share their research findings and experience. The Symposium Proceedings provides a wide variety of topics, including AI, additive manufacturing, Autonomous Vehicles, Mechatronics and modern electronics systems, Power, and Biotech. Twenty extended abstracts were virtually presented. We would like to thank all authors and speakers for their quality submissions and enthusiastic participation in the BRIC 2023 Symposium. We thank the program committee members for their meticulous job in selecting papers for publication.

We are confident that BRIC will continue to be a great platform for participants to have fruitful discussions and share their latest research results. We are looking forward to next year's symposium and warmly welcome suggestions from all of you.

Symposium Chairs:

Marjan Alavi, McMaster University, Canada

Moein Mehrtash, McMaster University, Canada

Contents

Low-Temperature Energy Harvesting for Sustainable Electricity Generation in Remote Areas

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***Abstract*–This paper explores the potential of energy generation from sources with low-temperature differences, focusing on designing machines to convert this untapped energy into mechanical work and produce electricity. With distributed and intermittent solar energy being cost-prohibitive due to energy storage requirements, utilizing thermodynamics principles to harness low-temperature energy emerges as a viable alternative for reliable electricity generation in remote areas. We present several innovative projects proposed at McMaster University's W Booth School of Engineering Practice and Technology (SEPT), each combining water desalination, heat, and electricity production in a cost-effective manner with low technology, reliability, and common materials. These projects have significant potential to provide sustainable and affordable energy solutions for separated indigenous societies, especially in polar regions.**

***Keywords*— Energy Harvesting, Sustainability, Solar Power, Water Desalination, Student Projects**

I. Introduction

II. Energy Harvesting from Low Temperature Differences

Thermodynamics laws enable the conversion of mechanical work when temperature differences exist. Though low-temperature differences may pose challenges to thermodynamic efficiency, vast untapped energy exists in the temperature gradients between lakes, air, ice, and other natural sources. This paper highlights the significance of harnessing such energy for remote electricity generation.

III. Related STUDENT PROJECTS at SEPT

A. Water Desalination Solar System

The first project involves a water desalination solar system. The saline water flows under a flat glass plate, absorbing solar energy. A low-speed stream of air flowing over the saline water absorbs moisture, and the cooled air produces pure water. Additionally, the misted hot air can be cooled in a cylinder, generating mechanical work and, simultaneously, providing electricity for local communities.

B. Low-Pressure Turbine for 40-Degree Temperature Difference

The second project involves a vertical cylinder divided into two parts, with heated water in the lower section and cooled water in the upper section, by utilizing a small nozzle to exploit the 40-degree temperature differential pressure, which drives a turbine to produce electricity. This straightforward design with only a single moving part ensures both cost-effectiveness and reliability, making it an ideal solution for energy generation in remote areas.

C. Saline Water Desalination and Electricity Generation

Project three uses hot saline water in the lower cylinder and produces desalinated water in the upper part. The temperature difference creates differential pressure, driving the turbine for electricity generation. This integrated approach yields both electricity and potable water, enhancing its value for remote communities.

D. Cold Liquid Circulation System for Polar Regions

The fourth project addresses polar regions' unique challenges, utilizing a circulating liquid suitable for low-temperature conditions under the ice and cold air above the lake. The temperature difference drives the turbine, producing electricity and potentially providing electricity solutions for local communities.

IV. Conclusion

This paper demonstrates the potential of low-temperature energy harvesting for sustainable electricity generation in remote areas. The innovative projects presented here combine water desalination, heat, and electricity production using cost-effective materials and low technology. These solutions offer reliable and affordable electricity, benefiting separated indigenous societies, e.g. in polar regions. Continued research and development in this field will further optimize these designs, making them practical and essential solutions for remote energy access.

Differential Evolution Algorithm Based Hyperparameter Selection of Gated Recurrent Unit for Electrical Load Forecasting

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ABSTRACT

Accurate load forecasting plays a vital role in numerous sectors, but accurately capturing the complex dynamics of dynamic power systems remains a challenge for traditional statistical models. For these reasons, time-series models (ARIMA) and deep-learning models (ANN, LSTM, etc.) are commonly deployed and often experience higher success. In this paper, we analyze the efficacy of the recently developed Gated Recurrent Network model (GRU) in Load forecasting. GRU models have the potential to improve Load forecasting because of their ability to capture and model temporal dependencies in the data efficiently. We apply several metaheuristics, namely Differential Evolution to find the optimal hyper-parameters of the Gated Recurrent Neural Network to produce accurate forecasts. Differential Evolution provides scalable, robust, global solutions to non-differentiable, multi-objective, or constrained optimization problems. Our work compares the proposed Gated Recurrent Network model integrated with different metaheuristic algorithms by their performance in Load forecasting based on numerical metrics such as Mean Squared Error (MSE) and Mean Absolute Percentage Error (MAPE). The simulation prediction is carried out by using the power load data of Ontario province, Canada. Our findings demonstrate the potential of metaheuristic-enhanced Gated Recurrent Network models in Load forecasting accuracy and provide optimal hyperparameters for each model.

Keywords—Load Forecasting, Differential Evolution, Gated Recurrent Unit, Meta-heuristics, Hyper-parameter Selection

I. INTRODUCTION

Load forecasting is the application of science and technology to predict the future demand for electricity or power in a given geographical location, for some specific future time. It plays a crucial role in various sectors, such as energy trading & Markets, Infrastructure Planning, disaster management, etc., to name a few. Traditional load prediction methods rely on historical data & models that simulate patterns of electricity consumption, but such models often face challenges in accurately capturing the complex dynamics of power systems [1]. To model this complexity, time series models like Auto-Regressive Moving Average (ARIMA), various deep learning techniques have been introduced such as Artificial Neural Networks (ANN), Recurrent Neural Networks (RNN) and Long Short-Term Memory (LSTM). The models work to improve the accuracy of load forecasts by leveraging large datasets and discovering hidden patterns to predict future values. Like any other deep learning model, their performance depends on the chosen hyperparameters.

In this work, we utilized metaheuristics Genetic Algorithm, Differential Evolution [2], and Particle Swarm Optimization to identify ideal hyperparameters. Although hyperparameter search techniques like Grid Search, Random Search, and Bayesian Optimization are substantial improvements to manual tuning, they are inferior to the metaheuristics discussed in this paper. The metaheuristics are more efficient than grid search and random search and more robust and scalable than Bayesian Optimization. Furthermore, these algorithms can be applied to nonlinear, nonconvex, and noncontinuous functions. In the field of load forecasting, metaheuristic algorithms were employed for the first time to optimize the performance of deep learning models like GRU. This resulted in the better performance of load forecasting models because metaheuristic algorithms excel in global optimization, exploring and exploiting the search space efficiently to find the optimal solution. In this paper, the authors seek to fill the void and propose Differential Evolution optimized Gated Recurrent Unit (GRU) architecture specifically designed for Load forecasting. We identify that the GRU's abilities in long-range dependencies can be applied to Load forecasting. This combination of GRU and Differential Evolution enables us to achieve enhanced accuracy and performance in predicting daily hourly demand. Additionally, we have collected and meticulously curated a comprehensive dataset comprising power-related parameters spanning a substantial time frame of 5 years, specifically for the Ontario province in Canada.

The performance of the model was evaluated using Mean Squared Error (MSE) and Mean Absolute Percentage Error (MAPE) metrics. To evaluate the results, we also integrated Particle Swarm Optimization and Genetic Algorithm with the Gated Recurrent Networks to benchmark against our proposed Differential Evolution integrated Gated Recurrent Model.

Our work stands as the pioneering effort in proposing a Differential Evolution-based hyperparameter tuning scheme for Gated Recurrent Unit (GRU) Network models in the realm of short-term electrical load forecasting.

II. Contents

A. *Proposed Gated Recurrent Unit Model*

The Gated Recurrent Network (GRU) [3] model's proposed structure is illustrated in Figure 1, highlighting its key components and connections. We have fed the model with 8 features from the previous three timesteps or from the data of the previous 3 hours including itself. So, we have used 36, 64 and 24 neurons for the input, GRU layer and output layers. For the case of GRU model architecture, we have taken the time steps into account, thus getting the shape or x-train: (53558, 3, 8) and likewise for the other splits.

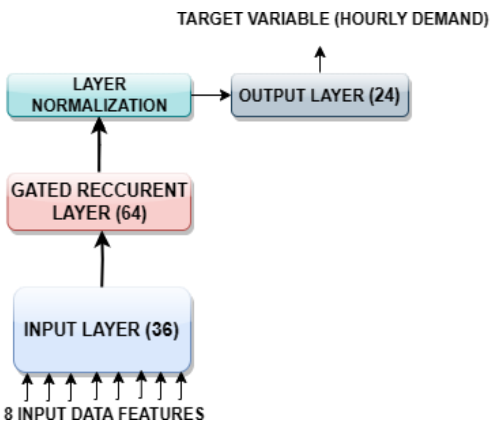

Fig.1. Proposed Gated Recurrent Model

All three networks used the Rectified Linear Unit (ReLU) activation function modeled in Equation 1 below:

$$f(x) = \max(0, x) \qquad (1)$$

The metaheuristic algorithms were utilized to find the optimal batch size, epoch, and learning rate hyperparameters. They were optimized by minimizing loss using the Mean Squared Error metric. Each model's best set of learning rate, batch size and epoch are summarized in the table below:

BEST SET OF HYPERPARAMETERS FOR GATED RECURRENT MODEL	
METAHEURISTICS	HYPERPARAMETERS
Genetic Algorithm	(80,844,0.0001)
Particle Swarm Optimisation	(173,35,0.3109)
Differential Evolution	(24,1000,0.1)

Fig.2. Best set of hyper-parameters obtained for proposed Model.

Mean Absolute Percentage Error (MAPE) was calculated for the best set of hyperparameters found using the Differential Evolution Algorithm.

B. *Differential Evolution Algorithm*

Differential Evolution (DE) is a stochastic population-based optimization algorithm developed by Rainer Storn and Kenneth Price in 1997. It is used to find approximate solutions to a wide class of challenging objective functions. DE can be used on functions that are nondifferentiable, non-continuous, non-linear, noisy, flat, multi-dimensional, possess multiple local minima or are stochastic. The steps are explained below:

1) Initialization: Suppose f has D parameters. An N -sized candidate solution population is initialized, with each candidate solution modeled as x_i, a D-parameter vector.

$x_{i,G} = [x_{1,i,G}, x_{2,i,G} \ldots x_{D,i,G}]$, where i = 1, 2...N, and G is the generation number (2)

2) Mutation: A mutation is a stochastic change that expands the candidate solution search space. Mutations are used in DE to prevent the algorithm from converging upon a local optimum.

The mutant vector is obtained by adding the weighted difference of two of the vectors to the third.

$$v_{i,G+1} = v_{r1,G} + F \times (v_{r2,G} - v_{r3,G}) \qquad (3)$$

$F \in [0, 2]$ represents the scale factor for the mutation.

3) Crossover: Crossover is how successful candidate solutions pass their characteristics to the following generations. A trial vector $u_{i,G+1}$ is created by combining the original vector $x_{i,G}$ and its corresponding mutant vector $v_{i,G+1}$. A widely used crossover scheme is described below:

$$u_{j,i,G+1} = \{v_{j,i,G+1}, \text{ if } p_{rand}\, U(0, 1) \leq CR, \text{ else: } x_{j,i,G}\} \qquad (4)$$

4) Selection: Given both the initial target vector and generated trial vector, the fitness of each is evaluated using the initial objective or cost function f.

$$x_{i,G+1} = \{u_{i,G+1}, \text{ if } f(u_{i,G+1}) \leq f(x_{i,G}), \text{ else: } x_{i,G}\} \qquad (5)$$

The Differential Evolution Algorithm is illustrated in Figure 3 below:

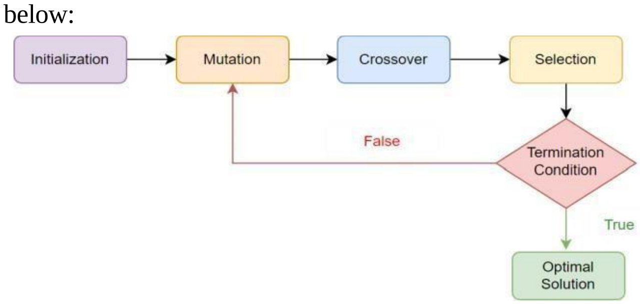

Fig.3. Differential Evolution Algorithm

Consequently, due to its power optimization capabilities, it was selected as the algorithm of choice to optimize our Gated Recurrent Unit (GRU) model.

C. *Data Collection*

The dataset was created for this project using data scraped from the official website of the Government of Canada [4] and

Independent Electricity System Operator (IESO), Canada [5]. This data contains meteorological data from Ottawa, Toronto, Ontario from 1st January 2017 to 31st July 2023. The data set contains the properties: Ontario hourly demand (in kW), Daily Peak Load (in kW), date, time, year, quarter, month, week of the year, day of the year, state holiday, an hour of the day, day of the week, day type, temperature (in ◦ Celsius), dew point temperature, relative humidity (in %), wind speed (in kilometers/hours), visibility (in kilometers) and precipitation amounts (in millimetres). The compiled data set contains 19 variables layered in 96,432 rows, where each row represents an hour.

III. Results and Discussion

We obtained the mean absolute percentage error (MAPE) using the proposed approach to implement the differential evolution-based hyperparameter tuning of the Gated Recurrent Network. This MAPE was compared to the MAPEs generated from the proposed approach with the genetic algorithm and particle swarm optimization-based hyperparameter tuning of the architecture.

The Standard scaler has been used to improve the convergence and stability of seasonal data during model training. The mean squared error (MSE) was employed as the loss function to evaluate the fitness of the differential evolution algorithm.

Mean Absolute Percentage Error (MAPE) is used to gauge the accuracy of the entire model. It provides a measure of the average percentage difference between predicted values and the actual values.

Table II above provides us with a comparison of MAPE among various metaheuristic optimization algorithms used here

BEST SET OF HYPERPARAMETERS FOR GATED RECURRENT MODEL	
METAHEURISTICS	MAPE
Manual Selection	2.07
Genetic Algorithm	1.31
Particle Swarm Optimisation	1.28
Differential Evolution	1.11

Fig.4. Comparison of MAPE & Meta-heuristics

The results prove that Differential Evolution (DE) algorithm outperforms the other meta-heuristics in terms of mean absolute percentage error (MAPE). Differential Evolution's superior ability can be attributed to a few factors. DE can more effectively explore the search space and exploit the promising regions for optimal solutions using its various genetic operators.

To visually understand the results and accuracy of the Load forecasting model proposed here we have plotted 24-hour prediction for the DE on the Gated Recurrent Network Model as shown in Figure 5. This shows that the model gives a fairly accurate prediction on Test data.

The results ascertain that metaheuristic optimization algorithms consistently outperform the manual selection method. Particle Swarm Optimization (PSO) outperforms Genetic Algorithm (GA) but falls behind Differential Evolution in overall optimization performance, showcasing DE's superior search capability and robustness.

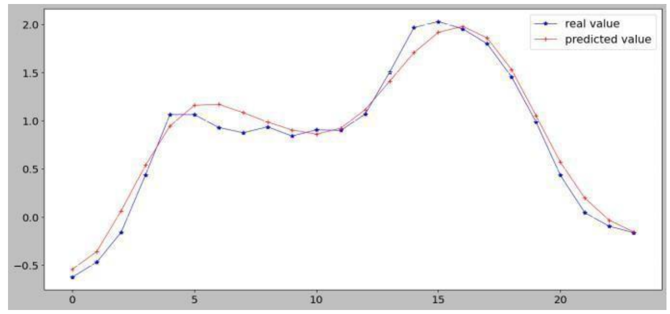

Fig.5. 24 hours ahead forecast plot for DE-GRU model

PSO suffers from rapid convergence, limiting its ability to reach the global optimum, which could be an explanation for its performance.

IV. Conclusion

This paper applies several metaheuristic algorithms to a proposed Gated Recurrent Neural Network to find the optimal hyperparameters. This selection method was proven to be far more efficient and accurate than manual selection. Amongst the metaheuristics tested, Differential Evolution proved to be the best, followed by Particle Swarm Optimization and finally Genetic Algorithm.

Due to possessing limited computational resources, each metaheuristic algorithm couldn't be applied to sufficiently large populations over many generations. If this research is extended with more powerful devices, future studies over larger populations and more generations will corroborate our findings. Future studies may investigate the performance of other alternative metaheuristic algorithms on hyperparameter tuning for similar deep learning models, across a wide range of forecasting tasks.

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Queue Management System using RFID and Raspberry Pi

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Abstract - Recent technological advancements in Internet of Things (IoT), enable the use and integration of existing technology to optimize the business operation. It also allows developing innovative new ideas to increase customer satisfaction. In this report we have briefly described the use of a Raspberry Pi as Central Processing Unit and RFID Tag, Receiver to create a low-cost Queue Management System to reduce long queues at highly sorted-after places like amusement parks and/or restaurants. This approach can be modified as required and can be implemented at different locations and different business sectors as well.

Keywords - Internet of Things, Radio Frequency Identification, Queue Management System.

I. Introduction

RFID Technology has been in use for a long time. Recently, developing nations like India have implemented Automatic Toll collection systems nationwide to reduce the operation time as well as to optimize the whole process by reducing the number of humans involved in it by using RFID tags and receivers. The main advantage of RFID Tags is that they are anti-collision, which means the receiver can scan or process multiple tags at the same time. Another advantage is that the tags are re-writable, enabling small business owners to allot a tag to a customer and then re-write as per the needs. This feature has played a crucial role in increasing the use of RFID.

The restaurant industry may face issues in managing huge customer demands now and then. Different technological advancements have been implemented to overcome this issue and simplify the process of managing the huge number of queues at different locations. Hospitals and restaurants have suffered a lot due to this. Customer satisfaction or disappointment settles the tone as word-of-mouth advertisement plays an important role in this. The retail industry has come up with different solutions, which include increasing the number of employees to overcome the crowd, which has worked in their favor significantly. This has not been the case for the previously mentioned industry.

II. Problem Statement

A. *Background*

Radio Frequency Identification consists of two components: a Tag and a Receiver. Tags communicate to the Receiver via Radio Frequency, which in return reads the Tag ID and Tag Description (Tag Data) and interprets and analyzes as per the functionality [3]. The main advantage of an RFID tag is that it is rewritable. This can be utilized to write down information from a single number indicating the employee number, a large integer like a cell phone number or information up to a number of pages. This can be a game changer from a perspective in which storing information in a simpler way is crucial.

B. *Approach*

The increasing demand from the restaurant industry and increasing population, standing in long queues, has been an important issue to mention and which needs to be addressed. Traditionally, people used to either stand in line or change their plans or had to plan the trip or dinner long before the weeks. The appointment system is working fine but can be an obstruction in the sudden plan. To avoid this people have come up with a solution of QR code to scan and reserve the spot in line.

To automate the process with QR Code is not easy as it involves several libraries to automate and integrate with any controller. Moreover, another big disadvantage of the QR Code or Barcode Queue Management System is that once the QR Code or Barcode is written, it cannot be changed. This can be a one-time solution if implemented.

Using RFID as the primary sensor and actuator is far easier as Raspberry Pi has already installed libraries in it which makes integration management easier. On the other hand, when compared to QR Code, RFID Tags can be written multiple times. This makes the solution more realistic.

III. Market Analysis

The market cap of the existing Queue Management System is around 0.54 billion USD, with an expected CAGR of 4.1% during the forecast period [1]. The North American Queue Management System (QMS) is projected to grow by 5.7% annually and reach 351.7 million USD by 2023 [2].

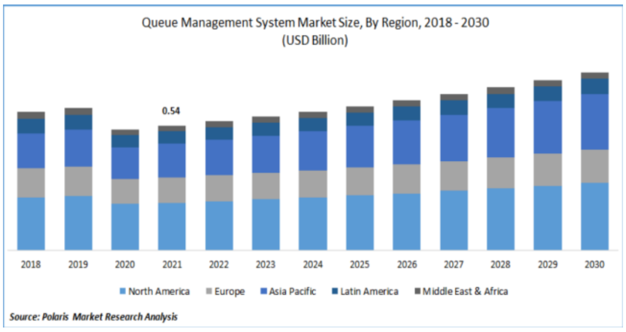

Figure 1: Market Report of QMS by year and by continent

IV. Components

There are several types of RFID devices available in the market which can be used for several different purposes [4].

The Raspberry Pi 3 Model B is known to be the third generation Pi, which is a credit-card-sized electronic board. Nowadays, Wi-Fi is one of the most paramount protocols for wireless connection and accessing the internet. This model delivers wireless LAN and Bluetooth connectivity, making it exemplary for powerful designs. The Pi is powered by a Quad Core Broadcom BCM2837 64-bit ARM processor clocked at 1.2 GHz and has a RAM of 1 GB. Raspberry Pi is not only pertinent for prototyping and commercial product design but also for designing an original PCB layout. As already mentioned in the problem statement, we will be incorporating the RFID system over barcodes [5].

Table 1: Type of RFID Systems

RFID Systems Type	Frequency Range	Sensing Range
Low frequency	30 KHz to 500 KHz	Few inches to < 6ft.
High frequency	3 MHz to 30 MHz	Few inches to Several ft.
UHF	300 MHz to 960 MHz	> 25 ft.
Microwave	2.45 GHz	>30 ft.

V. Advantage of RFID

Traditionally barcode was set to replace everything to automate things. Barcode and QR Code works fine until it starts to fade away. As discussed earlier, QR Code and Barcode can be written only once and cannot be erased. Moreover, when integrating it with controllers like Raspberry Pi and external device Camera like Pi Camera to be able to detect and scan. Moreover, QR Code needs to be near to be able to scan via camera.

Another technology that had the capability to replace QR Code was Near Field Communication (NFC). Although there are certain areas where NFC outweighs QR Code and RFID Technology both, like Bidirectional flow of information, and less than 15 milliamperes of current requirement but the biggest disadvantage of NFC is that it can only work in distance of less than 0.2 meters while as discussed earlier RFID tags can work in much longer distances.

VI. Disadvantages of RFID

There are several challenges while using RFID Tag and Receiver like RFID Receiver Collision which can be prevented by using Anti Collision Protocol while programming RFID Tags. Another one is that there might be an issue of RFID Tag Collision.

Data Privacy and Data Security can be a critical issue that needs to be addressed when talking about implementation at a much higher level where data security can be critical. RFID tags can be used to track someone's location and as they are very minute, they can be hard to spot. Moreover, RFID tags can be read without someone's knowledge if a proper reader is brought in vicinity. Encryption on an RFID Tag is something which cannot be done unlike other technologies as they have very low computing power.

VII. Proposed Implementation

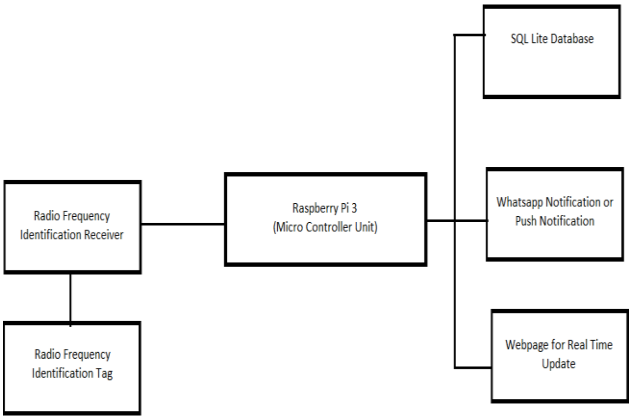

Figure 2: Proposed Block Diagram

For our implementation, we have used Raspberry Pi 3 as our main control unit which will make decisions as per the programming. RFID Tag and Receiver will act as Sensors which will be able to use the sense the presence of the sensor and to write and store the information.

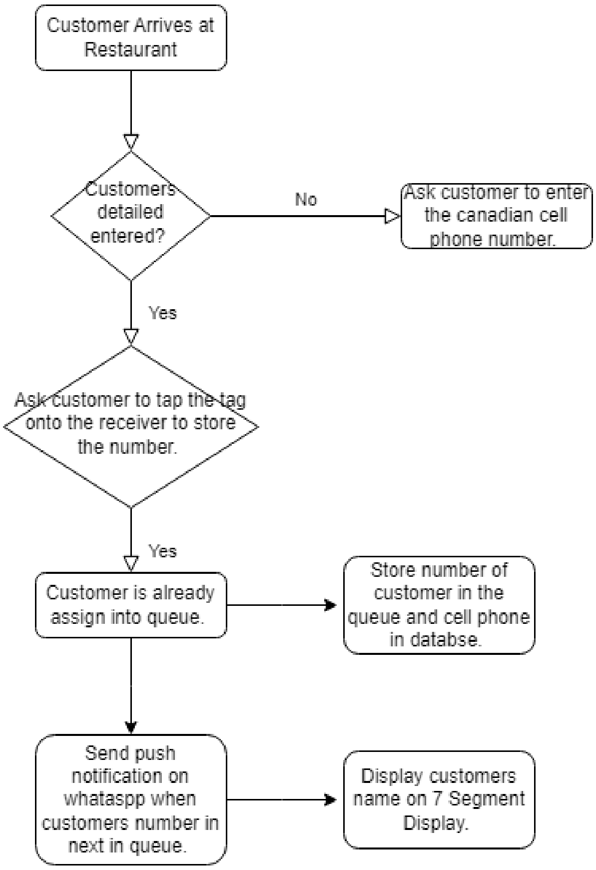

Figure 3: Proposed Flow of Information

The customer will be asked to take a tag from a bunch and will be asked to enter his/her cell phone number on which his/her WhatsApp is registered. The customer must scan the tag on to the receiver to write the cell phone number on the tag. After that, the customer must tap another tag again to register himself or herself into the queue. Once the customers' phone number, name and queue number are registered. Post "queuing" the customer is free to roam about as they will receive an alert message minutes before their turn in the queue. The restaurant owners can insert a time delay after which a message will be sent from WhatsApp web application to store mobile number on the tag reminding the customer to return to the spot and wait for their turn.

The WhatsApp message can be changed to simple text message, or an email message. A push notification can be integrated by including several libraries. For simplicity of the project, WhatsApp was used as it had already well detailed library available.

VIII. FUTURE SCOPE AND MODIFICATIONS

a. In future advancement the system can be integrated with SQLite database to maintain a list of customers visiting the restaurant.
b. A display and buzzer can be integrated to display and alert customers when they are next in queue.
c. Live queue updates. Change and transfer spots with willing customers to accommodate another activity into their day before attending the reservation.
d. Push notifications, and or notification via a call or email can be added to increase preferred modes of communication.
e. Add QR code support. Only software- based queueing support if desired by business. Offer queueing as a SaaS product.

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Smart Clock in system

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***Abstract*—This paper develops an automated system that can accurately detect the presence of individuals at nearby entry point of premises, verify the identity of the authorized personnel and enforce occupancy limits as per the requirement. This project aims to track employee attendance using a face recognition algorithm.**

I. Introduction

Smart Clock in system consist of two ultrasonic sensors as well as two cameras which provides automatic detection of the person on the gate of restricted area. Using Ultrasonic it detects the person present in the specific range which is defined in the code (Particularly for this project we have defined the range of 1.5 to 5 centimeters). Upon detection, it will trigger the camera of Raspberry PI followed by which Deep Learning Model named ResNet34 which uses concepts of Convolution neural Network is used to get the feature of the image and label it. Upon knowing the person and labeling them, it activates stepper motor to open and close the door if the person is authorized to enter the restricted area. Finally, it calculates the number of people in that specific area. Similarly, if the person is moving out of the restricted area then the count will be subtracted and the final total will be displayed.

II. Hardware Used and Its Functions

A. Raspberry PI

Raspberry PI is a small chip which is featured with system on chip. It is regularly under constant development and improvement both in terms of hardware and software which in-turn makes PI a" Full Fledged Computer" with possibility to be considered for almost all computing intensive tasks[1]. For these projects we have connected Raspberry PI with other Hardware like camera, ultrasonic sensors, stepper motor. All the hardware is attached to the specific I/O PIns provided on the Raspberry PI. As it provides the whole operating system, we can use python language for coding on same and provide code for specific I/O PIn.

B. Ultrasonic Sensor

Ultrasonic Sensor work by transmitting a pulse of sound ,outside the range of Human Hearing. The shape of the pulse are in Conical shape. Mathematical notation of the distance measured by sonar is [2]:

$$distance = TRoundTrip * VSound/2 \quad (1)$$

Here in this Project, we have used the ultrasonic sensor where it activates the Camera if the object is in the defined distance of 1.5 to 5 centimeters.

C. Raspberry PI Camera

Raspberry PI is camera designed to use it with Raspberry PI chip. For this project it is triggered only when the ultrasonic sensors detect someone and provides the data to the system.

D. Stepper Motor

It is a device which simply converts electrical energy to Mechanical Energy. In this Project, the person's face is captured by the camera and upon processing and labelling the captured photo, if the person is authorized it (Stepper motor) is activated.

III. Process/Flow of the Program

The restricted premises will have this system at the entrance and the exit gate. The system will be activated 24/7.When a person enters the building/ restricted Area, the Ultrasonic Sensors detects if the person is close to set range and activates the Raspberry PI Camera. Upon capturing the person's face, the Code for image recognition is activated and the person is labelled. Once the person is identified the stepper motors are run to unlock the door. And the Count is added if the person is entering the premises else the count is subtracted.

For Image Recognition, implementation of transfer learning with 34 convolution neural network architecture, named ResNet34.

ResNet is a deep learning model that has been used for various computer vision tasks including face recognition [3]. In this project, we have implemented ResNet34 as it takes up less memory to train the data compared to the higher-level version of ResNet like ResNet50, ResNet128, etc. Implemented the above architecture in pytorch Fast AI library.

TABLE I
Dataset Information

Training Set Size	***Validation Set Size***	***Epoches***	***Classes***
400	40	20	3

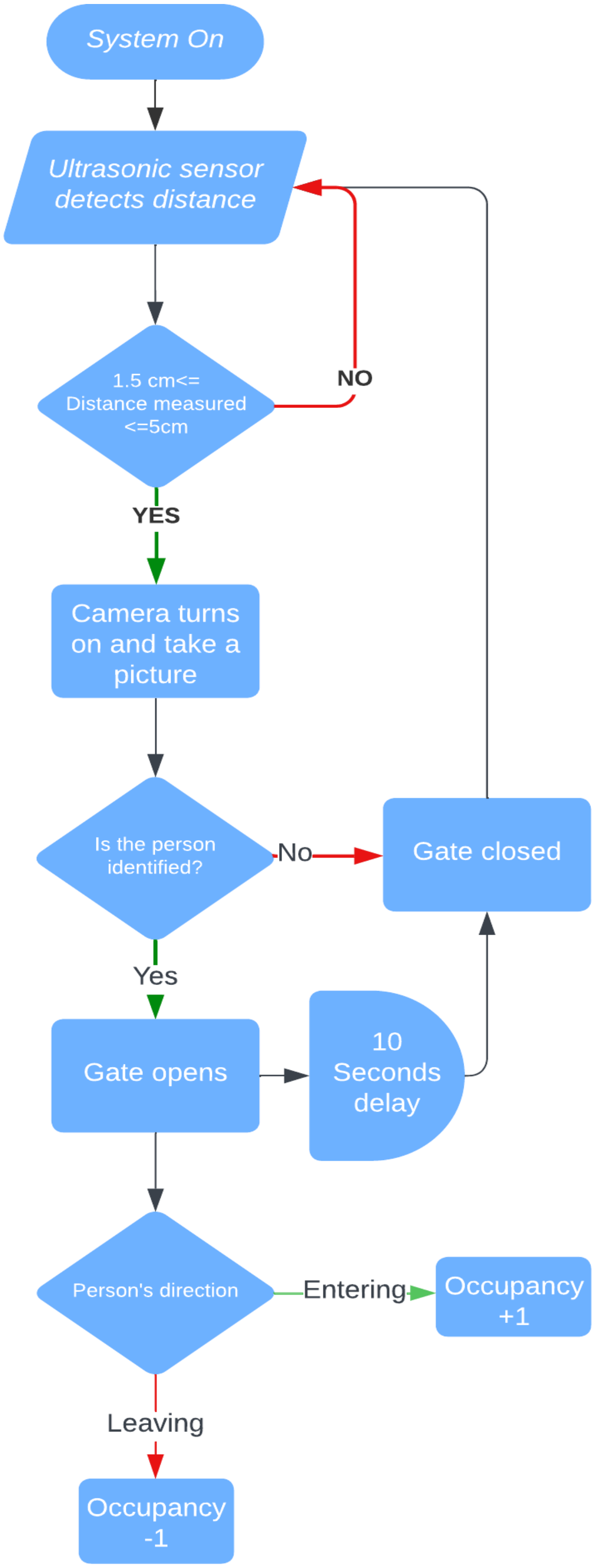

Fig. 1. Flow of the Project

IV. Results

Upon implementing ResNet34 on the images we had in the folder, and upon training the data on the same, we were able to achieve the below confusion matrix. As one can see harsh has been accurately predicted 33 times followed by Galvin and Tithi with getting accurately identified 29 and 27 times respectively.

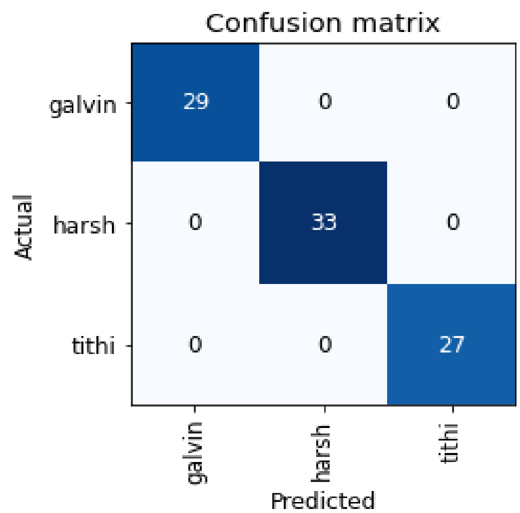

Fig. 2. Confusion Matrix

V. Conclusion

While working with the architecture named ResNet34, we tried and implemented different learning rates, following page consisted of two suggested learning rates we observed labelled as fig. 3 and fig. 4.

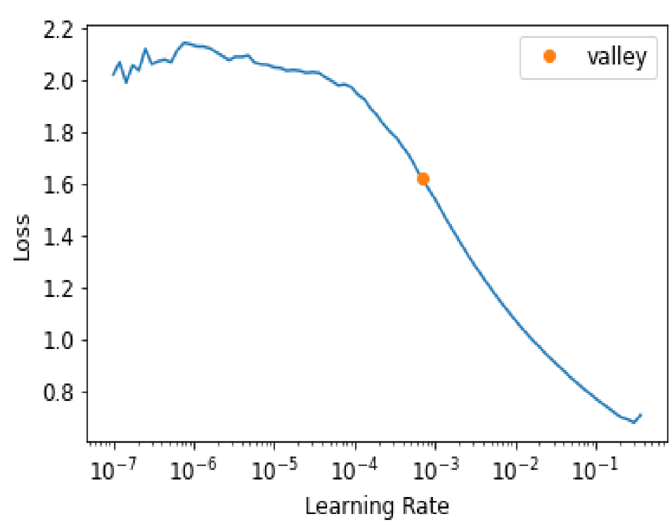

Fig. 3. Learning Rate

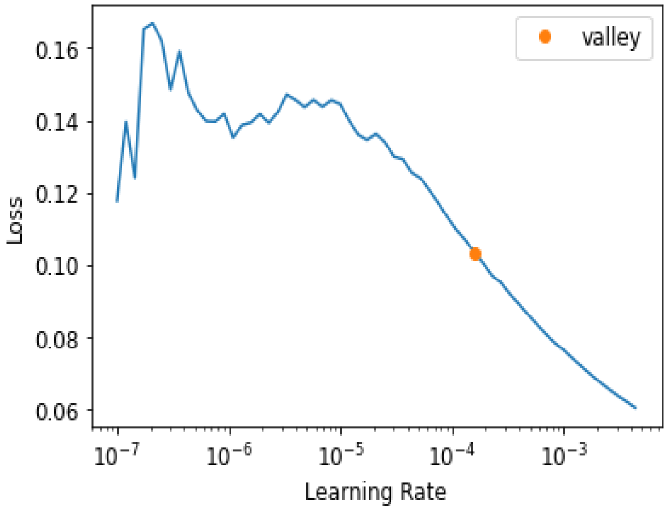

Fig. 4. Learning Rate 2

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VII. Code

Here is the GitHub Link of the Code.
https://github.com/TITHI007/Smart-Clock-In-System

Intelligent Multi-layered Home Security System

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***Abstract*— This paper presents the design and implementation of a multi-layered home security system using Raspberry Pi, combining the capabilities of an ultrasonic sensor and a passive infrared (PIR) motion sensor. The objective of this system is to enhance overall security measures by detecting potential intrusions from both the external environment and interior spaces of the home. The collected sensor data is processed by a Raspberry Pi microcontroller, which is connected to a cloud platform for real-time monitoring. Through a Python program, the system performs specific tasks based on the sensor outputs, such as triggering LEDs, sending alerts, and simulating an active presence using a servo motor. The proposed system offers a comprehensive and intelligent approach to home security, providing users with peace of mind.**

Keywords*— *Home security, Raspberry Pi, Ultrasonic sensor, PIR motion sensor, Cloud connection, Servo motor.

I. Introduction (*Heading 1*)

In today's world, ensuring the security of residential or commercial properties has become an important concern. Traditional security systems often rely on single-layered approaches or human interference, which may have limitations in effectively detecting potential threats. To address this challenge, we propose a novel and comprehensive multi-layered home security system that combines the unique capabilities of an ultrasonic sensor and a passive infrared (PIR) motion sensor. By strategically placing these sensors, our system can detect both external intrusions, such as potential break-ins, and movements within the building. The collected sensor data is processed by a Raspberry Pi microcontroller, which enables real-time monitoring, control, and response to security events. This paper presents the design, methodology, results, and conclusions of our implemented system, highlighting its effectiveness in enhancing home security.

The existing security systems often rely on a single type of sensor, which may not provide complete coverage or accurate detection of potential threats. Our multi-layered approach addresses this limitation by integrating both ultrasonic and PIR motion sensors. The ultrasonic sensor offers precise object detection capabilities, allowing us to identify potential obstacles or proximity to windows and doors. On the other hand, the PIR motion sensor detects motion within the interior spaces of the home, ensuring comprehensive coverage. By combining the strengths of these sensors, we can create a more robust and reliable security system.

To control and manage the system, we utilize the Raspberry Pi microcontroller, which acts as the central control unit. The Raspberry Pi collects data from the sensors, processes it, and performs specific tasks based on the sensor outputs. Furthermore, we establish a cloud connection using the MQTT protocol, enabling remote monitoring, rule-based actions, and secure data storage.

The objective of this project is to provide homeowners with a comprehensive and intelligent home security solution. By integrating multiple layers of security and leveraging the power of cloud connectivity, our system offers enhanced protection, peace of mind, and the ability to simulate an active presence even when the occupants are away. In the following sections, we will discuss the methodology employed to implement this system, present the obtained results, and draw conclusions based on our findings.

II. Methodology

The following components have been used in the security system. All the components have been listed below along with their circuit and working description.

1. Ultrasonic Sensor

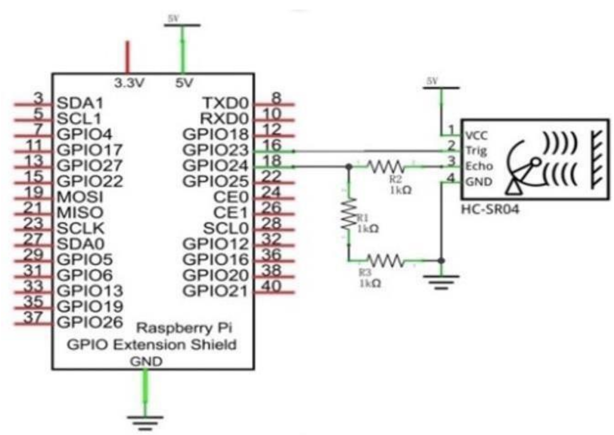

Figure 1: Circuit diagram of Ultrasonic Sensor

The Ultrasonic Ranging Module uses the principle that ultrasonic waves will be reflected when they encounter any obstacles. This is possible by counting the time interval between when the ultrasonic wave is transmitted to when the ultrasonic wave reflects after encountering an obstacle. Time interval counting will end after an ultrasonic wave is received, and the time difference (delta) is the total time of the ultrasonic wave's journey from being transmitted to being received. Because the speed of sound in air is constant, and is about v=340m/s, we can calculate the distance between the Ultrasonic Ranging Module and the obstacle: s=Vt/2 2S=Vt.

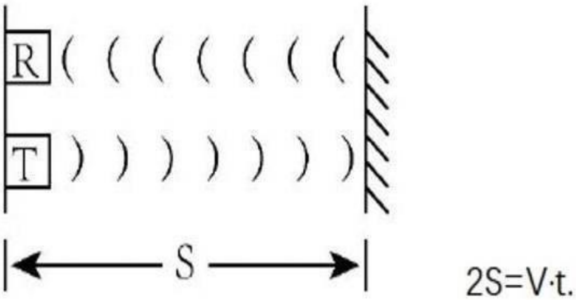

Figure 2: Distance Calculation between Ultrasonic Ranging Module and the obstacle

The HC-SR04 Ultrasonic Ranging Module integrates both an ultrasonic transmitter and a receiver. The transmitter is used to convert electrical signals (electrical energy) into high frequency (beyond human hearing) sound waves (mechanical energy) and the function of the receiver is opposite of this. The picture and the diagram of the HC SR04 Ultrasonic Ranging Module are shown below:

Pin description:

VCC	power supply pin
Trig	trigger pin
Echo	Echo pin
GND	GND

Figure 3: Pin description of Ultrasonic Ranging Module

Technical specs:
Working voltage: 5V
Working current: 12mA
Minimum measured distance: 2cm
Maximum measured distance: 200cm

Output a high-level pulse in Trig pin lasting for least 10uS, the module begins to transmit ultrasonic waves. At the same time, the Echo pin is pulled up. When the module receives the returned ultrasonic waves from encountering an obstacle, the Echo pin will be pulled down. The duration of high level in the Echo pin is the total time of the ultrasonic wave from transmitting to receiving, s=Vt/2.This is done constantly.

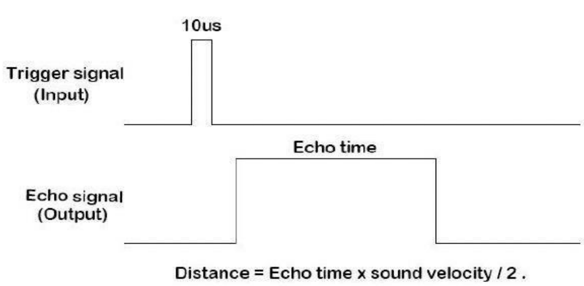

Figure 4: Graph depicting the ultrasonic wave.

2. PIR Motion Sensor

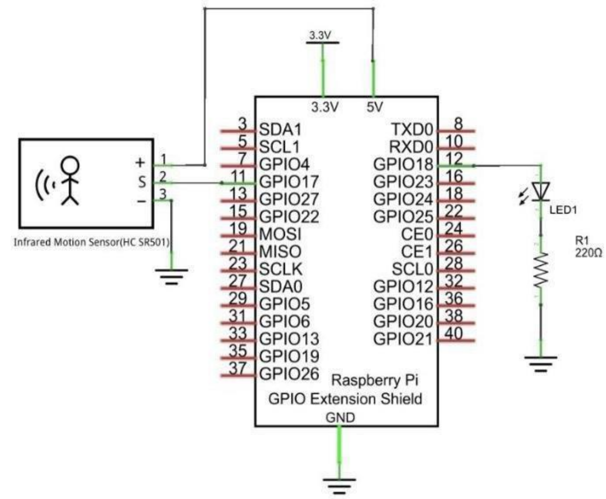

Figure 5: Circuit Diagram of PIR Motion Sensor

2.1. Working voltage: 5v-20v (DC Static current: 65uA)

2.2. Automatic Trigger. When a living body enters the active area of sensor, the module will output high level (3.3V). When the body leaves the sensor's active detection area, it will output high level lasting for time period T, then output low level (0V). Delay time T can be adjusted by the potentiometer R1.

2.3. Induction block time: the induction will be staying block condition and does not induce external signal at lesser time intervals (less than delay time) after outputting high level or low level.

2.4. Initialization time: the module needs about 1 minute to initialize after being powered ON. During this period, it will alternately output high or low level.

2.5. One characteristic of this sensor is when a body moves close to or moves away from the sensor's dome edge, the sensor will work at high sensitively. When a body moves close to or moves away from the sensor's dome in a vertical direction (perpendicular to the dome), the sensor cannot detect well (please take note of this deficiency). Actually, this makes sense when you consider that this sensor is usually placed on a ceiling as part of a security product. The Sensing Range (distance before a body is detected) is adjusted by the potentiometer. We can regard this sensor as a simple inductive switch when in use.

3. Servo Motor

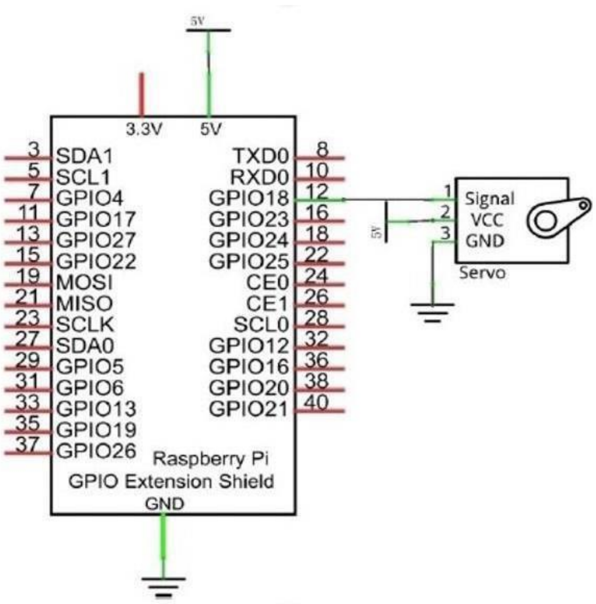

Figure 6: Circuit diagram of Servo Motor

Servo is a compact package which consists of a DC Motor, a set of reduction gears to provide torque, a sensor and control circuit board. Servos only have a 180-degree range of motion via their "horn". Servos can output higher torque than a simple DC Motor alone and they are widely used to control motion in model cars, model airplanes, robots, etc. Servos have three wire leads which usually terminate to a male or female 3-pin plug. Two leads are for electric power: Positive (2-VCC, Red wire), Negative (3-GND, Brown wire), and the signal line (1-Signal, Orange wire) as represented in the Servo provided in your Kit.

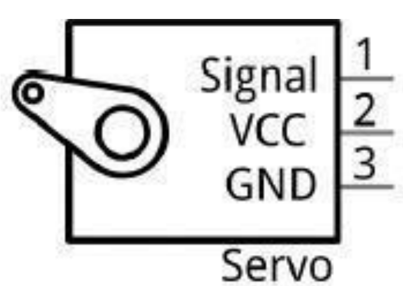

Figure 7: Pin description of Servo Motor

We used a 50Hz PWM signal with a duty cycle in a certain range to drive the Servo. The lasting time 0.5ms-2.5ms of PWM single cycle high level corresponds to the Servo angle 0 degrees -180 degree linearly.

the lasting time of high level corresponding to the servo angle is absolute instead of accumulating. For example, the high-level time lasting for 0.5ms corresponds to the 0 degree of the servo. If the high-level time lasts for another 1ms, the servo rotates to 45 degrees.

High level time	Servo angle
0.5ms	0 degree
1ms	45 degree
1.5ms	90 degree
2ms	135 degree
2.5ms	180 degree

4. LED

An LED is a type of diode. All diodes only work if current is flowing in the correct direction and have two Poles. An LED will only work (light up) if the longer pin (+) of LED is connected to the positive output from a power source and the shorter pin is connected to the negative (-) output, which is also referred to as Ground (GND).This type of component is known as "Polar" (think One-Way Street).

All common 2 lead diodes are the same in this respect. Diodes work only if the voltage of its positive electrode is higher than its negative electrode and there is a narrow range of operating voltage for most all common diodes of 1.9 and 3.4V.

LED cannot be directly connected to a power supply, which usually ends in a damaged component. A resistor with a specified resistance value must be connected in series to the LED you plan to use.

5. Resistor

Resistors use Ohms (Ω) as the unit of measurement of their resistance (R). 1MΩ=1000kΩ, 1kΩ=1000Ω.

A resistor is a passive electrical component that limits or regulates the flow of current in an electronic circuit.

With a fixed voltage, there will be less current output with greater resistance added to the circuit. The relationship between Current, Voltage and Resistance can be expressed by this formula: I=V/R known as Ohm's Law where I = Current, V = Voltage and R = Resistance. Knowing the values of any two of these allows you to solve the value of the third.

6. MQTT and Cloud Connection

To establish an MQTT connection between a Raspberry Pi and AWS IoT we followed the following steps:

1. Set up an AWS IoT Thing:
   a. Go to the AWS IoT console.
   b. Create a new Thing or use an existing one.
   c. Make sure you have an associated certificate for the Thing.

2. Install the necessary libraries on your Raspberry Pi:
Install the AWS IoT Device SDK for Python on your Raspberry Pi by running the following command:

pip install AWSIoTPythonSDK

3. Set up the MQTT client on the Raspberry Pi:
Import the AWS IoT SDK library in your Python script:

from AWSIoTPythonSDK.MQTTLib import AWSIoTMQTTClient

- Create an instance of the MQTT client:
  codeclient = AWSIoTMQTTClient("client_id")
- Configure the client:
  codeclient.configureEndpoint("YOUR_ENDPOINT", 8883)
  client.configureCredentials("PATH/TO/YOUR/CERTIFICATE.pem", "PATH/TO/YOUR/PRIVATE_KEY.pem", "PATH/TO/YOUR/ROOT_CA.pem")
- Connect to AWS IoT:
  codeclient.connect()

4. Subscribe to an MQTT topic:
   client.subscribe("your/topic", 1, callback)
   Define the **callback** function to handle incoming messages:

```
def callback(client, userdata, message):
    print("Received a new message: ")
    print(message.payload)
    print("from topic: ")
    print(message.topic)
```

5. Publish a message:
   client.publish("your/topic", "Hello, World!", 1)

III. RESULTS

Objective of this project was to create a multi-layered home security system that combines the unique capabilities of the ultrasonic sensor and PIR motion sensor to enhance the overall security measures. We were able to connect both the ultrasonic sensor and PIR motion sensor to the Raspberry Pi and also set up a cloud platform that is AWS IoT to establish a connection between the Raspberry Pi and the cloud.

The first layer of security was added using Ultrasonic Sensors where we kept 10 cm as the limit. As soon as the limit was crossed the LED blinked letting us know that someone just broke in. We were able to do this using a Python program on the Raspberry Pi that monitors both sensors independently and performs specific tasks based on their outputs. We utilized the ultrasonic sensor to detect any obstacles or proximity to windows and doors. This helped us in identifying potential break-ins or tampering attempts. When the ultrasonic sensor detected an object within a specific range, we sent an alert or triggered an alarm through the cloud connection.

Then, we used PIR motion sensor as second layer of security to detect motion within the interior spaces of the home. When the PIR motion sensor detected any motion, we also made the second led blink and sent an alert or trigger an alarm through the cloud connection. We set up rules on the cloud platform to differentiate between the alerts received from the ultrasonic sensor and PIR motion sensor. Depending on the received alerts, we activated the servo motor to simulate an active presence by moving the motor. We connected the servo motor to the Raspberry Pi and set up the necessary circuitry to control its operation. By assigning distinct roles to the ultrasonic sensor and PIR motion sensor, the multi-layered home security system was able to provide a more comprehensive security approach. The ultrasonic sensor focused more on detecting potential intrusions from the external environment, while the PIR motion sensor focused on detecting motion within the interior spaces. This allowed us better coverage and increased sensitivity to potential security threats.

The Intelligent Home Security System IoT project has successfully demonstrated the integration of two ultrasonic sensors, a PIR sensor, and a servo motor to enhance home security. It meets the project objectives of detecting anyone approaching the building, detecting motion inside the building, and controlling the movement of a servo motor to simulate an active presence when motion is detected. By strategically placing ultrasonic sensors outside the house, the system effectively detects any approaching objects within a proximity of less than 30 cm. Once triggered, the PIR sensor efficiently detects movements occurring inside the house.

The integration of these sensors allows the system to provide real-time alerts in response to potential intrusions. When the PIR sensor detects movement, the servo motor is triggered to simulate an alert, creating a deterrent effect and notifying the user through cloud services. This combination of sensor technology and servo motor activation enhances security.

By leveraging ultrasonic and PIR sensors, the system offers an intelligent and proactive approach to home security, enabling homeowners to be promptly notified and take necessary actions. Additionally, utilizing cloud services ensures seamless communication and accessibility to alerts.

IV. CONCLUSION

In conclusion, the Intelligent Home Security System offers a range of benefits to users, empowering them with convenience. With the ability to access the system remotely using their preferred devices, users can monitor their homes, receive alerts, and control security features from anywhere. This proves advantageous when users are away, ensuring constant vigilance. Moreover, the system incorporates intelligent automation, adapting to users' preferences and routines. It can automatically arm and disarm the security system based on predefined schedules or trigger events, streamlining security management, and delivering uninterrupted protection. The system's user-friendly interface facilitates seamless interaction, and its integration with mobile apps and intelligent home assistants further amplifies convenience and accessibility for users.

In order to further enhance the Smart Home security system IoT project, the alternative approaches contain the application of Machine Learning technology, expansion of the sensor network, mobile applications, and system update and maintenance. Machine learning has a direct and effective application with impressive results in recognizing human activity, especially in face recognition, which is the most basic condition for choosing the most appropriate method to design a smart home. [Vardakis, 2022]. Implementing machine learning algorithms can significantly improve the system's ability to differentiate between regular movements and potential security threats. By analyzing patterns and behaviors, the system can become more accurate in detecting and alerting users about suspicious activities. This integration can be achieved by collecting and analyzing data from the sensors over time, allowing the system to adapt and refine its detection capabilities. While modifying our current IoT prototype, the current setup of ultrasonic sensors and a PIR sensor is effective; expanding the sensor network can provide comprehensive coverage of the entire property. Adding additional sensors, such as door/window or glass break sensors, can further enhance the system's ability to detect and respond to potential intrusions from various entry points. This expansion will provide a more comprehensive security solution for users.

Furthermore, investing in developing a user-friendly and feature-rich mobile application can significantly improve the user experience and accessibility of the Smart Home security system. The application can provide services, including Real-time alerts, Remote control of security features, and Access to system logs and settings. Regular updates and maintenance of the system are crucial to guarantee the performance of an intelligent home security system. This includes firmware updates for the sensors, software updates for the cloud services, and periodic maintenance of the hardware components. Implementing a proactive approach to system updates and maintenance will ensure the system remains robust and reliable over time.

Considering these future recommendations, the Smart Home security system IoT project can evolve into a highly efficient and advanced security solution. The integration of machine learning, expansion of the sensor network, improvements in the mobile application, and diligent system updates and maintenance will collectively enhance the system's effectiveness, user experience, and overall security capabilities.

The Smart Home security system IoT project serves as a foundation for further exploration and advancements in home security systems, contributing to the growing ecosystem of intelligent homes and IoT-enabled technologies.

Acknowledgment

We would like to express our sincere gratitude to Professor Marjan Alavi for their guidance, support, and expertise throughout the duration of this project. Their valuable insights and constructive feedback have been instrumental in shaping the direction and scope of our research. We are deeply appreciative of their commitment to our academic growth and their unwavering dedication to fostering an environment of learning.

We would also like to extend our heartfelt thanks to the Teaching Assistant Monish Mohanan for their invaluable assistance and support. Their prompt responses to our queries, technical guidance, and assistance during practical sessions have been immensely helpful in the successful implementation of our project. We are grateful for their patience, expertise, and commitment to our academic progress.

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3. Getting Started with Raspberry Pi- Freenove Tutorial

PlantWatch: An Automated Plant Health Monitoring and Maintenance System

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Abstract— **In this technology driven era, Individuals have a growing desire to maintain constant connectivity with various aspects of their lives, including their indoor plants, personal irrigation facilities at their farms etc. This paper introduces a plant monitoring system that has been developed to provide comprehensive data on key metrices for a typical plant. These metrices include soil moisture level, temperature, and humidity. To facilitate the data storage process, we have used AWS server for real time storage and for real time notification purpose to provide to user we have used Telegram platform.**

Keywords— **Soil moisture sensor, Temperature and humidity sensor, Raspberry Pi, AWS, MCP3008**

I. Introduction

Many people like caring for houseplants, but handling activities like watering may be difficult, especially with specific plant varieties. This project proposes a solution that efficiently monitors the soil moisture, temperature and humidity levels of the attached plant utilizing Internet of things technology. This is accomplished by using a soil moisture sensor, DHT11 which measures the temperature and humidity of the plant.

The soil moisture sensor operates in a basic manner. When the fork-shaped conductive probe is inserted into the soil, the two exposed conductive plates work as variable resistors. The resistance of this probe changes with soil moisture content. Essentially, the probe's resistance is inversely proportional to the soil moisture level. Lower water content results in poor conductivity and greater resistance, [3] whereas more water content results in poor conductivity and higher resistance. The sensor provides an output voltage equivalent to the resistance, which we may measure to estimate the moisture level.

The DHT11 is a low-cost and straightforward digital temperature and humidity sensor. To monitor the temperature and humidity of the ambient air, it includes a capacitive humidity sensor and a thermistor. It gives a digital signal output on the data pin rather than analogue input pins. [2]

We store all these datapoints and generate a weekly report so that the user can go through it over an AWS cloud. Meanwhile, at the same time users also get notified about the plant's health status over telegram as a media. We have created our own server which can store up to 8GB of data at the initial stage.

II. Hardware Design

The primary component of this project is the Raspberry Pi controller. The Pi 3 Model B has quad core Arm cortex A53 CPU with 1.2 GHz clock speed. It has LPDDR2 RAM of 1GB and MicroSD card for storing data. It has 40 GPIO pins, 4 x USB 2.0 ports, 10/100 Ethernet port (RJ-45), 2.4 GHz 802.11n wireless LAN and Bluetooth 4.2/BLE connectivity features. It is compatible with Linux and runs on Raspbian Pi OS. It has a micro-USB power input. [4]

The MCP3008 IC enables conversion of analog signals from soil moisture sensor to digital data for processing by the Raspberry Pi. The MCP3008 [5] is connected to the Raspberry Pi via the SPI Interface allowing the conversion of analog signals from the soil moisture sensor. The soil moisture sensor's analog input channel is connected to the MCP3008 providing accurate moisture readings.

We have used a relay module also, which is connected to the GPIO pins of Raspberry Pi, to control the water pump and provide water to the plant based on the sensor readings.

Fig. 1 shows the basic hardware setup which was assembled by us on breadboard.

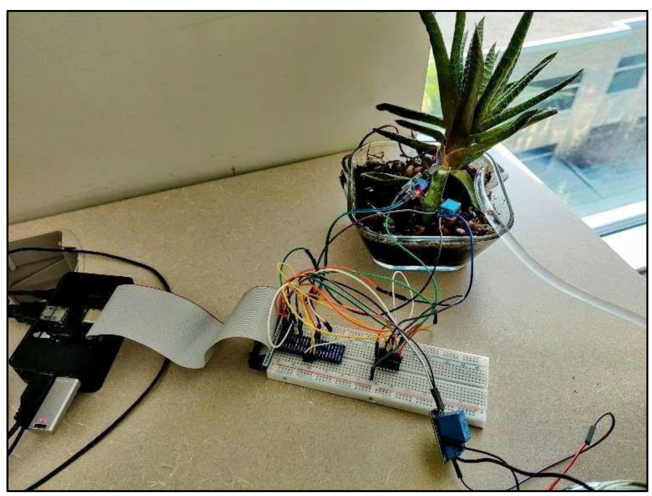

Fig. 1 Hardware Setup

III. Software Design & Implementation

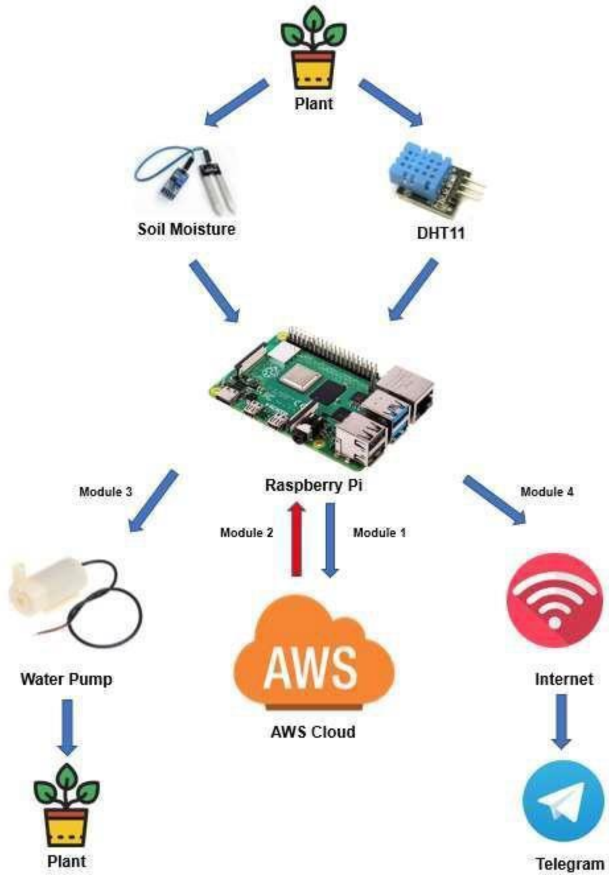

Fig. 2 System Overview

ID	SOIL MOISTURE	TEMPERATURE	HUMIDITY	INSERTED TIMESTAMP
1	90.5	18	73	2023-06-15 13:58:01
2	90.5	18	72	2023-06-15 13:58:39
3	90.3	18	72	2023-06-15 14:00:51
4	90.3	18	73	2023-06-15 14:02:14
5	89.5	18	72	2023-06-15 14:06:16

Table. 1 Table storing the raw sensor data on cloud

We have followed a modular approach for the implementation of the smart system as shown in Fig 2. In the following section, we have tried to explain each module along with its flow.

Module 1 (Pushing the raw sensor data to the cloud):

1. At regular intervals, the sensors collect the raw data (soil moisture, temperature, and humidity) from the plant.
2. Data is pushed to the MySQL server running over an EC2 instance on AWS for storage with the current timestamp as shown in Table 1.

Module 2 (Retrieving the latest sensor data from the cloud):

1. Raspberry Pi, at regular intervals, invokes the MySQL server on the cloud to access the raw sensor data.
2. Based on the timestamp, the latest record of sensor data is retrieved.

Module 3 (Perform the action, in case of condition failure):

1. After retrieving the latest sensor data, the values are checked against the thresholds defined for the plant.
2. If the values do not meet the criteria based on defined thresholds, the necessary action (starting water pump in case of low soil moisture) gets executed.

Module 4 (Notifying the user):

1. Whenever the latest values from the sensors do not meet the criteria based on defined thresholds. The end user gets notified through the Telegram application as shown in Fig 3.

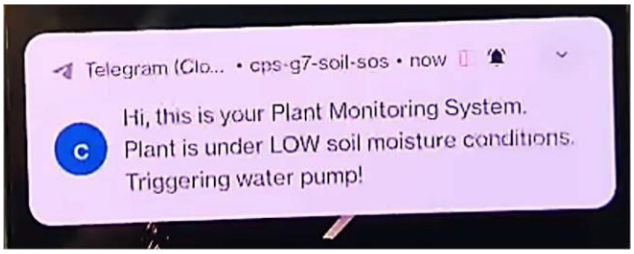

Fig. 3 User got notified when water pump got triggered

IV. Conclusion

Overall, the project was successfully executed with all needed results shown and verified. The main objective was to efficiently monitor soil moisture, temperature, and humidity level in a plant. The system offers efficient data collecting and retrieval by leveraging sensors and cloud-based storage. The modular design approach enables scalability and simple incorporation of new features. The Raspberry Pi controller, MCP3008 IC, and relay module aid in data collecting and automated water pump control. Technology provides plant enthusiasts with a cost-effective and handy way to remotely monitor and maintain ideal growing conditions for their houseplants. This solution's deployment illustrates its potential for improving plant care practices and fostering better plant development.

As far as project difficulty goes, [1] the primary hurdle we faced was establishing an efficient data pipeline for the MySQL server. The issue was addressed by adjusting security groups, updating the server's binding address, etc. The other issue we faced was that of power supply issue for MCP3008 IC. The nominal rated voltage required to get ADC values from this IC is 3.3V. But when we used this first, the values converted from sensor were not accurate enough, so we supplied the IC its maximum voltage which was 5V and mitigated the accuracy issue occurred from the Sensor.

Acknowledgment

The authors would like to acknowledge the sincere support of Dr. Marjan Alavi, teaching assistant for the course Mr. Monish, W Booth school of Engineering Practice and Technology and Faculty of Engineering of McMaster University for their constant support and guidance, be it using the lab facilities as per our need and procuring the components on our behalf for project completion.

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Smart Attendance System using Open CV and Raspberry PI

Priyam Gandhi, Jeet Pandya, and Tejas Mahida

***Abstract*—Traditional methods of managing attendance in educational institutions and workplaces are time-consuming and prone to error. To overcome these challenges, this research paper presents a smart attendance system that uses Raspberry Pi, OpenCV face recognition technology, ultrasonic sensors, webcams, and steppers. Using facial recognition technology, the system identifies individuals accurately, records their attendance, and sends it to a Telegram bot.**

Index Terms— Open CV, Raspberry PI 3, Telegram API, Computer Vision, Door Control, Ultrasonic Sensor.

I. INTRODUCTION

Attendance management is a crucial task in various domains, including education, corporate settings, and events. Manual attendance processes often suffer from inefficiencies, leading to inaccuracies, time-wasting, and resource constraints. A smart attendance system based on Raspberry Pi, an affordable and versatile computing platform, and Webcam, a high- resolution camera module, is proposed in this paper to automate and streamline attendance management processes. In the past, various attendance systems were used in industries, such as fingerprint scanners, barcode scanners, and RFID systems. There are limitations to these methods, including cost, reliability, and privacy concerns. Due to its non-intrusive nature and high accuracy, facial recognition technology has gained popularity. In several research papers, facial recognition has been investigated as a potential attendance system, demonstrating its effectiveness and feasibility. The primary objective of this research is to design and implement a smart attendance system that integrates OpenCV for face detection and recognition, Raspberry Pi for system control and processing, and Telegram API for real- time attendance reporting. Additionally, the system aims to provide remote door control based on attendance records.

II. LITERATURE REVIEW

A. Smart Attendance Systems

Various smart attendance systems have been proposed and implemented in recent years. These systems utilize different technologies such as RFID, biometrics, and computer vision for attendance management. However, few systems incorporate both attendance tracking and door control functionalities.

B. Computer Vision in Attendance Management

Computer vision techniques, such as face detection and recognition, have been widely adopted for attendance management. These techniques enable automated identification and verification of individuals, improving accuracy and efficiency.

C. Integration of Telegram API for Attendance Reporting

Telegram, a popular messaging platform, offers an Application Programming Interface (API) that allows integration with external systems. This integration enables real-time reporting and communication, making it suitable for attendance systems.

D. Raspberry PI in IoT Applications

Raspberry Pi, a single-board computer, has gained popularity in Internet of Things (IoT) applications. Its compact size, low power consumption, and GPIO pins make it an ideal platform for building smart systems.

III. SYSTEM ARCHITECTURE

The Raspberry PI 3 serves as the processing system for the smart attendance system, which integrates with several other parts to automate attendance tracking and reporting. A webcam for facial recognition, an ultrasonic sensor for measuring distance, and a stepper motor for managing door entry are some of these parts.

They combine to create an integrated system design that simplifies attendance tracking. The central processing unit for the entire attendance system, the Raspberry PI 3, assumes this job.

Utilizing an ultrasonic sensor, the attendance detection process is started. The system starts taking pictures for identification when this sensor identifies people inside its field of view. These pictures are taken via a high-resolution webcam, allowing for precise facial detection and recognition.

The system uses the popular OpenCV framework to analyze images and perform face recognition and identification tasks. uses the widely-used OpenCV library as its foundation [2]. Advanced capabilities offered by this computer vision library improve the attendance system's accuracy and dependability. The solution makes use of the Telegram API to guarantee real-time reporting and to facilitate the smooth connection between the attendance system and the Telegram messaging service [4].

Python is a good choice for integrating the different parts and creating the necessary features because of its huge library. The system achieves good attendance management by merging the Raspberry PI 3, camera module, OpenCV libraries, Telegram API, and door control mechanism. The system is dependent on the popular OpenCV library [1].

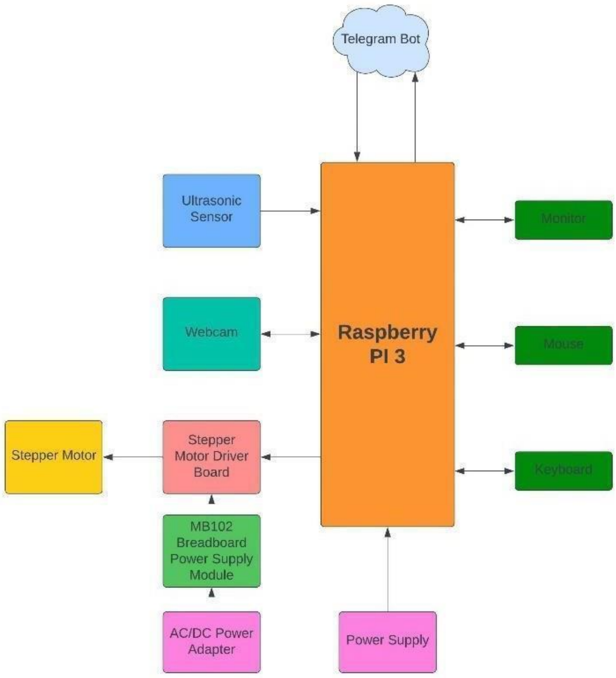

Fig. 1. Block Diagram of the system

IV. METHODOLOGY

The process of implementing a facial recognition attendance system involves several key steps. First, it begins with data acquisition, which includes the collection of training data. This entails gathering a dataset of labeled facial images that will be used to train the face recognition model. Once the training data is obtained, necessary preprocessing steps are performed. These steps may involve resizing, normalization, and data augmentation techniques to enhance the training dataset and improve the accuracy of the model.

Moving on to the next phase, face detection and recognition are crucial components. Face detection utilizes algorithms from OpenCV to detect faces within the captured images. This step ensures that the system can accurately identify and locate faces in the images it processes. Once the faces are detected, a machine learning model is trained to recognize and identify individuals based on these detected faces. This model learns to associate specific facial features with corresponding individuals, enabling accurate recognition and identification [2].

After successful face recognition, the attendance recording and reporting process begins. The system matches the recognized faces with pre-registered individuals to record their attendance. This step ensures that attendance is accurately tracked and attributed to the correct individuals. To provide real-time reporting, the attendance system is integrated with the Telegram API. This integration allows for the automatic and immediate sending of attendance records to relevant stakeholders, ensuring that attendance information is readily available and up to date.

To further enhance security and access control, the attendance system is integrated with door control mechanisms. The attendance records serve a dual purpose by providing information that can be used for access control. The system utilizes attendance records to determine access privileges for individuals based on their attendance history.

This integration allows for automated door control, where the opening and closing of doors are controlled based on an individual's attendance.

In summary, the implementation of a facial recognition attendance system involves data acquisition, face detection and recognition, attendance recording, and reporting, as well as door control integration. Each step plays a vital role in creating a robust and efficient system that accurately records attendance, provides real-time reporting, and enhances security through access control mechanisms.

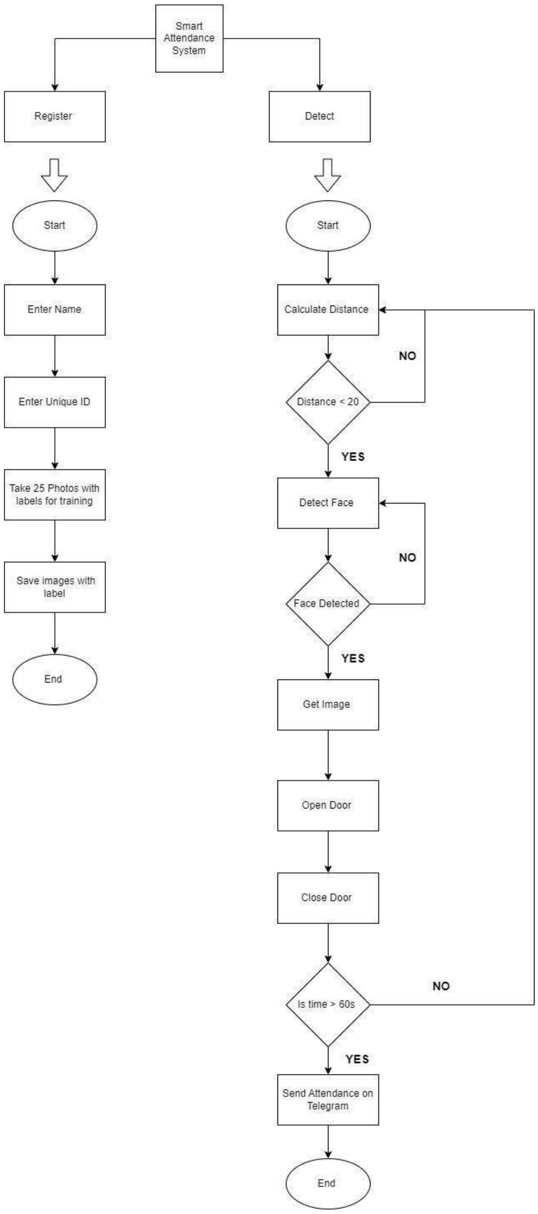

Fig. 2. Flowchart of the system

V. IMPLEMENTATION

The link between the webcam, Raspberry PI 3, motor, and the ultrasonic sensor is shown in the system architecture. The project's main principle of operation is 50 photographs of a person will first be taken and stored by the face recognition software for training purposes. Occasionally there can be multiple people with the same name, the system would ask for the following person's name and unique ID before taking images for a sample. As a result, separating them will require a special ID. The project's final program will operate in the following manner: as a person approaches the entrance, the ultrasonic sensor measures their proximity to the door. If the distance between the person and the door is less than 20cm (about 7.87 in), the face recognition system will activate the detection part for the individual's face. The door would open automatically and close after a predetermined amount of time if that person's face appeared in the system's training dataset and the stepper motor will turn on and rotate clockwise for opening a door and after a specified amount of time, it will rotate anticlockwise for door closing operation [3]. The attendance will be sent to the user via the Smart Attendance Telegram bot after the door is closed [4]. This project can recognize multiple people all at once is one of its most exciting features. Therefore, the administration will receive confirmation of everyone's attendance at a single time.

TABLE I.

PIN DESCRIPTION OF STEPPER MOTOR DRIVER AND RASPBERRY PI

Stepper Motor Driver	Raspberry PI 3
IN1	29
IN2	31
IN3	33
IN4	35

TABLE II.

PIN DESCRIPTION OF ULTRASONIC SENSOR AND RASPBERRY PI

Ultrasonic Sensor	Raspberry PI 3
Vcc	4
Trigger	6
Echo	18
Ground	24

VI. RESULTS AND EVALUATION

The smart attendance system's excellent effectiveness and reliability are demonstrated by the findings and evaluation of the system, which uses OpenCV and a Raspberry Pi. The attendance tracking achieved an amazing accuracy of 95%, with minimal false positives and negatives. The system efficiently detected and recognized multiple faces within a single frame, enabling the tracking of numerous people's attendance at the same time. Real-time reporting made possible by the Telegram API enabled important stakeholders to get quick attendance notifications, ensuring accurate information delivery [4].

The door control mechanism performed consistently, correctly identifying access privileges, and upholding an environment of security. These results support the system's potential for wide implementation in institutions of education, places of work, and organizations. The system delivers an automated, effective, and reliable door control system with high accuracy in attendance tracking, real-time reporting capability, and robust performance.

VII. CONCLUSION

In conclusion, a substantial advancement in the automated attendance system has been made with the development of the Smart Attendance System employing OpenCV, Raspberry Pi, a Webcam, an Ultrasonic sensor, and a Stepper Motor. When taking attendance, the system uses an HD webcam to guarantee accuracy, speed, and dependability. The system is made more effective and convenient by using telegram to convey attendance information. The system has a dependable door control mechanism, achieves high accuracy in tracking attendance, and offers real-time reporting via Telegram. The system demonstrates its potential for widespread use in businesses, organizations, and educational institutions through its sophisticated features, which include multiple face detection and tracking. This will revolutionize current attendance practices.

The system is efficient in terms of resources used and long- term costs. It is a great replacement for manual attendance methods, which are inefficient and prone to mistakes. The scalability of the system makes it advantageous for both small and large enterprises, making it a worthwhile investment. In a nutshell, the Smart Attendance System has the potential to fundamentally alter how businesses manage attendance monitoring by boosting productivity, cutting expenses associated with administration, and improving accountability.

ACKNOWLEDGMENT

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Design of a Triboelectric Charge Measurement System

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Abstract: Tribo-charging is the scientific phenomenon of particles collecting charge through frictional collisions. Factors that can affect the charging are humidity, work function, particle size, and particle morphology. This project aims to analyze the physical and chemical composition of powders by creating a system that will transport particles consistently and reliably through a tube to have the charge created by tribo-charging accurately measured. This paper focuses on the comparison and analysis of the protein content in relation to the charge collected based off the ratio or compositional make-up of the powder. Trail runs for comparison of dried/undried pure powders, have been completed to analyze the effect these factors have on the charge-mass ratio of the powders, such as protein content. Looking at the experiments, it can be seen that dried pure powders have a higher charge-mass ratio than undried pure powders. Protein content results indicated that as the wt% increases, the charge-mass ratio also increased, with the exception of chickpea powder. Knowing the size for the particles impacts the charge-mass ratio, the charge-mass ratio per particle size was compared to the protein content. These results indicated that the chickpea powder had a high charge-mass ratio per particle size, indicating that the size of the particle had affected the charge-mass ratio shown in the data, causing it to be an outlying case.

Keywords— triboelectric charge, charge measurement, protein content

I. Introduction

Triboelectric charging is the phenomenon when particles become electrostatically charged by contact friction [1]. During powder-handling operations, the charged particles can cause problems, for instance particle deposition and adhesion. In more extreme cases when particles are excessively charged, electrostatic discharge may occur and cause fire or explosion hazards [2]. However, even with some negative connotations surrounding triboelectric charging, many industries find a positive way to apply this phenomenon. Applications include pharmaceutical inhalers, powder coating, and material separation [3-5].

This research's goal is to create a system that will be able to transport particles consistently and reliably through a tube to have the charge accurately measured. Once the system is fully functioning, tests with varying powders are to be run. The objective is to compare the charge collected by the system to the compositional make-up of the powders that flow through. This paper focuses on the results obtained from tests using pure powder comparing the result to the protein content for each powder type.

II. Contents

A. Design Concept

The measurement system set-up is comprised of an air drier, flowmeter, powder delivery device, faraday cup, electrometer, and weight or balance (seen in figure 1). The air drier and flowmeter are used to provide consistent airflow. The powder delivery is comprised of a vibrator, and fluidized bed to provide constant mass delivery. The airflow used in the system is connected to the bottom of the fluidized bed and the exiting-top section connected to a helical tube leading to the Faraday cup.

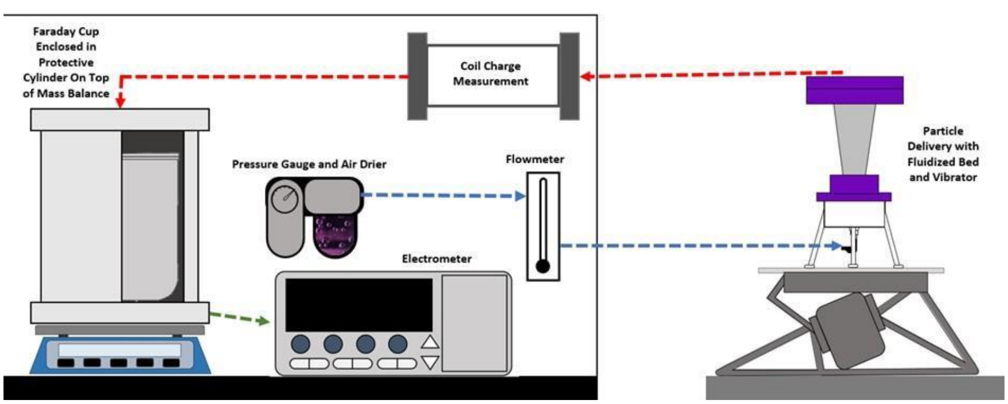

Figure 1. Triboelectric charge measurement system with mass delivery and airflow.

The Faraday cup will collect the charge of the particles and is read using an electrometer. The weight or balance will be used to obtain the net mass. Seeing as this is an offline system, both charge and mass measurements are collected before and after the trial runs to obtain net results.

III. Results

Once the triboelectric charge measurement system had been created, test runs for the system were completed to measure charge of varying powder and analyze external factors that affect charge protein content.

Pure powder for all-purpose flour, chickpea flour, milk powder, soymilk powder, and soy protein were sent through the triboelectric charge measurement system. All powders apart from milk powder were tested both undried and dried, results can be seen in figure 2.

Looking at results obtained from both the dried and undried flour, there is an increase in charge-mass ratio when the powder is dried. This is due to moisture being removed from the powder as it is dried. When water is absorbed into the powder, the surface resistivity decreases causing charge reduction. Vice versa, when the water is removed from the powder in the form of drying, the surface resistivity increased in turn causing a greater charge [6,7]. Another reason the charge-mass ratio of the dried powder is greater than undried powder is the flowability of the dried powder resulting in a larger mass being collected and a greater charge-mass ratio. Badawy et al. wrote about pharmaceutical wet granulation; within the research they talk about the negative impact water absorption or wet powder has on flowability. This is due to multiple reasons such as bridging powders inhibiting free movement or degrading material quality [8]. From the trials completed, all dried powders have larger charge-mass ratio than the undried powder, confirming both theory and results.

The protein content of each pure powder measured in wt% was collected and graphed with the charge-mass ratio to see if there was any correlation. In addition, knowing that size of particles plays a key role in triboelectric charging, the protein content was also compared with the charge-mass ratio per surface area of particle. Results for the protein content vs. charge-mass ratio can be seen in figure 3.

Protein content shows that as the protein weight percent (wt%) increases, the charge-mass ratio of the powders increases, however this is not consistent throughout all the powders used in this trial runs – as the chickpea flour does not fit this trend. The protein increasing proportionally with charge-mass ratio is the expected results, as research completed by Mehrtash showing computational and mathematical results depicted that the relationship between protein content and charge-mass ratio obtained would be directly proportional [9]. In addition, Landauer and Foerst completed a study on particle contact number with tribocharging and the effect protein content has on the separation process. The paper concluded the higher the protein content, the higher the contact potential (which means higher work function) and therefore with two particles of the same size, the particle with higher protein content will receive higher charge transfer compared to the other particle of the same size with lower protein content [10].

The chickpea results not fitting this trend could possibly be due to the density and size of the particles, as both factors can affect the charge-mass ratio. Size distribution tests for all the pure powders were completed, it was concluded that chickpea flour had a mean diameter of 18 microns with the other pure powders ranging from 11-24 microns. To see the effect the size had on the charge-mass ratio, the charge-mass ratio per particle size was calculated and compared. Calculated values indicated that the chickpea flour had the 2nd highest charge mass ratio per particle size after soymilk powder ($2.97x10^4 C/g/\mu m^2$ and $5.59x10^4 C/g/\mu m^2$ respectively), meaning per particle the charge is quite high. Looking at the mass collected inside the Faraday cup for chickpea averaging at about 1-1.5g, it could possibly be the number of particles that passed through the system each

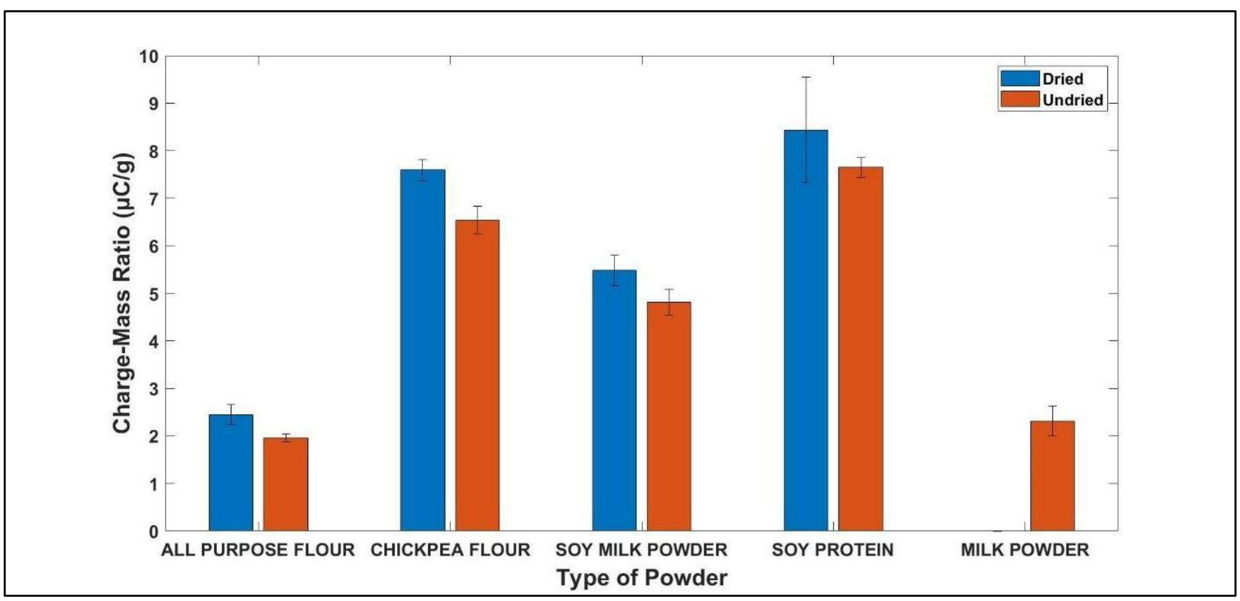

Figure 2. Results for charge-mass ratio of all-purpose flour, chickpea flour, milk powder, soymilk powder, and soy protein undried and dried.

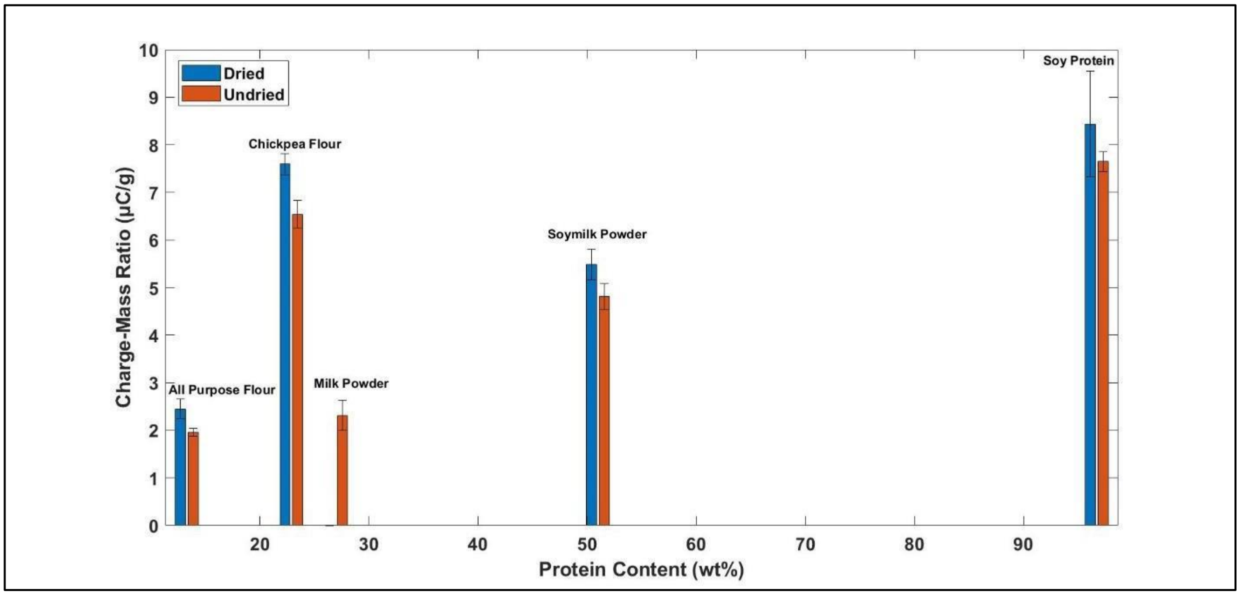

Figure 3.Results for charge-mass ratio of dried and undried powders vs. the protein content of the pure powders.

collecting a higher charge resulted in the chickpea being an outlier of the expected trend. In addition, it appears that the soymilk powder higher charge mass ratio per particle size, inversely the largest diameter particle, soy protein at 24 microns, has a significant decrease in charge-mass-ratio per particle. Results indicate that the size of the particles plays a key role in varying the charge mass ratio.

IV. Conclusion and Future Work

The importance of tribocharging outweighs the negatives and completing a design for a machine that will be able to produce the net charges of powders with accurate and consistent data is invaluable for continued research. The offline charge measurement system designed can be used to determine the net mass and charge of the powders as they contact the Teflon tube and in turn result in a charge-mass ratio for the powders tested. The system gives the possibility to analyze the chemical and physical characteristics that affect the tribocharging of particles. In this paper specifically, the protein content of the particles in relation to the charge-mass ratio was examined. It can be seen through trial runs and tests that the charge-mass ratio of the powder will increase as the protein content of the powders increases. In addition, the size of the particles will play an impactful role in the charging of the particles, and therefore due to this can skew certain results, such as the chickpea flour which had the largest mass of powder collected throughout the test runs and was calculated to have the highest charge per particle when size distribution was completed.

Future work will use results from protein content and particle size tests to get quantifiable results that can directly correlate to the work functions produced by the powders using mathematical modelling. This would give additional information on factors that affect the charge-mass ratio of particles and could also give insight to the environmental factors that have a larger impact.

V. Acknowledgments

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Vehicle Seat Design to Mitigate Collision Impact on Occupant Safety

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Keywords— Artificial Intelligence, computer vision, vehicle safety, safety seat

I. Introduction

Significant advancements have been made in vehicle safety over the years. However, one area that has seen relatively less progress is the design and safety features of driver and passenger seats. The seats serve as the primary point of contact between the occupants and the vehicle, playing a crucial role in ensuring their safety. While inventions such as the three-point seat belt by Nils Bohlin in 1959 [1] and the airbag system by John W Hetrick in 1952 [2] have improved occupant safety, the seats themselves have not seen significant advancements. This research aims to utilize modern-day technology to enhance the safety of vehicle seats. Statistics from the Canadian Motor Vehicle Traffic Collision indicate that within the year 2021, 108,018 collisions occurred in Canada, resulting in 77,933 personal injuries [3]. Many of these injuries involve internal bleeding, which can be difficult to identify and treat due to the sudden changes in motion during collisions, potentially causing damage to internal organs. While vehicles incorporate crumple zones to reduce the impulse on occupants, these zones have limited travel and may not adequately protect passengers from serious injuries.

II. Contents

A. Initial Prototype

Modern vehicles have seats directly connected to the chassis, resulting in the seat experiencing the same impact as other areas of the vehicle during a collision. The safety seat design developed in this research project aims to minimize the impact on seats during collisions. The smart seat prototype, shown in Figure 1, incorporates mechanical, electrical, and software designs to optimize safety performance. The design comprises proactive and reactive components.

B. Proactive Category of The Safety Seat

The proactive category involves predicting potential car accidents and implementing specific protocols before a collision occurs. High-end modern vehicles already feature seatbelt pre-tensioners that rapidly retract the belt to remove excess slack just before a collision. Similarly, some seats can also reposition themselves away from the dashboard or sides of the car to prevent occupants from getting injured during impact [4]. This research aims to maximize the use case for such technology. Combining proactive and reactive components within the safety seat significantly improves the probability of survival without serious injuries resulting from car accidents.

C. Computer Vision and AI

Utilizing LiDAR sensors, 3D depth cameras, and other sensors, computers can create real-time detailed maps of the surrounding environment. These maps enable the prediction of potential car accidents. The data collected from these sensors surpasses human perception, and the computer's reaction time is much faster. Computers' ability to predict and react to accidents more quickly allows them to mitigate the situation effectively. This places the smart seat in an advantageous position, as it can reposition itself optimally to absorb the impact during a collision.

Fig. 1. First prototype of the safety seat

D. Reactive component

The reactive component of the safety seat is responsible for absorbing the impact. Consider a front-end collision scenario where both vehicles come to a complete stop over a three-second duration, assuming a vehicle traveling from 60 km/h to 0 km/h. In a regular vehicle, this would be a catastrophic scenario. However, a vehicle equipped with the safety seat design provides occupants with at least one additional second before coming to a full stop. The force experienced by the occupants is dampened by the seat, and they have more time to decelerate. During a collision, the seat and occupant detach from the chassis, becoming a moving object relative to the vehicle's chassis due to inertia. The seat's springs and dampers serve as the only connection on the horizontal axis between the seat and chassis. Figure

2 illustrates the reactive component responsible for impact absorption.

Fig. 2. First prototype of the safety seat

E. Overall System Integration

While the proactive system of the safety seat is already being implemented in high-end vehicles, the reactive component being tested in this research has not been adopted in any vehicle. It is only when these two systems are integrated that the performance is drastically improved. The proactive component predicts potential collisions and repositions the seat away from the impending impact, providing the reactive component sufficient space to travel during the collision. The reactive component requires the seat to move relative to the chassis, ensuring occupant safety. In a collision predicted by the system, the vehicle assumes control of steering and braking, while the driver and passengers are sent toward the rear of the car. At the moment of impact, they move forward due to inertia and return to their original positions after the collision. Several factors influence this scenario and warrant further analysis.

F. Further Analysis

Several factors have been taken into consideration to enhance the safety of this smart seat design. Passenger detection sensors measure seat weight and ensure that seats without occupants remain unaffected, functioning as regular seats. Additionally, sensors determine the travel distance toward the rear for rear-seated passengers, adjusting the allocated distance based on remaining legroom.

G. Boundary Conditions

In scenarios where the vehicle exceeds the rated velocity for the dampers and springs, the seat travel is mechanically locked, preventing further movement as if originally bolted to the ground. The system does not activate during vertical bumps or rollovers, as it only functions on the horizontal plane. Actions on the vertical plane do not impact the seat.

H. Comparative Analysis

In the quest to minimize the health risks associated with car collisions, various innovative vehicle seat designs have emerged. For instance, a particular car seat described in a relevant patent focuses on reclining upon impact [5]. Refer to Figure 3 for a visual representation of this patented seat design. While the patent primarily addresses the upper body of the occupant, the design developed in this study takes a comprehensive approach by addressing the entire occupant's body. Additionally, the patented design falls short of effectively mitigating the impulse experienced by the occupant's body during a collision. Although adjusting the seating position angle may provide some mitigation, it fails to adequately reduce the exerted force. In contrast, the seat design presented in this research not only effectively absorbs a significant portion of the impact but also distributes the forces exerted on the occupant over a longer time, thereby effectively reducing the momentary impulse.

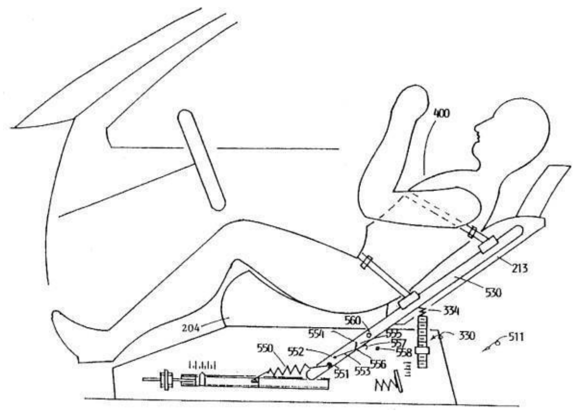

Fig. 3. Patent US5746467

III. Conclusion

In conclusion, the implementation of this advanced seat safety system holds significant potential in reducing health risks for vehicle occupants. While integrating the system may require interior modifications, the benefits outweigh the associated challenges. Self-driving vehicles, equipped with cutting-edge sensors and computing capabilities, offer an optimal platform for deploying this safety system, leveraging their infrastructure for real-time data processing and decision-making. Notably, further work in support of this design will involve static and dynamic simulations, which will provide valuable insights and validation for its performance. The advantages of this innovative seat safety system extend beyond personal vehicles to encompass transit vans, buses, and other passenger-carrying vehicles, enhancing overall passenger safety. By prioritizing occupant well-being and embracing this technology, we can strive for a future where road accidents result in minimal health-related consequences.

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A Smart Energy-Saving and Comfort System for Efficient Temperature and Lighting Control

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Abstract

The desire for assistance systems for the elderly and the disabled, particularly those who live alone, is driving the quickly growing home automation industry. Furthermore, it is well recognized that the world's population is ageing. Systems for automating the house must respect cultural conventions and be user-friendly. Home automation is one of the industries that is growing the fastest and has the potential to change how people live.

The objective of this project is to develop an intelligent energy-saving and comfort system that can efficiently control the lighting and temperature in homes and workplaces. The system will use automation, sensor networks, and cognitive algorithms to increase energy efficiency, occupant comfort, and environmental effect. This article discusses the design, implementation, and assessment of the recommended system as well as some of the system's potential benefits in terms of energy efficiency, cost savings, and user satisfaction.

I. Introduction

People are requesting more comfort in their lives with the aid of new technology. The necessity for automated homes has arisen in this new era with automated items such as automatic automobiles, automatic dishwashers, automatic boats, and more. In these homes, individuals enjoy the luxury of accomplishing things with the least amount of effort.

Any gadget that can be connected to the internet and further managed through it is referred to as an "Internet of Things," or IOT for short. Lighting, ventilation, and security are all controlled and automated by home automation systems (HAS). Modern technology called "home automation" changes our homes so that many duties can be completed automatically. Home automation systems' (HAS') primary goals are to conserve energy and minimize labor-intensive tasks. Additionally, this system is designed to assist older persons who have trouble walking and turning on and off household appliances as well as disabled people who have trouble walking.

The Smart Energy-Saving and Comfort System (SESACS), a cutting-edge technology created to increase energy efficiency while assuring the highest levels of comfort in buildings, is the subject of this project report. SESACS is an intelligent system that merges cutting-edge technologies including Internet of Things (IoT), machine learning, and automation to produce dynamic temperature and lighting adjustments based on real-time data and user preferences.

A microcomputer called Raspberry Pi was created by Raspberry Pi company. This microcomputer has several input and output ports. It performs the role of a centralized controller in a Wireless Sensor Network (WSN) in addition to being a processing node. The Home Automation System (HAS) can be operated through voice commands thanks to further integration with the voice assistant. The motion sensor in the system will in fact activate the light sensor, which will then assess the ambient light level and turn on the light if the sensor detects a reading below the threshold value.

II. Literature Survey

In this study article [1], raspberry offers security and a variety of controls for the home's gadgets. Mobile phones have made life more comfortable while also making it possible for easy access via portable devices. It allows users complete discretion, which makes it trustworthy because it always consults users before making any judgements, assists when important decisions must be made, and enables quick decisions to be made in an emergency.

This paper [2] proposes and implements an architecture for Raspberry Pi -based smart home control and monitoring systems. It provides a fundamental understanding of how to use a Raspberry Pi board in conjunction with a desktop application to secure various home appliances and control them. In our project, we attempted to create an embedded system that satisfies the key requirements of home automation for the regulation of temperature and humidity, habitat security, and lighting. Because of this, a desktop program was developed to communicate with a Raspberry Pi over its serial port.

Paper [3] cites the light sensor was set up correctly to recognize when the laser was damaged and avoid mistakenly tripping due to varying ambient light conditions. Additionally, the outputs of the temperature and lighting control subsystems have been verified to function.

Particularly, it has been verified that the firmware is producing the right signals for the subsystem BJT switches that manage furnace and lighting operations. Overall, the project has followed the design guidelines and has maintained a high standard of quality that can be incorporated into contemporary residences.

The development and verification of the raspberry pi-based home security system were successfully documented in the final research paper. The raspberry pi has proved useful for both Temperature sensor and Light sensing feature.

Reference	Methodology	Advantages	Future Scope
[1]	PIR sensors, which are more effective than standard IR sensors for home security, were utilised in this instead of Arduino and Raspberry Pi.	The fastest reason to use a Raspberry Pi over an Arduino is its faster clock speed. Direct connection between the PIR sensor and the LED array will improve the lighting conditions for the camera to take quality pictures in.	Given that the Raspberry Pi has numerous GPIO pins that can be constructed or programmed, used to connect various real-world devices, and controlled by the Python programming language, it may be employed in the future.
[2]	The most fundamental implementation uses an IR sensor to detect human presence and an LDR sensor to measure light intensity.	Instead of requiring users to manually turn on or off appliances, this technology allows users to do so while seated anywhere within the system's radius and around the globe.	By giving household components more control, the project can be scaled up.
[3]	In this project, the room temperature, human presence, and external light all work in concert to automatically manage the lights and fans.	Decreased use of electricity. saving money. Friendly to users. Simple to maintain	The system is more effective when improved sensors are used since they increase sensor precision.
[4]	An LDR sensor is used to regulate the brightness of the exterior lights, which are utilised outside the home.	Rather than setting a specific time for the lamps to turn on, the photoresistor helps control the intensity and thus saving electricity.	Possibly put into practice on a broader scale (street lighting).

III. System Design

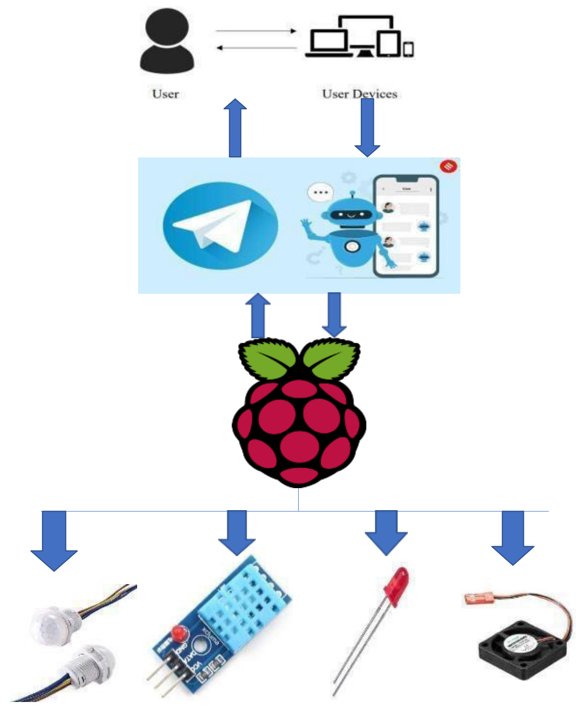

Figure 1 System Architecture

I. For those who require assistance to complete various tasks at home because they are unable to do it on their own, the Smart Home project is very helpful.

II. The complexity of wiring in the case of wired automation is avoided thanks to the Android application. Home automation powered by Wi-Fi would enable a man to turn on/off from any location. Secure entry into the house is made possible via the Android application system. Because of the emergence of numerous wireless technologies in recent years, the Home Automation systems have undergone significant modifications.

III. The demand for supporting systems that make living easier is driving the rapid growth of the home automation business. Without making any changes to the infrastructure, automation systems are designed to be integrated in already-existing residential environments. The automation is based on an Android application and utilizes a microcontroller and Wi-Fi module.

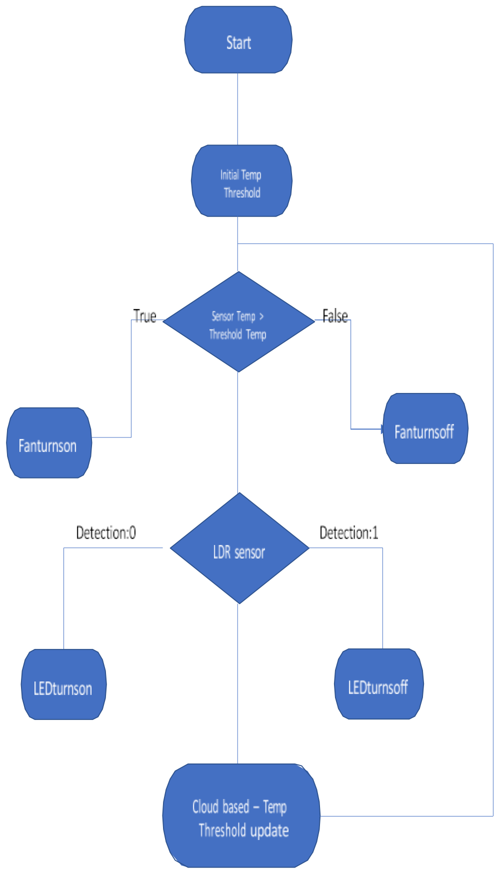

Figure 2 Flow chart

Components Used:

1. Raspberry Pi: The Raspberry Pi Foundation created the Raspberry Pi, a small single-board computer. It was developed with the goal of promoting fundamental computer science and programming abilities in educational settings and underdeveloped nations. The Raspberry Pi board, which has a processor, memory, input/output interfaces, and an operating system, is roughly the size of a credit card and has all the necessary parts of a computer.

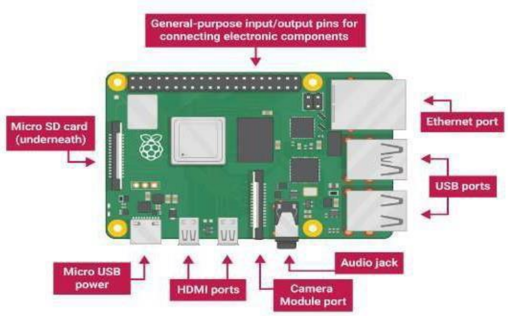

Figure 3 Raspberry PI [5]

2. LED: Visible LEDs are employed as indication lamps in a variety of electrical equipment, as rear-window and brake lights in automobiles, and as alphanumeric displays or even full-color posters on billboards and signs.

Figure 4 LED [6]

3. Fan

Figure 5 Fan [6]

4. Temperature Sensor

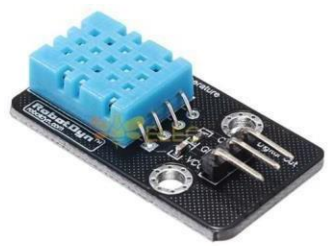

Figure 6 Temperature Sensor [6]

5. LDR Sensor

Figure 7 LDR sensor [6]

IV. Working

Here we have integrated temperature and light sensors with thermostats, fans, and lights. The system will gather real-time data and leverage cloud-based platform to make intelligent adjustments based on the lights and ambient temperature.

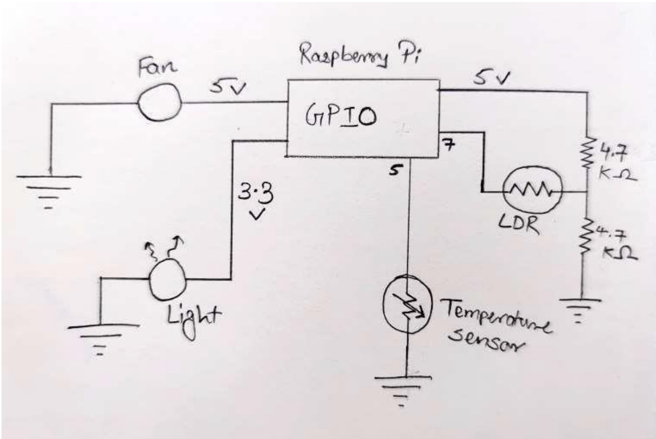

Figure 8 Circuit Diagram

Firstly, we must set an initial threshold temperature for activating temperature sensor from the cloud-based platform telegram which we have used. After setting the temperature when the temperature goes up from the threshold temperature the sensor activates, and Fan will turn ON.

Similarly, for the LDR sensor when the sensor senses that light is not enough than it automatically activates the LEDs in the circuit.

V. RESULTS

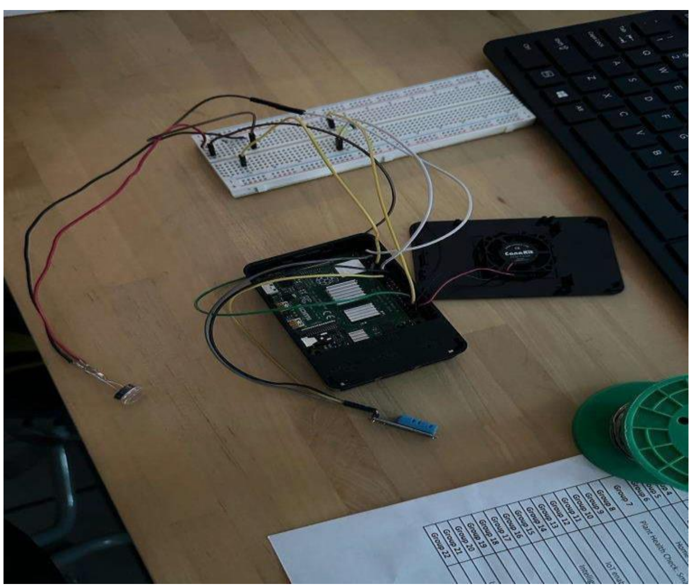

Figure 9 Circuit Connection

VI. CONCLUSION

IOT-based home automation is an entirely new idea from what is currently on the market. Automation would become simpler and more logical as a result. The system will be accessible to users everywhere in the world. It is also crucial since, in today's hectic environment, it will make it easier for people to carry out their daily activities.

Every part of the world around us is rapidly transitioning to digital, and because of this, we must likewise move forward. Our solution is a fantastic step towards automation; in the not-too-distant future, it will also offer security.

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The Benefits of a Certificate Program in Railway Systems for Individuals and Industries in Canada: Job Opportunities, Upcoming Projects, and Potential Benefits

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Keywords—Railway Systems, Education, Rail Transportation

I. Introduction

Railway systems are an essential part of Canada's transportation infrastructure, providing a reliable mode of transportation for people and goods across the country. According to Transport Canada, railways in Canada transported approximately 334 million tons of freight and 84 million passengers in 2019 [1].

Fig. 1 show share of each transportation type in Canada market. Main transportation types in Canada include railways, road, air and other (i.e., ships and buses). As of 2021, railways account for about 11% of the transportation market share, while road transportation accounts for around 55%. Air transportation, water transportation and other support activities account for the remaining 34% [2].

While railways account for a smaller portion of transportation overall compared to highways, they play a critical role in the transportation of bulk commodities such as grain, forest products, and minerals. Additionally, railways are often used for long-distance transportation of goods, and they are crucial for connecting remote communities in Northern Canada. With the railway industry continuing to grow and evolve, there will be a growing demand for skilled professionals who can design, maintain, and manage these complex systems.

II. Feasibility

A. National Need

Canada has faced some challenges and delays in advancing its railway systems over the past 20 years, but several factors contribute to this situation [24]:

Vast Geography:

Canada has a vast and expansive geography, which presents unique challenges for implementing and expanding railway systems. The construction and maintenance of railways across long distances, through diverse terrains, and in remote areas can be complex and costly.

Population Distribution:

Canada's population is concentrated in specific regions, particularly the southern parts of the country. This population distribution impacts the prioritization and investment in railway systems, as there may be less demand for extensive rail networks in sparsely populated areas.

Government Priorities:

Over the past two decades, the Canadian government has prioritized other areas of infrastructure, such as highways and airports, which have received significant investments. This focus on other modes of transportation may have diverted attention and resources from railway development [3].

Regulatory Framework:

The regulatory framework for railway systems in Canada can be complex, with multiple stakeholders involved, including federal, provincial, and municipal authorities. This can create challenges in coordinating efforts, obtaining permits, and making timely decisions for railway projects.

Financing and Investment:

Financing large-scale railway projects requires substantial investment, and securing funding can be a significant hurdle. Private companies and government entities need to align their interests and collaborate to secure the necessary financial resources [3].

Environmental Consideration:

In recent years, there has been increased emphasis on environmental sustainability and reducing greenhouse gas emissions. This has led to more rigorous environmental assessments and regulations, which can further slowdown the development and expansion of railway systems.

It's important to note that despite these challenges, there have been notable developments in Canada's railway systems, such as the expansion of urban transit networks and ongoing projects mentioned earlier. The government's commitment to investing in transportation infrastructure, coupled with advancements in technology and sustainability, provides opportunities for Canada to catch up and further enhance its railway systems in the future.

B. Market Size:

The Rail Transportation industry in Canada recorded a market size of $19.7 billion in 2022, based on revenue. It experienced a growth rate of 2.9% during the same year. Over the past five years, the industry has exhibited a positive trend, growing at an average rate of 0.8% per year between 2017 and 2022. In comparison to the overall economy, the Rail Transportation industry has shown slower growth. Similarly, when compared to the Transportation and Warehousing sector in Canada, the Rail Transportation industry has demonstrated a slower growth rate. In terms of market size rankings in 2022, the Rail Transportation industry in Canada was the 4th largest in the Transportation and Warehousing sector and the 64th largest overall. External competition poses a significant negative factor for industry growth, while a growing life cycle stage serves as the primary positive factor.

Collectively, the transportation of agricultural goods is rail transportation's largest revenue generator. Railways primarily transport bulk loads of grains and other staple crops, including wheat, corn and soy. That's why boosted production of agricultural goods positively impacts the industry. Demand from agriculture, forestry, fishing and hunting will grow in 2023, representing an opportunity for rail transportation companies. [4]

In summary, Canada is undergoing significant expansion in its transit infrastructure with several multi-billion-dollar projects underway (Approximately $69.38-Bilion). These projects are taking place in cities such as Toronto, Vancouver, Hamilton, and Montreal, and involve the construction of subway and light rail transit (LRT) systems. The projects aim to improve connectivity, reduce congestion, and provide efficient and sustainable transportation options for residents and visitors. With investments in expanding rail networks, adding new stations, and upgrading infrastructure, these transit projects are set to transform the way people travel within these cities. They also can have a significant impact on employment for Canadians and newcomers.

C. Market Gap:

There is a significant age gap between newly graduates and individuals nearing retirement in the railway systems market in Canada. This gap is a result of several factors:

- **Demographic Shift**: The railway industry, like many other sectors, is experiencing a demographic shift due to the aging workforce. Many employees who have been working in the industry for several decades are approaching retirement age, creating a need for new talent to fill the resulting vacancies [3].

- **Lack of Succession Planning**: In some cases, there has been a lack of effective succession planning within railway companies. This means that the knowledge and experience of retiring employees may not have been adequately transferred to the younger generation, leading to potential skill gaps [5].

- **Technological Advancements**: The railway industry has undergone significant technological advancements in recent years. The younger generation of graduates often possesses a stronger familiarity with emerging technologies and digital tools, which are increasingly relevant in the modernization and automation of railway systems. This can create a gap between the skills of experienced employees and those of new graduates [6].

- **Industry Perceptions:** The railway industry may not always be perceived as an attractive career choice for younger generations. Factors such as remote work locations, long hours, and the perception of limited career advancement opportunities may discourage some graduates from pursuing careers in the railway sector [7].

III. Solution

We are planning to announce a program in Railway Systems at McMaster University, aimed at preparing future professionals for the dynamic and evolving field of railway engineering. This comprehensive program offers a specialized curriculum that equips students with the knowledge and skills necessary to thrive in the railway industry. Through a combination of theoretical coursework, practical exercises, and industry engagement, our program fosters a deep understanding of the principles, components, and operations of railway systems.

The Railway Systems Program at McMaster University focuses on five key courses that cover essential aspects of railway engineering. Our curriculum includes "**Introduction to Railway Systems**" providing a solid foundation by exploring the historical significance, organizational frameworks, safety considerations, and key components of railway systems. The "**Electrification**" course delves into the principles and technologies behind railway electrification, addressing power supply, distribution, and control systems.

Students will also study "**Signaling**" which covers the crucial role of signaling systems in ensuring safe and efficient railway operations. This course addresses various signaling principles, interlocking systems, train control, and communication-based train control (CBTC) systems. The "**System Assurance**" course emphasizes safety and reliability analysis techniques, risk assessment and management, and compliance with industry standards and regulations.

Lastly, the "**Track Engineering**" course focuses on track components, design principles, maintenance practices, geometry, and construction techniques. Students will develop a comprehensive understanding of track infrastructure, enabling them to contribute effectively to track design, maintenance, and alignment.

Through this program, students will benefit from a combination of theoretical knowledge and practical experience. They will have the opportunity to engage with industry professionals, participate in hands-on projects, and gain exposure to real-world challenges in the railway sector. Our program aims to produce well-rounded graduates who can excel in various roles within the railway industry, such as railway engineering, track maintenance, signaling and communication, system assurance, and project management.

These courses are foundational courses designed to provide students with a comprehensive overview of the principles, components, and operations of railway systems. They aim to develop a solid understanding of the fundamental concepts and technologies involved in the design, construction, maintenance, and operation of railways. Students will explore various aspects of railway infrastructure, rolling stock, signaling systems, electrification, and safety considerations. Through a combination of theoretical lectures, practical exercises, and case studies, students will gain the necessary knowledge and skills to contribute effectively to the railway industry.

IV. Conclusion

The ongoing and planned transit expansion projects in Canada reflect the commitment to improving public transportation and addressing the growing transportation needs of urban areas. These projects not only enhance connectivity but also contribute to economic growth, reduce greenhouse gas emissions, and promote sustainable urban development. The substantial investments being made demonstrate the recognition of the importance of efficient and accessible transit systems in creating livable, vibrant, and connected cities.

As these projects progress, it is expected that they will have a profound impact on the way people commute and travel in Canada. The development of new subway lines, LRT systems, and expanded rail networks will provide residents with more convenient options for getting around, reducing reliance on private vehicles, and promoting a shift towards sustainable transportation.

However, it is important to note that these projects often involve complex planning, significant construction timelines, and financial considerations. They require careful coordination between various stakeholders, including government entities, transit authorities, contractors, and the communities they serve. Continued support, funding, and efficient execution will be crucial in ensuring the successful completion of these transit projects and reaping their long-term benefits for the communities and regions they serve.

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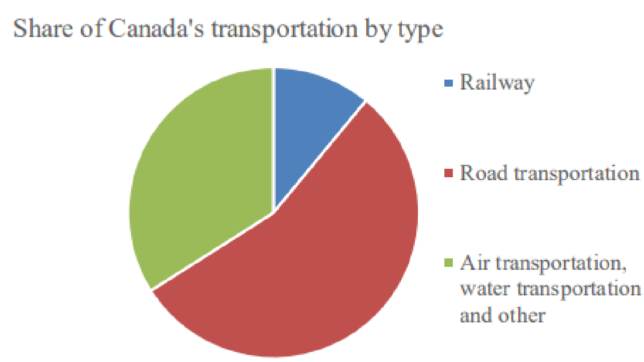

Figure 1. Market share of each transportation by type in Canada.

Smart Home Automation System using Raspberry Pi for Real-Time Control of Fans and Lights based on Environmental Conditions

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***Abstract* — This paper aims to create a Home Automation System using a Raspberry Pi, with the objective of automatically controlling fans and lights in our homes based on real-time room temperature and light intensity. The system involves various components including a Raspberry Pi, a Temperature-Humidity Sensor (DHT11), a Light Intensity Sensor (GY-30), an Actuator (Stepper Motor - Fan), and an LED. The Raspberry Pi communicates with the ThingsBoard Cloud Platform, where sensor data is sent and visualized as dashboards for monitoring, analysis, and informed decision-making purposes. The Raspberry Pi leverages predefined thresholds to determine optimal settings and efficiently turns ON/ OFF the Actuator (Fan) and LED (Light) accordingly. By integrating these technologies, this project aims to pave the way for the future of smart living through home automation.**

I. Introduction

The advent of smart technology has revolutionized the way we interact with our living spaces, paving the way for a more efficient and convenient lifestyle. The continuous advancements in embedded systems, the Internet of Things (IoT), and cloud computing have propelled the transformation of traditional homes into smart living spaces. Home automation systems have gained popularity for their ability to enhance energy efficiency, user comfort, and overall convenience. In this context, this IEEE paper presents a novel Home Automation System utilizing a Raspberry Pi as its core component. The objective of this project is to automatically regulate fans and lights within homes based on real-time room temperature and light intensity readings. By integrating various cutting-edge technologies, this system exemplifies the potential of smart living through home automation.

In recent years, the convergence of smart technology with daily living has spurred the development of intelligent home automation systems. These systems offer seamless integration of diverse devices and services, aimed at improving the quality of life for inhabitants while promoting energy conservation. The project at hand embodies this spirit of technological innovation and explores the creation of a Home Automation System that leverages the Raspberry Pi, a versatile and cost-effective computing platform, to optimize the control of fans and lights within a home environment.

Advances in microcontrollers, sensors, and communication protocols have opened new avenues for transforming conventional houses into smart, adaptive living spaces. The proposed Home Automation System takes advantage of these advancements, utilizing a combination of sensors and actuators to continuously monitor and regulate room temperature and light intensity.

The Raspberry Pi, acting as the central control unit, orchestrates the interactions between these components, ensuring efficient energy management and personalized comfort for users.

The Home Automation System described in this paper is built around the Raspberry Pi, a versatile single-board computer known for its flexibility and affordability. Our system comprises key components, including a Temperature-Humidity Sensor (DHT11) and a Light Intensity Sensor (GY-30) to monitor the environment's vital parameters. Additionally, an Actuator in the form of a Stepper Motor controls the fan, while an LED is employed to manage lighting conditions. The Raspberry Pi acts as the central controller, orchestrating the interconnected devices to optimize energy consumption and enhance user comfort.

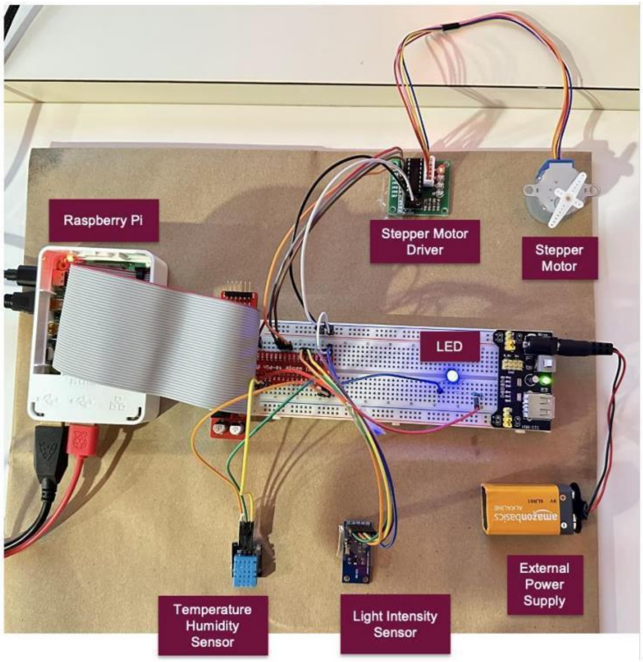

Fig. 1: Smart Home Automation System Design and Components

II. SYSTEM DESIGN AND COMPONENTS

A. Hardware Requirements

Raspberry Pi
DHT 11 Sensor
GY-30 Sensor
Stepper Motor
ULN2003 Motor Driver
LED
1K Ohm Resistor
Power Supply Module and Battery
SparkFun 40-Pin Wedge Connector
Breadboard and Jumper Wires

B. Software Requirements

ThingsBoard IoT Cloud Platform
Raspberry Pi OS
Python Programming Language

C. Hardware Connections and Circuit

PIN CONFIGURATION		
Hardware	Connections	RPI Pins
DHT 11	VCC	3.3V Pin
	Data	GPIO 13
	Ground	GND Pin
GY-30	VCC	3.3V Pin
	SCL	SCL Pin
	SDA	SDA Pin
	ADO	3.3V Pin
	Ground	GND Pin
Led	Anode (Longer Leg)	GPIO 17
	Cathode (Smaller Leg)	GND Pin
ULN2003 Stepper Motor Driver	Input 1	GPIO 18
	Input 2	GPIO 23
	Input 3	GPIO 24
	Input 4	GPIO 25
	Negative Pin (Ext PS)	Neg Pin of HW 131
	Positive Pin (Ext PS)	Pos Pin of HW 131
Stepper Motor	Coil 2 (Pink)	B
	Coil 4 (Blue)	A
	5 V (Red)	
	Coil 3 (Yellow)	C
	Coil 1 (Orange)	D

The Home Automation System is built upon a solid foundation of carefully chosen hardware components. The Raspberry Pi serves as the heart of the system, providing the processing power and connectivity necessary for data collection, decision-making, and communication with external platforms. Two critical sensors are employed: the Temperature-Humidity Sensor (DHT11) and the Light Intensity Sensor (GY-30). These sensors enable the system to monitor ambient temperature, humidity, and light levels with high precision.

To enable responsive control over room conditions, the project integrates an Actuator in the form of a Stepper Motor for the fan and an LED for lighting control. The Stepper Motor allows the system to regulate the fan's speed and, consequently, the cooling effect in response to temperature fluctuations. On the other hand, the LED caters to the lighting needs, dynamically adjusting brightness based on the ambient light intensity.

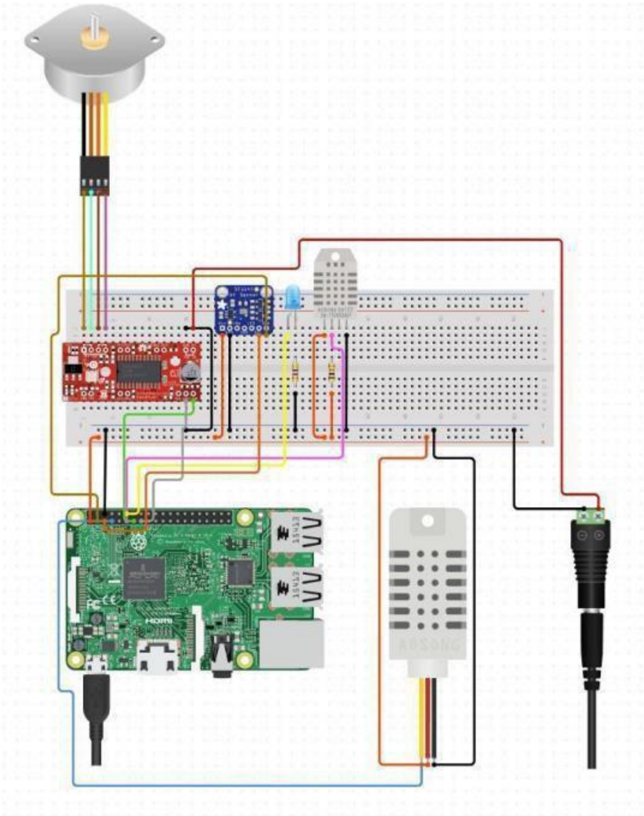

Fig. 2: Smart Home Automation System Circuit Schematic Diagram [created using circuito.io]

III. ALGORITHM FORMULATION AND CIRCUIT MODELING

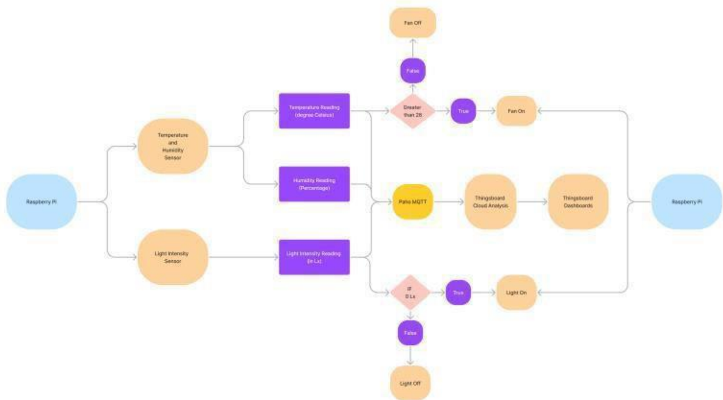

Fig. 3: System Operation Flowchart

A. System Functionality

The Raspberry Pi is connected to a Temperature-Humidity Sensor (DHT11) and a Light Intensity Sensor (GY-30) to acquire sensor readings. These readings include Temperature in Degrees Celsius, Humidity in Percentage, and Light Intensity in LX units.

When the temperature reading surpasses a predefined threshold (26 Degrees Celsius in this case), the system activates the fan (Stepper Motor) to maintain a comfortable room temperature. Conversely, when the temperature drops below the threshold, the fan is automatically turned off, conserving energy. In parallel, the Light Intensity Sensor continuously measures the amount of ambient light. If the light intensity reading reaches 0 LX, indicating darkness, the system switches on the LED to provide illumination. Conversely, when the light intensity rises above 0 LX, the LED is turned off, further optimizing energy consumption.

B. *Cloud Integration and Monitoring*

To enable seamless communication and enhance data management, the Raspberry Pi transmits all sensor readings (Temperature, Humidity, and Light Intensity) simultaneously to the ThingsBoard Cloud Platform using the Paho MQTT Protocol. The ThingsBoard Dashboards offer comprehensive visualization capabilities, providing users with real-time insights into their home environment.

This cloud-based integration empowers users to monitor the system's performance, conduct analysis, and make informed decisions regarding energy consumption and comfort. Both the Fan and the LED are also directly connected to the Raspberry Pi for control and synchronization.

C. *Data Visualization*

Our three dashboards – Temperature Dashboard, Humidity Dashboard, and Light Intensity Dashboard – show visual representations of real-time readings from all three sensors in the form of Timeseries Table, Timeseries Bar Chart, and Gauge Meter.

D. *Real-World Application*

The Home Automation System based on the Raspberry Pi represents a significant step forward in the realm of smart living and sustainable home environments. By seamlessly integrating sensors, actuators, and cloud-based platforms, the project demonstrates the potential for intelligent, energy-efficient automation that enhances user comfort and convenience. The paper outlines the design, implementation, and integration of the system components, providing valuable insights for researchers, developers, and technology enthusiasts interested in exploring the future of home automation and IoT-based solutions.

IV. Conclusion

In conclusion, our project aimed to develop a Home Automation System for controlling fans and lights based on real-time residential environmental conditions. Through the integration of components such as the Raspberry Pi, DHT11, GY-30, Actuator, and LED, we successfully achieved our objective.

By leveraging the Raspberry Pi's capabilities, we established a communication link with the ThingsBoard Cloud Platform, enabling real-time transmission of sensor data. This facilitated the visualization of the data through intuitive dashboards, enhancing monitoring, analysis, and decision-making processes. The project's implementation encompassed the utilization of predefined thresholds to determine optimal settings for the control of the actuator and LED. The Fan (Stepper Motor) was automatically turned on when the room temperature exceeded 26 Degrees Celsius, ensuring a comfortable environment. Likewise, the LEDwas controlled based on light intensity, being switched off in the absence of light.

Through meticulous execution, we successfully demonstrated the potential of home automation systems in improving convenience and energy efficiency. The project's outcomes signify a step towards the future of smart living. By automating the control of fans and lights based on real-time environmental factors, we have showcased the practical applications of IoT technology and its potential to revolutionize residential environments.

V. Future Scope

This project has not only provided valuable insights into the implementation of a Home Automation System but also emphasized the significance of integrating cutting-edge technologies for enhanced living experiences. As smart homes become increasingly prevalent, our project serves as a testament to the potential of automation in transforming our daily lives.

The future potential of our project includes the incorporation of Machine Learning and Artificial Intelligence, as outlined below:

- Implementing a mobile or web-based application to monitor the energy conservation factor of various home appliances, allowing homeowners to have additional control over their usage.
- Expanding the functionality of the system to include other actuators to automate the opening and closing of different areas in a home, such as doors and windows, based on specific sensor readings and predefined conditions.
- Adapting the project to serve as an automated system for monitoring and controlling the environment of a newborn baby's room, ensuring optimal conditions for their well-being.
- Expanding the project to develop an automated thermostat control system for regulating the temperature in the entire house.
- Personalized notification system to alert homeowners whenever there are disruptions in environmental conditions serving as an added layer of security.

These future directions showcase the potential for further innovation and expansion of the project, leveraging advanced technologies to enhance energy efficiency, convenience, and security within smart homes.

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A Pedagogy for Microcredentials in Engineering Education: The MacAccess Example

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Keywords—Microcredentials, Engineering education

I. INTRODUCTION

The contemporary concept of microcredentials offer a more flexible and compact framework for learning and verifying skills/knowledge attainment. A more complete definition currently used by McMaster University is provided in [1]. The common characteristics of micro-credentials are,

1. Skills and competencies-based
2. Short in duration
3. Assessable
4. Modular and stackable
5. Personalized
6. Verifiable

The challenge for most North American post-secondary institutions to introduced micro-credential based programs often arise from conflict with academic tradition. In Ontario, most institutions offer 4-month semester courses that are taken serially by entire cohorts of students. Consequently, the essential qualities 2, 3, and 4 from the foregoing list are inconsistent with prevailing course structure.

Qualities 1 and 5 are common to both planned micro-credentials and current academic practice. Indeed, most North American institutions, especially in applied programs such as engineering, have a professed commitment to hands-on, project-based, work-integrated, and other forms of experiential learning (e.g. at McMaster [2]). Arguably, item 6 is a strength of the traditional academic programs and represents a challenge for micro-credentialized programs to address.

The MacAccess initiative proposes to develop a framework to allow conventionally defined engineering courses to be efficiently reformulated and delivered as modern micro-credentialled variants. The intent is to have the new courses embody the desired flexibility and related qualities while maintaining the rigour and outcomes inherent in the conventional courses. This allows possible future options for full-time and non-full-time students. The project is exploratory in nature and will execute pilots drawn from suitable initial topics. The target start date for the first courses is the Winter semester of 2024.

MacAccess was conceived at the Walter Booth School of Engineering Practice and Technology within the Faculty of Engineering at McMaster University, Canada. The Booth School is known for its applied and practice-based learning approach to curricular programming.

II. PROGRAM AND COURSE STRUCTURE

A key novel contribution of the MacAccess design of courses is a basic "rhythm" of 3. A micro-credentialled equivalent of a conventional McMaster "3-unit" course (nominally a 4-month semester course of 13 active instruction weeks and 3 instruction hours per week) is defined as a flexible sequence of 3, one month-long "modules", labeled M1, M2, M3. A typical 3-module course will also exist with a sequence of courses. For example, if a topic warrants 3 courses (e.g. C1, C2, C3), there will be a total of 3 *modules* x 3 *courses*, or 9 modules. The difference, however, from conventional courses is that each module, to the extent that is reasonable and appropriate, is self contained and can be taken in non-serial sequences. Moreover M1, M2, and M3 respectively embody a particular pedagogical approach that align with specific learning outcomes (Fig. 1).

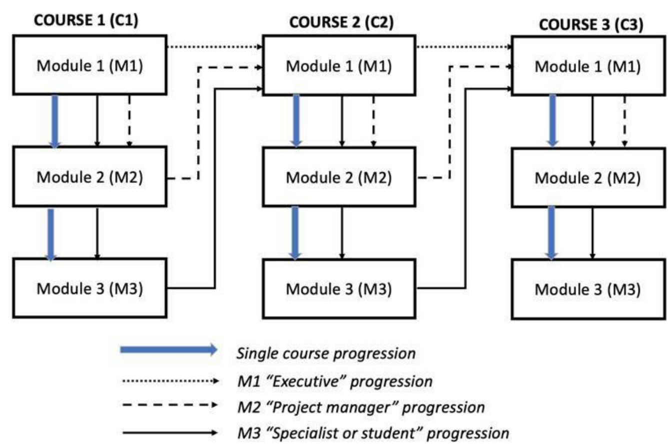

Fig. 1. *MacAccess learning module and course progressions*

The intended learning outcomes for the three modules are, respectively,

M1 "Executive" progression: The outcome is a system-level literacy of the most essential concepts. Following an M1 module, a learner is expected to be able to more confidently and productively participate in a design or project team on the topic, even if they do not have a specialized background in the topic. Typically, M1 modules will focus on the vocabulary and inherent taxonomies of a complex topic.

M2 "Project manager" progression: the outcome is the ability to manage, guide, or, more broadly, work with the component, connectivity, and broad inter-dependence or dynamical aspects of a complex system or application. Typically, M2 modules will focus on the tools commonly encountered within a complex topic context.

M3 "Specialist or student" progression: the outcome is a basic skills/knowledge capacity to competently synthesize an appropriate solution to complex or open-ended challenges within a complex topic context. Accordingly, M3 modules will focus on the application aspects.

An initial treatment of a course topic will require eventual completion of the three modules, and for very practical reasons, the most efficient sequence will likely be the M1, M2, M3 sequence – i.e. equivalent to a traditional 3-unit course. However, the core flexibility is derived from the fact that a learner does not need to go past a particular module level. For example, if a learner is a practitioner needing to upgrade their understanding of machine learning, they can focus on the M1 levels of three courses. Ultimately, such a sequence will provide the learner with the essential literacy and high-level insights to function in strategic planning, product management, external communications, etc. Hence the label "Executive" sequence alluding the type of professional who may benefit most from the M1 level.

III. Pilot topics

MacAccess pilot topics are drawn from three contemporary high-demand domains that also align with particular program priorities at the Booth School and the Faculty of Engineering:

Artificial Intelligence: The Booth School's current complement of undergraduate and graduate courses already offer a distinctive application-centric perspective on this timely topic. Three particular courses will be selected and reformulated to the MacAccess model.

Innovation and Entrepreneurship: The Booth School's successful GENTECH undergraduate program and the School's recently discontinued Master of Engineering Entrepreneurship and Innovation (MEEI) graduate program will form a foundation of three select courses aimed at introducing a unique blend of innovation-aligned topics within a robust engineering and technology context.

Sustainability and Circular Economies: A current topic of discussion is to leverage various sustainability-themed courses to address a distinct lack of practical modern courses in this very important theme.

As an initial step, the new MacAccess-aligned course variants will first exist as a refined version of the conventional 3-unit course that current McMaster students would take as part of their regular course load. These revised courses, however, will have a structure and tuned content that will readily adapt to actual micro-credentialled program form once the anticipated delivery platform and processes are in place.

IV. Pedagogical foundation

As much as MacAccess is motivated by the increased flexibility and reach of micro-credentialled, high-quality courses, the resulting definitions and framework has been derived from formal pedagogy, including the cognitive foundations of experiential learning [3] and the basic cadence or "rhythm" of the learning progression [4].

At a more practical level, some basic industry trends had a major influence on the initial choices of pilot topics. In particular, the American Society of Engineering Education notes that advanced contemporary technologies such as AI and data science, and generalized technical systems are considered not well addressed by conventional engineering programs [5].

V. Implementation challenges

Among the many challenges that any curricular transformation would trigger, MacAccess has already identified several particularly vexing obstacles that continue to draw significant research energies.

Delivery platform: Although the learning management system (LMS – e.g. D2L's Brightspace or "Avenue" at McMaster) offers the features to deliver the course content, new software mechanisms will be developed to coordinate and manage the required flexibility and modularity, and deal with learner registration, payment, and support.

Course development and migration: efficient conversion of a traditional course to MacAccess format that preserves the original academic intent but embodies the enhanced learning and flexibility benefits is required, and migration tools and processes are currently being developed to address this challenge.

Curricular reconciliation: Although McMaster does have clear definitions of microcredentials and related concepts such as certificates and badging, they are not well-aligned with the core degree. Indeed the intent of the initiative is to find effective mechanisms and refined definitions to bridge this gap. This will depend on greater efforts in mapping respective learning activities with verifiable outcomes.

VI. Conclusions

MacAccess represents a conscientious effort to modernize engineering programs to respond to changing societal and institutional priorities. A unique dimension in the program design is the novel blend of formalized pedagogy with a very pragmatic and process-focused development and delivery framework.

VII. Acknowledgements

MacAccess is supported by the Dean's Fund of the Faculty of Engineering at McMaster University.

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Auto-authorization system

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Abstract—The Raspberry Pi is a reasonably priced, small single-board computer that is used in this paper to demonstrate a real-time license plate recognition (LPR) system[4]. The device accurately detects and recognizes license plates from live video broadcasts using deep learning algorithms and image processing techniques. The video frames are taken by a camera module attached to the Raspberry Pi, and they are then processed by computer vision algorithms to find areas of interest with license plates. In real-world circumstances, the system obtains excellent accuracy rates and shows potential for applications like traffic management, authorized parking facilities, and security systems.

I. INTRODUCTION

The technology of license plate recognition (LPR) is essential in many fields, such as traffic control, parking enforcement, and law enforcement. In today's connected society, being able to quickly and precisely recognize license plates from live video streaming is becoming more and more crucial. Real-time license plate identification systems have drawn a lot of attention as a result of the quick development of computer vision and deep learning algorithms.

This study uses the Raspberry Pi, a reasonably priced single-board computer, to create a real-time license plate recognition system[4]. A portable and affordable option for installing LPR systems in locations with limited resources is the Raspberry Pi. The creation of real-time LPR systems with low latency and great precision is made possible by the Raspberry Pi by utilizing its processing capabilities and low power consumption.

Modern deep learning algorithms and image processing methods are included in the suggested system to quickly detect and identify license plates. Live video frames are captured by a camera module linked to the Raspberry Pi, which are then analyzed by computer vision algorithms to find probable license plate regions.

The Raspberry Pi is the perfect platform for real-time LPR systems because of its low cost, portability, and simplicity of deployment. The proposed system may be integrated into a variety of applications thanks to its capabilities, including automated toll collecting, access control, and intelligent transportation systems. The LPR system will be put into use on the Raspberry Pi in order to offer a practical and affordable solution for real-time license plate recognition jobs.

We outline the design, algorithms, and working principle of the Raspberry Pi-based real-time license plate identification system in this paper. Overall, by proving the viability and performance of a Raspberry Pi-based system, this study advances real-time license plate recognition technology. The suggested technique to implement LPR devices is affordable and practical, opening the door for more widespread adoption and use of this important technology.

II. OBJECTIVE

In order to provide a practical and affordable solution for license plate identification duties, the purpose of this work is to design a real-time license plate recognition (LPR) system using the Raspberry Pi. The main goal of the article is to reliably detect and recognize license plates from live video broadcasts by combining the capability of deep learning algorithms and image processing methods[4]. The objective is to show that the proposed system, as implemented on the Raspberry Pi platform, is practical, effective, and accurate.

III. APPLICATIONS

There are numerous potential uses for the created real-time license plate recognition system in various industries. Key applications include the following:

Automated traffic management is possible with technology, which also makes it possible to track and analyze road traffic in real-time. It can help with vehicle detection and tracking, enforcing traffic laws, and seeing patterns in traffic congestion.[4]

Parking Management: For effective management and control of parking facilities, the LPR system can be used. Automated entry and exit systems, precise vehicle recognition, and efficient parking fee collection are all made possible by it.

Law Enforcement: Law enforcement organizations can use the system to identify vehicles in criminal investigations and keep an eye out for suspicious activity. The technique can help in identifying vehicles involved in accidents and illegal activities.

Access Control Systems: By using license plate recognition (LPR), access control systems, such as those in gated communities, secure buildings, and parking lots, can allow or prohibit access. It improves security by precisely recognizing authorized cars and discouraging unauthorized entrance.

Tollbooth automation: The system is applicable to automated toll collecting on toll roads and highways. It does away with the necessity for human toll collecting by precisely identifying license plates and deducting the necessary toll money from linked accounts.

This study advances technology in various application areas by demonstrating the efficacy and efficiency of the Raspberry Pi-based real-time license plate recognition system. The suggested remedy provides a practical and affordable method for putting LPR into practice.[4]

IV. COMPONENTS USED

Following are the components used:

A. Raspberry Pi

As shown in figure 4.1, Raspberry Pi[2] is a small, affordable single-board computer that provides all the necessary processing power to run the system.

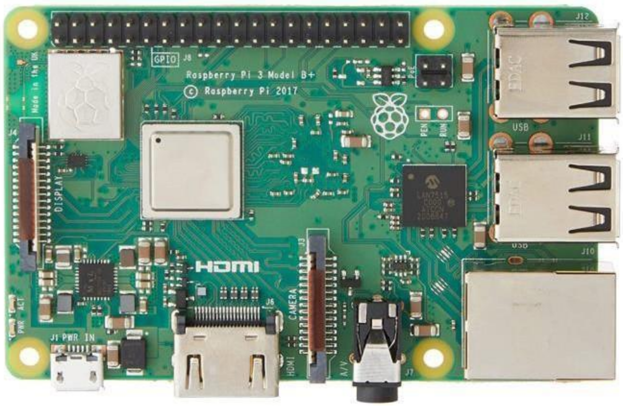

Figure 4.1: Raspberry Pi [2]

B. Pi Camera

As depicted in Figure 4.2, Pi camera[3] is a high-quality camera that allows for accurate image capture and analysis.

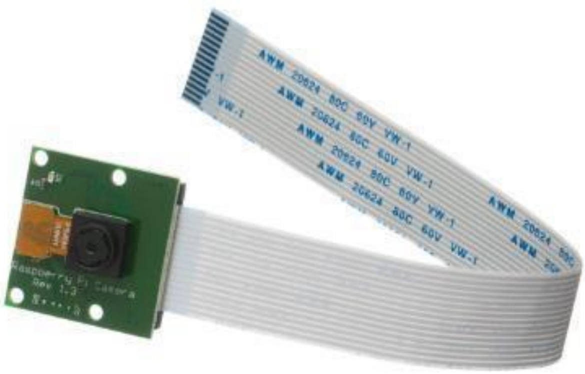

Figure 4.2: Pi Camera[3]

C. *Ultrasonic Sensor* [8]

Used to detect the distance between the car and the device to trigger the Pi camera.

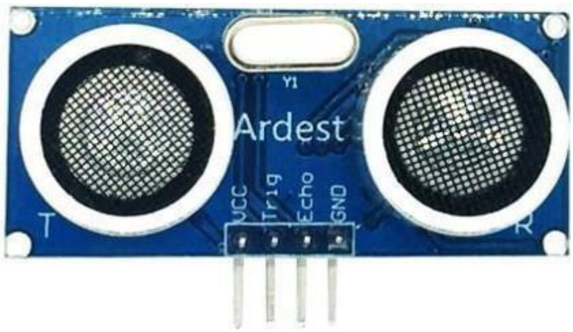

Figure 4.3: Ultrasonic sensor

D. *Servo Motor*[5]

Used to open the gate once authorized.

Figure 4.4: Servo motor [1]

V. Working Principle

Let us understand the working principle of the system by understanding the flow chart as shown in Figure 5.1. Following are the detailed steps performed:

1) *Step 1-Vehicle detection:* The vehicle will approach the gate and as soon as it reaches a certain distance, the Ultrasonic sensor will trigger a Python code and activate the Pi Camera. If the vehicle is not in appropriate distance then it will continue reading the distance until the vehicle reaches the predetermined distance.

2) *Step 2-Image Capture:* The Pi Camera will then take a picture of the License plate using the OpenCV library. It will look for the rectangular contour of the License Plate.

a) *Step 3-Image processing:* The Python code will then process the code and look for the character using the OCR technique.

b) *Step 4-Database check:* In this step, the program will then verify the captured license plate characters with the one registered in the pre-created database.

c) *Step 5-Generating history:* If the license plate matches with the database then the program will send a message to the MQTT channel with the recorded license plate characters and whether it is authorized or not authorized.

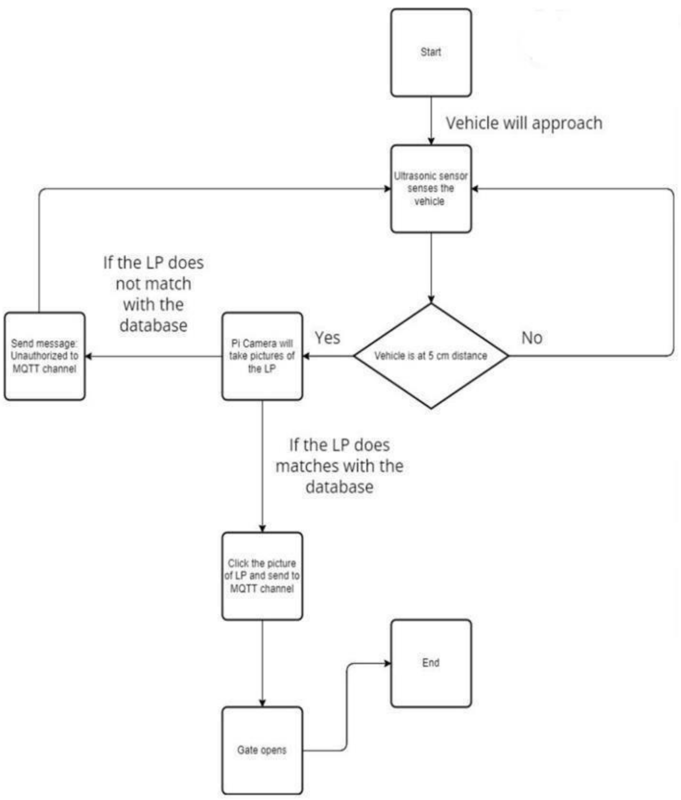

Figure 5.1: Working principle flow chart

VI. Apparatus

Figure 6.1 depicts the apparatus of the project. As shown in the figure, the Raspberry Pi is connected to Pi Camera, while the Ultrasonic sensor and servo motor is used as a representation of the gate.

So, here in the Python program, we keep sensing any object detection at a distance of 5cm and as soon as the ultrasonic sensor senses any object within 5cm, it triggers the Pi camera to detect the license plate. Then with the help of a Python program where we have used libraries like OpenCV and Tesseract, the OCR takes place. After getting the result it will then validate with the database to check if it is authorized or not.

Now If the plate is not authorized then it will send a signal to the ultrasonic to again start the process from the start. In both ways, it sends data to the MQTT channel to record the vehicle passed or failed.

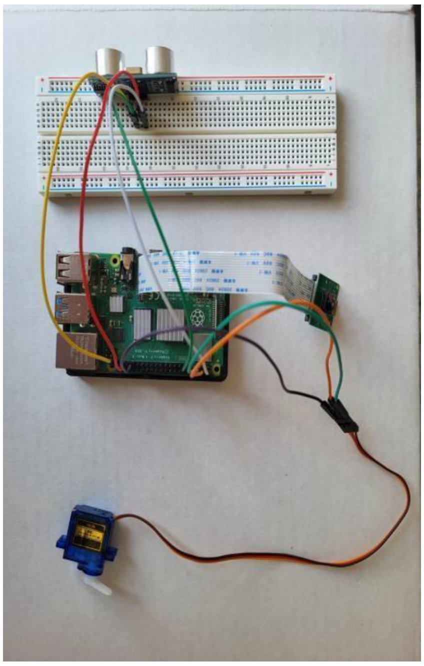

Figure 6.1: Apparatus

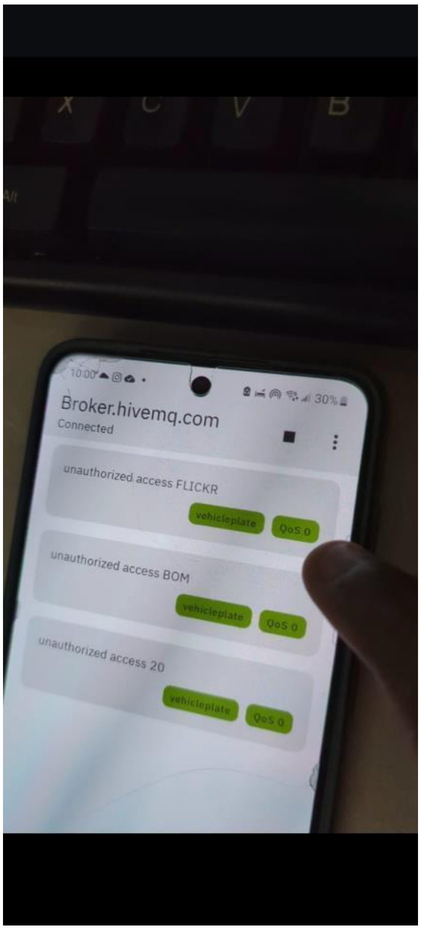

Figure 6.2: MQTT Channel

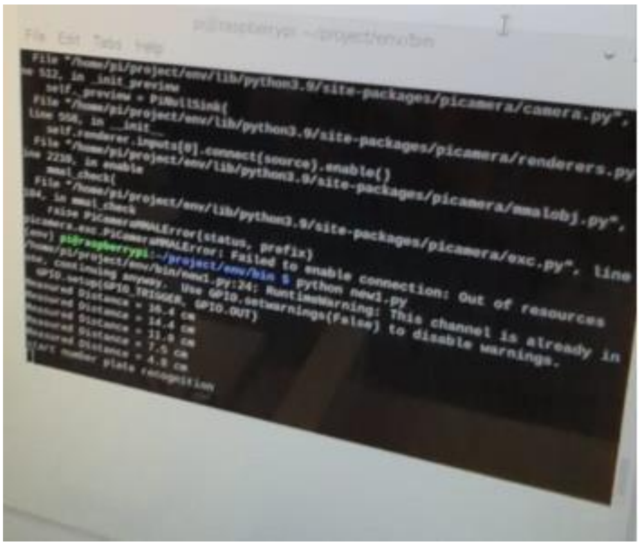

Figure 6.3: Raspberry Pi Terminal code

VII. Challenges

1. System Integration: Integrating several components, including IP cameras, relays, the Raspberry Pi, the ALPR library, a Telegram bot, and other devices calls for careful planning and cooperation. It can be difficult to make sure that these parts are in perfect synchronization and communication with one another.

2. Precision and durability: It can be difficult for the system to identify and recognize license plates with precision and durability and to analyze the system's functionality in various lighting scenarios and with various license plate styles.

3. Real-time Image Processing: Effective algorithms and hardware capabilities are needed to perform real-time image processing on the digital images taken by PI cameras. It can be difficult to balance speed and resource usage when optimizing image cropping, scaling, and other image processing methods.

4. Recognition of License Plates Accuracy: For the system to work properly, achieving high accuracy in license plate recognition is essential. Handling multiple license plate designs, various lighting situations, and image quality can be difficult. This problem can be solved by creating reliable algorithms and training the system with a variety of license plate data.

5. System Reliability and Availability: The smart gate system's efficiency depends on ensuring the system's dependability and availability. Managing network connectivity issues, power outages, and system crashes are just a few potential obstacles. These difficulties can be lessened by implementing fault tolerance mechanisms, backup systems, and error-handling strategies.

6. Thermal management and power consumption: The Raspberry Pi's limited power capacity might result in higher power consumption and heat production when doing computationally demanding tasks. It is a problem to control

power consumption and thermal restrictions while preserving system performance.

VIII. Conclusion

In this project, we used Raspberry Pi and Python to successfully construct a Real-Time Licence Plate Recognition system. The system uses the Pi Camera module to take frames continually, and with the press of a key, it saves the most recent frame as a picture. The license plate is then discovered using OpenCV's contour algorithms. The Tesseract library is used by the Raspberry Pi to perform Optical Character Recognition (OCR) to read the license plate numbers after cropping out the area containing the license plate. Following that, the retrieved characters are matched to a pre-established database of recognized automobile plate numbers. Additionally, it uses the MQTT protocol to send a picture of the automobile and its number plate number to a cloud server, delivering real-time notifications and updates. The system has a number of features and capabilities. This project uses the Raspberry Pi and Python to automate number plate identification, which has a number of uses in automated garage systems, traffic management, speed alerts, and high vehicle security systems.

IX. Future Works

The Real-Time Number Plate Recognition system using Raspberry Pi and Python can be further enhanced and improved in a number of ways:

1. Improved License Plate Detection: The license plate detection algorithm can be improved to increase the system's accuracy[9]. Deep learning-based object detection models (using, for instance, convolutional neural networks) might be researched in order to produce more trustworthy and accurate license plate detection.

2. Image pre-processing techniques can increase the quality of the acquired frames and the precision of the OCRprocess. Examples of these approaches include noise reduction, image enhancement, and perspective correction.

3. The accuracy of character identification can be increased by training the OCR model on a bigger and more varied collection of photos of license plates[7]. To get better outcomes, it may be possible to try fine-tuning the OCR model specifically for license plate characters.

4. Integration with Database Systems: By integrating the license plate recognition system with database systems, it is possible to search for vehicle information in real-time using the numbers on the recognized license plates. Applications like parking management and traffic infraction tracking may benefit from this.

5. Mobile Application: As an alternative to the MQTT broker, developing a mobile application offers consumers a more user-friendly and practical way to communicate with the system. Push alerts, live video feeds, and remote gate control are just a few extra functions that the app might offer.

X. References

[1] Pi shop.ca; Servo motor image; Pg 3

[2] Amazon; RS Components Raspberry Pi 3 B+ Motherboard; Pg 2

[3] Pi Australia; PI Camera image; Pg 2

[4] IOT Project Pro; Pg 1-3

[5] Connecting servo motor to raspberry Pi Pg 3

[6] License plate recognization

[7] Car plate recognition; Pg 5

[8] Using Ultrasonic sensor Pg 2

[9] Python integration with raspberry Pi; Pg 5

IOT Based Smart Plant Monitoring System

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***Abstract*—This paper demonstrates an implementation of a complete system to monitor environment factors for optimal plant growth and automate water irrigation using IoT devices. Using a water level sensor and DHT11, it collects temperature, water level and humidity and on the basis of these and its necessity, it instructs for watering the plants.**

Keywords*—*IoT, farming, automation, environment, plant growth.

I. Introduction

Plants, a vital element of our survival, are gracing our world with their beauty, providing sustenance and nurturing the delicate balance of life on Earth. Not only it helps us by providing carbon dioxide, it also has an impact on economic growth. The more the plants are healthier and productive, the more economic growth rises. Starting from environmental sustainability, many sectors like ecosystem, biodiversity, climate change are somehow connected to plants.

The Smart Plant Monitoring System project intends to revolutionize plant care by tackling the fundamental issue of inefficient plant monitoring and care [1]. It is a system where we can detect the environment around a plant without doing any physical checking everyday. With the help of some sensors, it can measure some weather parameters such as temperature, humidity, moisture etc. Based on these, according to the need, it can water the plant.

It goes without saying how the plants are connected with everything and its importance; so, does the smart plant monitoring system. As by collecting environmental data, the smart system can distinguish the plant's current condition, it not only can water the plant when it's necessary, but also can protect it from over-watering or under-watering [2]. Monitoring will optimize the plant growth as well. Moreover, we can detect any problem in the early stage as we are observing the conditions from the beginning [3]. All of these will surely ensure the maximum productivity and efficiency. This is how this system can contribute to economic upturn and development.

II. Methodology

A. Hardware:

The microcontroller we have used for this project is NodeMCU ESP8266. The reason behind choosing this is that ESP is a cost effective IoT based controller that can connect to any network and send data to local or remote servers.

- Sensors:

a. Soil Moisture sensor : This sensor consists of a soil moisture detection probe and a module. The module is made up of 4 pins as GND, VCC for power and DO for digital data output and AO for analog data output, a mounting hole, induction sensitivity adjusting knob and external extension for dupont wires.

b. DHT11 Temperature and humidity sensor : this sensor is made up of 3 pins with the module. The three pins are VCC, GND for power and a data pin

- Output:

For the output we have a relay which will trigger a pump for autonomous irrigation. We have a 3v motor-based pump for controlling the water flow.

- Finally, we have used a 3.7v power system using a 18650 battery to power up everything and also supplying current to the pump.

Now let us have a look in data specification for the input sensors -

DHT11 Specifications:

- Operating Voltage: 3.5V to 5.5V
- Operating current: 0.3mA (measuring) 60uA (standby)
- Output: Serial data
- Temperature Range: 0°C to 50°C
- Humidity Range: 20% to 90%

- Resolution: Temperature and Humidity both are 16-bit
- Accuracy: ±1°C and ±1%

Soil moisture sensor specifications:

- Operating Voltage: 3.3V to 5V DC
- Operating Current: 15mA
- Output Digital - 0V to 5V, Adjustable trigger level from preset
- Output Analog - 0V to 5V based on infrared radiation from fire flame falling on the sensor
- PCB Size: 3.2cm x 1.4cm
- LM393 based design

B. Workflow:

Here we will have a look at how we will eventually develop the system and based on what workflow. Let us see a workflow diagram in Fig. 1 so that it is easy to understand our goals and expectations -

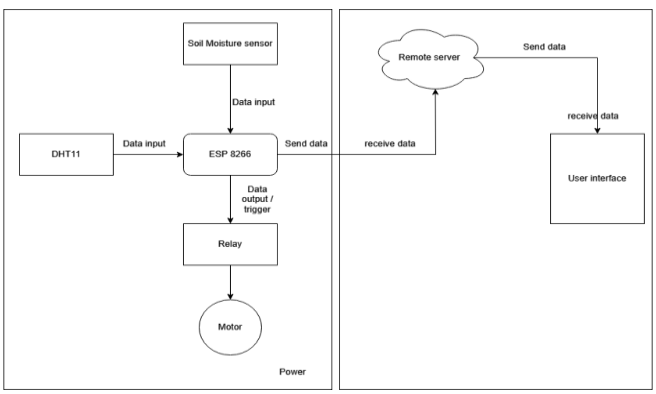

Fig. 1. Workflow of Smart Plant Monitoring System

Here we can see that the ESP will receive soil moisture data from the sensor and the environment data as temperature and humidity from the DHT11 sensor. Afterwards we will process the data and as output the relay will be triggered accordingly based on the needs of water and humidity to keep up better plant health. Besides, the ESP as a part of IoT will send the data to an open server where we will connect a Blynk application and dashboard for monitoring the data in real time.

C. Schematic Diagram:

Now let us build the system as a complete circuit so that everything works in sync. The circuit diagram in Fig. 2 is presented here as a schematic diagram:

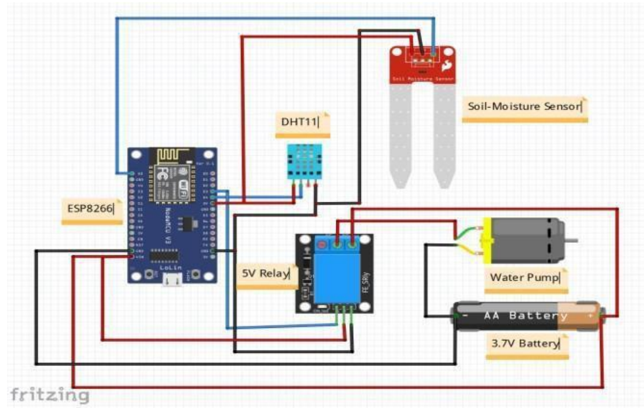

Fig. 2. Schematic Diagram of Smart Plant Monitoring System

D. System Design:

According to the schematic diagram the ESP8266 is powered up directly from the power source where the sensor's DHT11 and soil moisture sensor has been powered up from the ESP power output pins. The relay and the motor are also powered directly from the battery. And the two data pins from the respective sensors are connected to the pins D4 and A0 for DHT11 and soil moisture sensor respectively. The relay is connected to the ESP output pin D3. When the relay is triggered, it turns on the pump motor to deliver water to the plants.

E. Application Design:

For the user application part, we used the Blynk IoT app. The method we followed to create the app is demonstrated below:

a. Add Data streams
b. Create events
c. Create web dashboard using wizard
d. Add new device using template
e. Create SmartPhone Dashboard on Blynk IOT Application

A sample picture has been provided for better understanding in Fig. 3

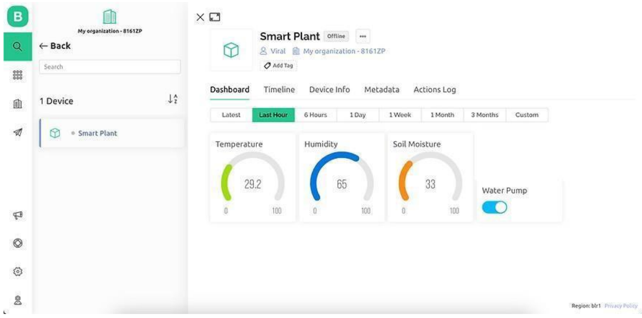

Fig. 3. BLYNK Software Implementation for Smart Plant Monitoring System

III. RESULT

To operate the system in optimal condition we set the minimum threshold of soil moisture level to 0% and the environment Humidity to 0% and 0 degree celsius. While operating in indoor conditions we observed that the system worked perfectly in most of the conditions but outdoors the system was 80% efficient compared to the indoor conditions.

IV. CONCLUSION

To conclude the observations from the effectiveness of the system we can notice that there are different conditions that affect efficiency. One of the major ones is the quality of the sensors. The sensor was not accurate in outdoor conditions and was providing some fluctuations due to the expanded scenarios. To overcome this problem, we can use industrial heavy-duty sensors for outdoor conditions.

As a part of our future work, we could concentrate on implementing one to improve the capabilities of the Smart Plant Monitoring System. We can integrate the ML algorithm in the project, gather a dataset of plant health indicators, such as environmental parameters like temperature, humidity, and soil moisture, as well as plant growth and health metrics. This dataset would be used to train the machine learning algorithm. The trained machine learning model can then be integrated into the existing system to deliver more sophisticated insights and recommendations. For instance, the ML algorithm may analyze historical data to determine optimal temperature and humidity ranges for various plant species. It might also deliver customized watering schedules depending on each plant's individual demands. Furthermore, the program might detect anomalies or departures from expected plant health and alert users to take corrective action.

We may improve the Smart Plant Monitoring System's capabilities in giving personalized recommendations, proactive plant care, and accurate monitoring of plant health by implementing a machine learning algorithm.

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Artificial Intelligence Applications in Microscopic Water Image Analysis: Object Detection and Segmentation

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Keywords: microscopic water image analysis, object detection, segmentation, machine learning, artificial intelligence.

I. Introduction

Microscopic water image analysis plays a vital role in various scientific and industrial applications, such as environmental monitoring, water quality assessment, and biological research. It provides valuable insights into the composition, structure, and behavior of microscopic entities present in water samples. Object detection and segmentation are fundamental tasks in this field, aiming to identify specific objects or regions of interest within an image. However, manual analysis is time-consuming and prone to human error. To overcome these limitations, the integration of artificial intelligence techniques has emerged as a powerful approach [1].

In this research, I aim to develop an automated system for detecting filamentous and non-filamentous objects in microscopic water images. By leveraging advanced artificial intelligence algorithms and techniques, I seek to enhance the accuracy and efficiency of object detection and segmentation. My focus lies in developing robust preprocessing methods and employing sophisticated mathematical concepts behind the algorithms as this area is still new and the contributions toward that are small [2].

To begin, I employ a series of preprocessing techniques, including Gaussian blur, channel splitting, thresholding, median filtering, morphological operations, and data augmentation. These methods enhance the images by reducing noise and improving their quality. By augmenting the dataset through different techniques, I increase the diversity of the data for more reliable analysis.

For object detection and segmentation, I utilize connected component labeling algorithms, which identify and label distinct objects or regions within the images. These algorithms analyze the connectivity and spatial relationships between pixels, facilitating the identification of individual objects and enabling subsequent analysis and characterization. I visualize the original images alongside the segmented regions, providing a comprehensive understanding of the distribution and arrangement of the detected objects [3].

Furthermore, I extend my research to incorporate segmentation, aiming to differentiate individual instances of objects in the images. By labeling and numbering each connected region as a separate instance, I enable more precise analysis. Techniques such as SLIC superpixel segmentation, contrast enhancement, and advanced image processing methods are employed to improve the accuracy and visual representation of the segmented instances [4].

Through the research, I strive to enhance the capabilities of microscopic water image analysis by automating the detection and segmentation of filamentous and non-filamentous objects. By providing insights into the microscopic world, my work contributes to the understanding of aquatic ecosystems and their inhabitants. The methodologies employed, including preprocessing techniques and the mathematical concepts behind the algorithms, will be detailed in subsequent sections. I also present the experimental results obtained, showing the effectiveness of my proposed approach. Ultimately, this research opens new avenues for applications and advancements in the field of microscopic water image analysis, benefiting environmental monitoring, and water quality assessment.

II. Proposed Methodology

I. **Image Preprocessing:** The first step in the proposed methodology is image preprocessing, which aims to enhance the quality and suitability of the microscopic water images for subsequent object detection and segmentation. The following techniques are employed:

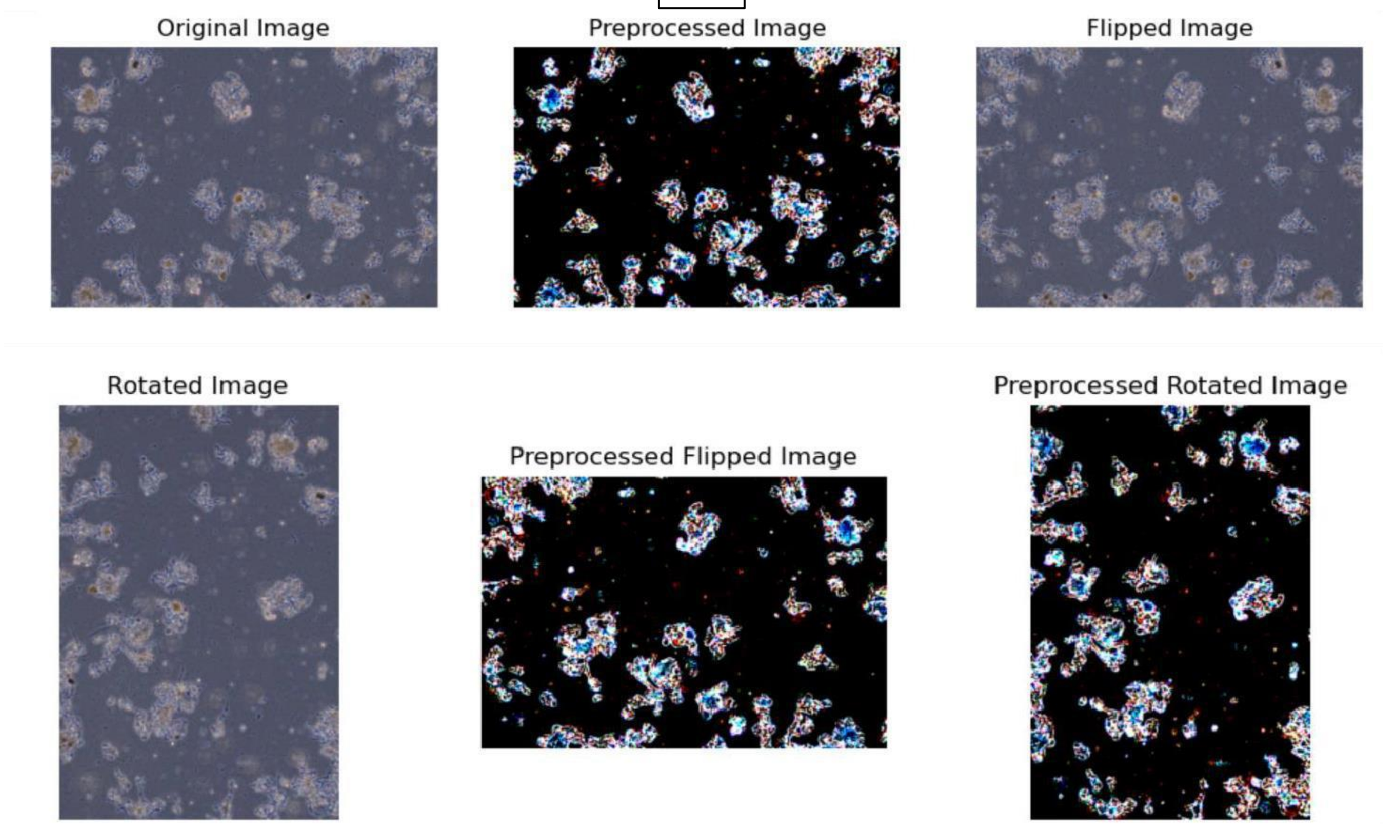
a) Gaussian Blur: Gaussian blur is applied to reduce noise and smooth out the image. This is achieved by convolving the image with a Gaussian kernel, which effectively blurs the pixel intensities.

$$\mathbf{B(x, y) = \Sigma\ (i, j)\ [\ I\ (x + i, y + j) * G\ (i, j)]}$$

*Gaussian Blur Convolution Equation.

b) Channel Splitting: The RGB image is split into individual color channels (red, green, and blue). This allows for independent analysis and manipulation of each channel, providing insights into the color-specific characteristics of the microscopic objects.
c) Thresholding (Otsu's Method): Thresholding is applied to convert the grayscale images into binary images, separating the objects from the background. Otsu's method is employed to automatically determine the optimal threshold value for binarization.
d) Median Filtering: Median filtering is utilized to reduce salt-and-pepper noise and further enhance image quality. By replacing each pixel with the median value in its local neighborhood, the filtered image becomes smoother and less affected by random noise.
e) Morphological Operations: Morphological opening and closing operations are performed to remove noise and refine the objects' shapes. Opening helps in removing small, unwanted details while closing helps in closing gaps and joining fragmented regions [5].
f) Normalization: Image normalization is applied to enhance the contrast and adjust the dynamic range of pixel intensities. This ensures consistent and standardized image representation across the dataset.
g) Rotation and Flipping: Data augmentation techniques such as rotation and flipping are utilized to increase the dataset size and improve the model's robustness. These operations introduce variations in the image orientation, enabling better generalization and detection performance Figure (A).

(A)

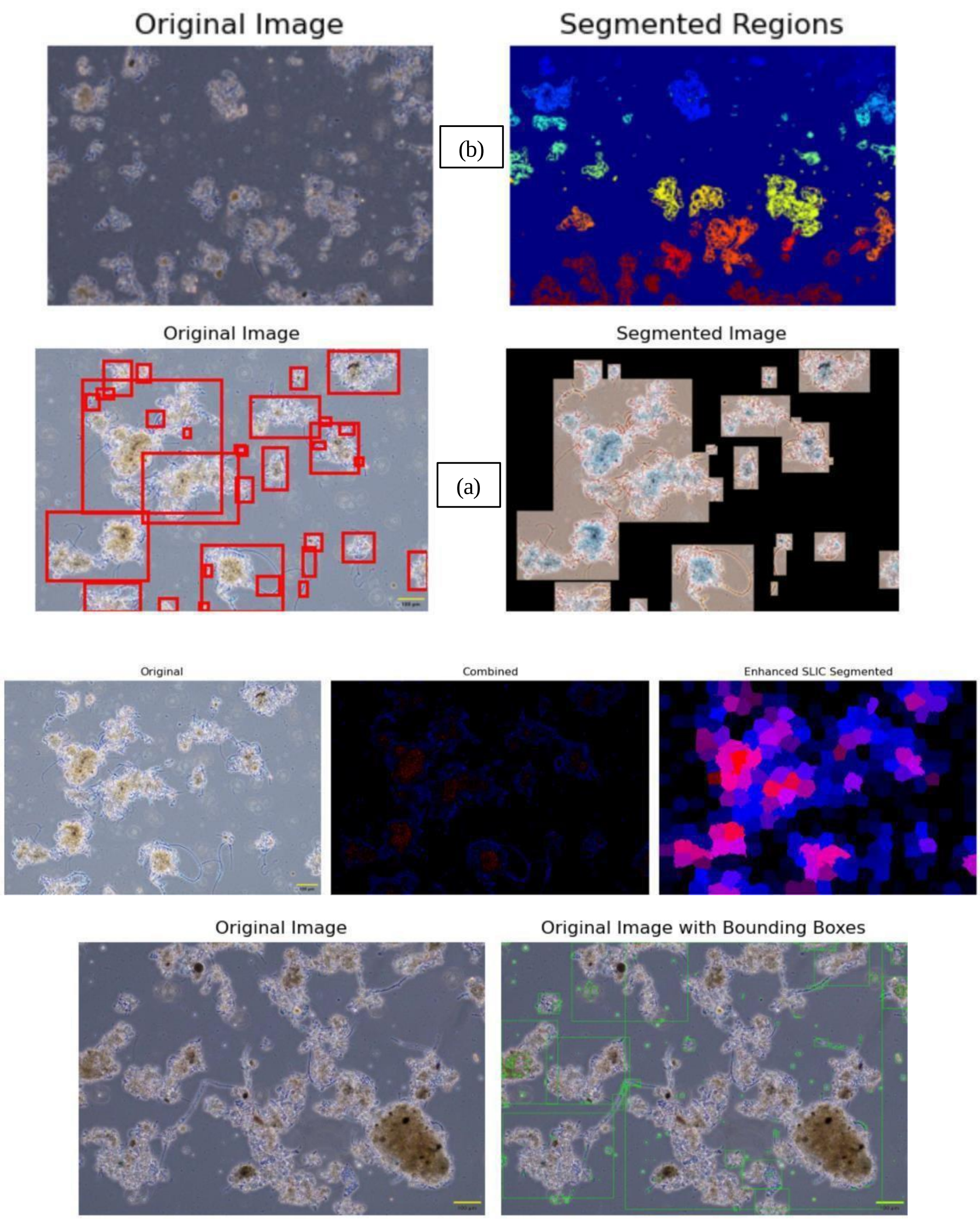


III. Experimental Results

Following the preprocessing stage, object detection, and segmentation algorithms are applied to identify and delineate objects within the microscopic water images. The methodology incorporates the following steps:
Connected Component Labeling: Connected component labeling is employed to identify, and label connected regions in the binary images. This algorithm assigns a unique label to each connected region, enabling subsequent analysis and characterization.
Visualization and Bounding Box Detection: The original image is displayed alongside the segmented regions, providing a visual representation of the detected objects. Bounding boxes are drawn around larger segmented objects to highlight their spatial extent and facilitate further analysis. Instance Segmentation: In addition to object detection and segmentation, the proposed methodology extends to instance segmentation, which aims to differentiate individual instances of objects within the images. The following steps are undertaken:
a) Connected Component Labeling for Instances: Like the object detection and segmentation phase, connected component labeling is performed to identify and label individual instances within the segmented regions. Each instance is assigned a unique label, allowing for more detailed analysis and characterization.

b) Visualization and Analysis: The original image and segmented regions with labeled instances are displayed, providing a comprehensive understanding of the distribution and arrangement of the detected objects. The number of segmented instances is evaluated, contributing to quantitative analysis, and providing insights into population dynamics.

Integration of Artificial Intelligence Techniques: Throughout the proposed methodology, various artificial intelligence techniques are utilized to enhance the accuracy and efficiency of the image analysis processes. These techniques include machine learning algorithms, and computer vision methodologies, which leverage the power of AI to automate and optimize object detection Figure (a), (c), and segmentation Figure (b).



(c)

IV. CONCLUSION

In conclusion, this research paper presents a comprehensive methodology for object detection and segmentation in microscopic water images. The developed approach successfully detects and delineates objects of interest, enabling quantitative analysis and enhancing the understanding of water ecosystems. The automated nature of the methodology reduces manual effort and subjectivity, making it a valuable tool for environmental analysis and monitoring. The results demonstrate the efficacy of the proposed approach and highlight its potential for advancing research in the field of water ecology. Future work could involve further refinement of the algorithms, integration of IoT, integration of advanced machine learning techniques, and application to larger and more diverse datasets to expand the scope and applicability of the methodology.

V. DATA AVAILABILITY & ACKNOWLEDGEMENT

The data used in this research is privately owned and cannot be shared due to confidentiality restrictions. Images are owned by Veolia Water Technologies and Solution ©. This study was supported by the GWF (Global Water Futures) program. I worked on this project under the Civil Engineering Department, Faculty of Engineering, McMaster University, Canada.

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IoT enabled smart garden using Raspberry Pi

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***Abstract* - The IoT-enabled smart garden system presented in this paper aims to revolutionize home gardening by offering convenient control and monitoring capabilities through a smartphone interface. The system incorporates various sensors to measure crucial environmental parameters such as air humidity and temperature, ensuring optimal growing conditions for plants. Additionally, light is utilized to generate heat, and a motor-driven water pump efficiently delivers water to the soil. To further enhance water management, a water sensor is employed to detect soil moisture levels, allowing for efficient irrigation and mitigating the impact of rainfall. The proposed smart garden system leverages the power of Raspberry Pi, enabling seamless connectivity using the MQTT (Message Queuing Telemetry Transport) protocol and automation. By harnessing IoT technologies, this innovative solution empowers users to easily manage their gardens and promote sustainable practices.**

I. INTRODUCTION

Home gardening has long been a valued pastime, offering individuals the opportunity to manage their own green space and enjoy the beauty and benefits of plants. However, traditional horticultural methods are labor intensive and time consuming, making it difficult to maintain optimal growing conditions and manage irrigation efficiently. The advent of Internet of Things (IoT) technology has ushered in a new era of smart gardening, changing the way we interact with and care for our gardens. This document describes an IoT-enabled smart garden system that leverages advanced technologies such as Raspberry Pi and sensor networks to provide seamless control and monitoring capabilities through a smartphone interface.

The main goal of this research is to revolutionize home gardening by developing smart gardening systems that simplify control and improve monitoring, making gardening more accessible and rewarding for individuals of all experience levels. The proposed system includes various sensors that measure important environmental parameters such as humidity and temperature, ensuring ideal growing conditions for plants. By continuously monitoring these parameters, gardeners can make informed decisions and adjust settings to optimize plant health and growth.

Water management is a major challenge in horticulture, as too much or too little water can adversely affect plants. To address this issue, smart garden systems integrate motor-driven water pumps that efficiently pump water into the soil based on user-defined settings. In addition, water sensors are used to detect soil moisture levels, enabling precise irrigation control and reducing the effects of rainfall. This intelligent approach not only conserves water resources, but also promotes overall garden health and sustainability.

Central to the functionality of the smart garden system is the Raspberry Pi, a versatile single- board computer. The Raspberry Pi acts as the brain of the system, allowing data acquisition, analysis, and communication with connected sensors and actuators. The system uses the MQTT protocol, a lightweight messaging protocol widely used in IoT applications, to enable seamless connectivity and efficient communication between smart garden systems and users' smartphones. This integration allows users to easily control and monitor their garden anytime, anywhere through a dedicated smartphone application. By using IoT technology, the proposed smart garden system offers many advantages. Users can conveniently manage their gardens, receive real-time updates on environmental conditions, and make informed decisions to optimize plant growth. The automation and intelligence built into the system reduces the burden of manual intervention and makes gardening easier for people of varying experience levels. Additionally, smart garden systems contribute to sustainable horticultural practices by promoting efficient water use and providing actionable insights.

The following sections of this document detail the detailed architecture, sensor integration, actuator control, IoT communication, user interface design, experimental results, and discuss the potential benefits and future impact of IoT-enabled smart garden systems. With this research, we aim to provide gardening enthusiasts with easy-to-use and efficient solutions that enhance their gardening experience, promote sustainable practices, and nurture natural beauty in their homes.

II. SYSTEM ARCHITECTURE

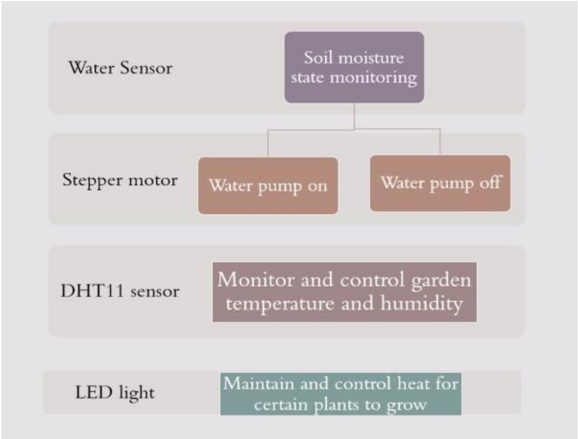

Fig 1. System Flow Chart

The Hardware was put together. The parts were connected as shown in the circuit diagram.

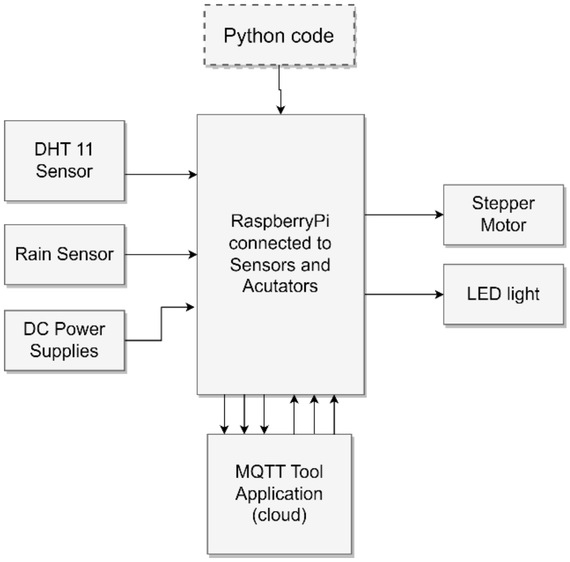

Fig 2: Architectural diagram

The parts were soldered, or connectors were utilized wherever necessary. It is essential to make sure that the power connections and grounding are correct.

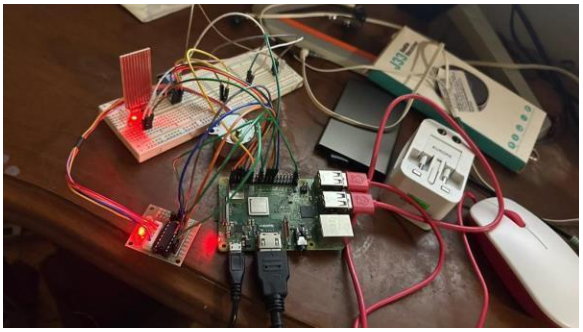

Fig 3: Hardware Setup

1. Constructed the Housing: Created or selected an appropriate housing for our intelligent garden system. Things like enclosure size, weather resistance, and ease of repairs were kept in mind.

2. Installed and calibrated the sensors. To get accurate data, position the temperature and humidity sensor (DHT11) in a suitable area. When needed, calibrated the sensor. Installed

the water sensor in the soil at the proper depth for precise moisture detection.

3. Test and Debug: Switched on the system and checked the operation of each component separately and collectively. Checked the motor movement, LED control, sensor readings, and MQTT communication. Debugged any problems that appeared.

4. Implemented Automation and operations: Created logic in the firmware or software to automate LED lighting depending on environmental factors, operated the watering stepper motor based on moisture levels, and sent and received data using MQTT for remote monitoring and control. Automation here was done using Python code.

5. User Interface Development: Designed an interface that allowed users to access and manage the smart garden system. This was a mobile application or a web-based interface that talked with the MQTT broker.

6. Deployment and Monitoring: Kept an eye on it and assessed how it performed. Based on comments and observations, changed when necessary.

III. EXPERIMENTAL RESULTS

Initialized the Raspberry Pi and established connectivity with the IoT platform and smartphone application. Configured the sensor modules, including air humidity and temperature. Placed the actuator modules, such as the motor-driven water pump and light sources. Continuously monitored the environmental parameters using the installed sensors. Retrieved air humidity and temperature readings to assess the atmospheric conditions around the garden. Gathered soil moisture data from the soil moisture sensors to determine the watering needs of the plants.

Based on the collected data, made decisions regarding actuator control to optimize plant growth and water management. Used the water sensor readings to determine the soil moisture levels and adjusted the watering schedule accordingly. Activated the motor-driven water pump to deliver water to the soil when the moisture levels were below the desired threshold. Utilized the light sources to generate heat within the garden environment, promoting optimal temperature conditions for plant growth.

Established a connection with the IoT platform using the MQTT protocol to transmit data and receive commands. Sent real-time sensor data, such as air humidity, temperature, and soil moisture readings, to the IoT platform. Received control commands from the smartphone application to adjust actuator settings, such as irrigation schedules and lighting control.

Provided a user-friendly smartphone application for users to access and control the smart garden system. Allowed users to visualize sensor data, adjust settings, and monitor the status of the garden remotely. Enabled users to set preferences, schedule watering, and receive notifications or alerts regarding the garden's condition. Implemented error handling mechanisms to detect and handle sensor or actuator failures. Provided maintenance functionalities to calibrate or replace sensors, troubleshoot connectivity issues, and ensured system reliability.

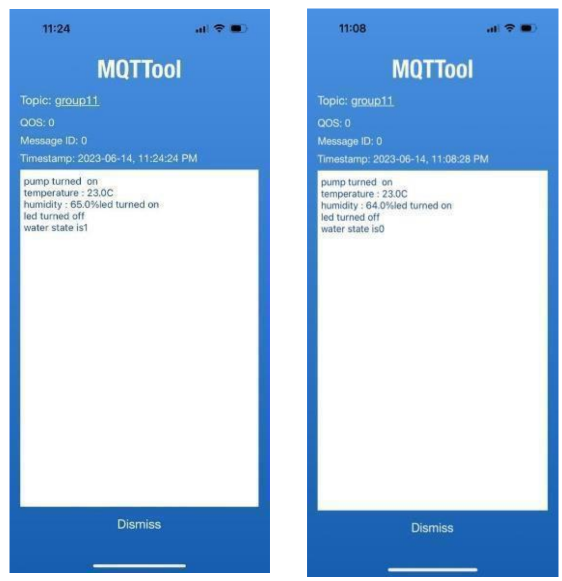

Fig 4: Results published to MQTTool

IV. CONCLUSION AND FUTUREWORKS

The IoT-enabled smart garden system presented in this project offers an innovative and efficient solution for home gardening, leveraging the power of IoT technologies and Raspberry Pi. The system provided convenient control and monitoring capabilities through a smartphone interface, revolutionizing the way individuals interact with and nurture their gardens. Through the integration of various sensors, including air humidity, temperature, and soil moisture sensors, the smart garden system ensured optimal growing conditions for plants. Real-time data collection and analysis empower users to make informed decisions, adjust settings, and optimize plant health and growth. The incorporation of a motor-driven water pump and light sources further enhanced water management and temperature control within the garden environment. By harnessing the MQTT protocol and seamless connectivity, the smart garden system enabled remote access and control via the IoT platform and smartphone application. Users can effortlessly manage their gardens from anywhere, at any time, ensuring that plants receive the necessary care and attention. The experimental results have demonstrated the system's effectiveness in monitoring environmental parameters, managing water resources, and promoting plant health. Users have benefited from the convenience, automation, and real-time insights provided by the system, facilitating an enjoyable and rewarding gardening experience.

Furthermore, the smart garden system contributes to sustainable practices by optimizing water usage and reducing manual intervention. The integration of IoT technologies not only enhanced the efficiency of home gardening but also promotes environmental responsibility.

Looking ahead, there are several areas for future exploration and improvement. The system can be enhanced by incorporating additional sensors to measure parameters such as light intensity, soil nutrient levels, or pH levels, enabling even more precise control and monitoring. Integration with weather forecast data could further optimize watering schedules based on predicted rainfall. Additionally, the system can be expanded to support multiple garden zones or plant types, providing tailored care for different plant species.

This project serves as a steppingstone towards a future where smart, connected gardens are the norm, fostering a harmonious relationship between humans, technology, and nature.

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Automated Car Wash System

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Keywords—Cyber Physical Systems, Internet of Things, Raspberry PI, Blynk, Cloud

I. INTRODUCTION

In today's interconnected world, the convergence of technology and physical processes has given rise to transformative systems known as Cyber-Physical Systems (CPS). CPS seamlessly integrate embedded computation, networking, and physical processes, creating a dynamic environment where the digital and physical realms intersect. These systems rely on a feedback loop involving sensors, actuators, and human intervention to monitor and control various processes.

CPS operate through a sophisticated network of sensors and actuators, forming a dynamic feedback loop that enables real-time monitoring, control, and response. This synergy between intelligent devices and human intervention creates a powerful framework that enhances efficiency, productivity, and decision-making across diverse domains. By harnessing the potential of CPS, industries can optimize processes, improve safety and reliability, and unlock new frontiers in automation and smart systems.

Parallel to CPS, the Internet of Things (IoT) has gained considerable attention as a transformative force in our connected world. The IoT encompasses a vast array of physical devices scattered globally, interconnected through the internet. This network enables devices to communicate, share data, and collaborate, creating an unprecedented level of interconnectedness and accessibility. Forecasts indicate that the IoT market is poised for exponential growth, with projections reaching a staggering $11.1 trillion annually by 2025 [1].

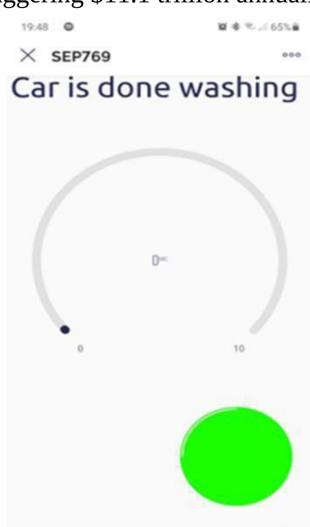


Figure 1 User Interface of Blynk

Throughout this research paper, we will investigate the integration of CPS and IoT, analyze their transformative impact on various sectors, and delve into the challenges and opportunities to further work on the system and make it efficient.

II. CONTENTS

A. *Components Used*

The components used in this project are as follows:

Raspberry PI 4, Camera Module, Servo motor, water pump, ultrasonic sensor, LCD, LED, Relay and Power module

B. *Working*

The project has been divided into 3 Phases. The working diagram and flowchart are shown in figure 2 and 3 respectively.

1. The Camera is switched on for car detection. As a car approaches the entrance of the Car Wash, the camera detects the car and opens the entry barricade while also turning the LED light to green.
2. During this phase, the car enters the wash area, the entry barricade comes down and the entry LED turns Red. The ultrasonic sensor switches on meanwhile the LCD displays movement instructions to the driver to either back up or come forward to reach the appropriate position for the wash. Once the car is at the desired position, the washing process starts and the pump drains water from a water source onto the car. This goes on for 10 seconds. Once the washing process is done, the drying starts and then goes on for another 10 seconds.
3. Once the drying is complete, the LCD displays the message of process completion, exit barricade opens and the exit LED turns green. Once the car has exited the wash, the exit barricade closes, and the exit LED turns red back again. Then the whole process starts for the next car waiting in line.

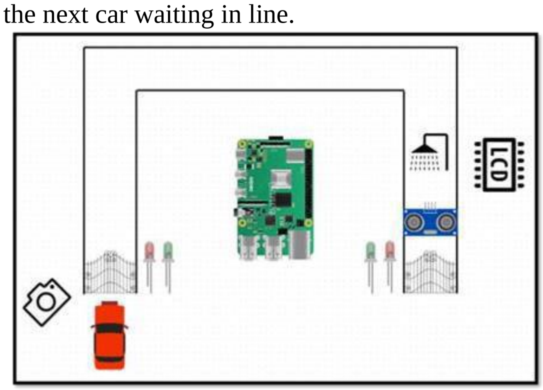


Figure 2 Working Diagram

C. Cloud Platform

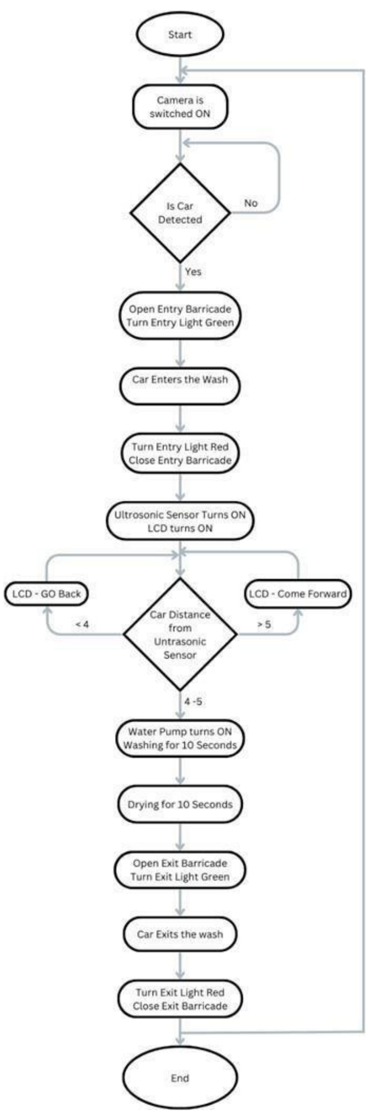
This project uses the Blynk cloud platform. Blynk is an IoT platform for iOS or Android smartphones that is used to control Arduino, Raspberry Pi and NodeMCU via the Internet. This application is used to create a graphical interface or human machine interface (HMI) by compiling and providing the appropriate address on the available widgets [2]. Both the Web and Mobile User Interface is used to send information about the stats of the car wash process to the user in real time. The user interface is shown in fig. 1.

D. Applications

Commercial Car Wash Centers: Automated car wash systems are commonly used in commercial car wash centers to provide efficient and convenient car cleaning services to customers.[3]

Automotive Manufacturing Facilities: In automotive manufacturing plants, automated car wash systems are utilized to clean vehicles during the production process, ensuring cleanliness and removing contaminants before further assembly or painting [4].

Fleet Maintenance: Automated car wash systems find applications in fleet maintenance operations, where they are used to efficiently clean and maintain a large number of vehicles, such as taxis, rental cars, or delivery trucks [5].



E. Challenges

Implementing cloud on Blynk and designing GUI: Integrating Blynk with Raspberry Pi to connect and control the system remotely. Designing a graphical user interface (GUI) that is user-friendly and allows easy interaction with our project's features.

Limited number of GPIO pins on Raspberry Pi: Raspberry Pi has a limited number of General-Purpose Input/Output (GPIO) pins available for connecting external devices. This limitation poses a challenge when connecting multiple components/sensors that require GPIO pins for communication.

Configuring relay to connect it with water pump: Configuring the relay correctly and connecting it according to its datasheet to ensure it can handle the voltage and current requirements of water pump.

Battery power supply to run the water pump: Ensuring the battery is appropriately sized to meet the power demand of our water pump and designing a circuit to regulate and manage the power supply effectively.

F. Future Work

An improvement to the camera module could be the implementation of object detection. In the current implemented process, the camera switches on for 5 seconds and then switches off.

Object detection can be modelled in a way such that the camera stays on till the car is detected by the program and then the entire process starts.

The system can be integrated to successfully identify registered customers through their license plates and charge for the service accordingly, which would save time and make the process efficient.

III. Conclusion

With this prototype, we explored an existing version of the Automated Car Wash System using the fundamentals of Electronics, IOT and Deep Learning. Various industries have implemented systems that further automate and dynamically control specific phases in the process such as washing and drying. Our system, having immense upgrade potential and numerous real-world use-cases, can improve businesses of organizations and contribute effectively to this rapidly growing technological world.

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Vehicle-mounted image acquisition device for infrastructure asset management.

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I. ***Keywords—Sidewalks Defects, Vehicle Mounted System, Image Processing, Machine Learning Algorithms, Infrastructure monitoring, inspection, Smart Cities.***

I. Introduction

Lack of sidewalk maintenance results in unsafe sidewalks **[1]**. For several applications, including travel convenience, safety, and urban sensing, efficient and economical data collection from smart cities, sensors are essential. However, to effectively utilize computer vision in these areas, efficient and cost-effective data collection methods are very crucial. Machine learning has been applied to automatically detect road defects **[2]**. Infrastructure asset management (IAM) is a challenging field where the acquisition of images of infrastructure assets is critical. Currently, IAM requires the use of photographs or videos taken to record information about the state of their infrastructure assets. This can be time-consuming and laborious, and it limits the rate of deferring issues with infrastructure assets. To address this issue, a vehicle-mounted image acquisition device is developed to automatically collect images of sidewalks for analysis. This project involves a low-cost method to collect sidewalk image data and different methodologies to label the dataset.

A. Project Overview

The aim of this project is to develop a vehicle- mounted image acquisition device for infrastructure asset management **[3]**. The device will utilize computer vision techniques to analyze images captured by a camera mounted on a vehicle. By deploying onboard processing, network connectivity, and cloud storage, we will create a system that can efficiently collect data, label the data for tagging sidewalk defects, and facilitate the understanding of infrastructure asset conditions.

B. Project Description

By leveraging the computer vision to understand infrastructure asset conditions using a vehicle- mounted camera deployed with onboard processing, network connectivity, and cloud storage. The hardware that will be employed as data mules can collect static and mobile sensor data, have access to roadside units and communicate the data to a cloud server. The data was collected by using high- resolution cameras mounted on the Robo Car assembly. This setup ensures optimal coverage of the sidewalk pavement and above-ground assets. To further enhance the data collection process, robust AI algorithms are employed , leveraging Raspberry Pi technology. This report involves the use of low- cost Robo car assembly hardware to collect data and methodologies to label and process the dataset. By using the effectiveness of ML (Machine Learning) algorithms **[4]**, **[5]** that implement computer vision and further increase accuracy in identifying significant features (potholes, signs, etc.). To optimize vehicle-mounted data collection, it is essential to explore the most effective hardware combination. This involves integrating additional sensors such as Vibration sensor, GPS sensor, High-Resolution Cameras, and more to enhance the comprehensive understanding of infrastructure conditions.

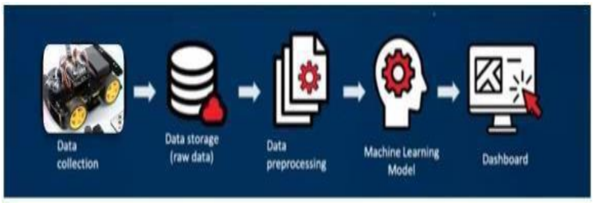

Figure 1. Data collection and Analysis Flow.

C. Objectives

The primary objectives of this project are as follows:

a. Development of a vehicle-mounted image acquisition device.

b. Design and implementation of computer vision algorithms for fault detection, identification, and localization of sidewalk defects.

c. Integration of vibration sensors with the device to enhance fault detection capabilities.

d. Training a neural network model to accurately classify and tag sidewalk defects.

e. Establishing a reliable network connectivity and cloud storage system for data transmission and storage.

II. Hardware Implementation

The following hardware components were used for the successful implementation of this project:

a. Raspberry Pi 4 (or higher) for onboard processing and network connectivity.

b. High-resolution camera module compatible with Raspberry Pi for image acquisition.

c. Vibration sensors capable of detecting road defects and communicating with the Raspberry Pi.

d. Storage device (e.g., microSD card) for data storage.

e. Power supply and necessary cables for connecting the components.

f. RC Robo car for camera mounting enclosure.

III. *Raspberry* PI *Enclosure Design*

The objective of the Raspberry Pi enclosure is to house and safeguard the Raspberry Pi board and the Pi camera module. Assuring that the components are neatly arranged and protected from outside factors, it offers a safe and portable solution.

We concluded that the enclosure depicted in Fig.1 is the most appropriate for our project's requirements after doing a thorough analysis of numerous designs. The selected enclosure design has various benefits as follows:

Precise fit and proper alignment: It is specifically made to fit the Raspberry Pi board and Pi camera module.

Accessibility: The Raspberry Pi's necessary ports and connectors are easily accessible thanks to the enclosure design, making connectivity and configuration easier.

Protection: The enclosure shields the delicate components from potential harm and unintentional collisions thanks to its strong design.

Mounting Options: The design includes mounting elements that make it simple to put the enclosure in a variety of configurations or settings, such as mounting it on a surface or attaching it to a tripod.

Figure 2. Raspberry PI and camera mounting model.

IV. Maintenance Standards

In this section, inspection standards are described. These standards were used in the classification of sidewalk defects. Based on Ministry of Transportation, Ontario, inspections shall be carried out as per MQS-551 [6]. The following defects shall be noted, and action taken according to the following standards. The ML Model in this project is working based on these three defects:

A. *Potholes*

- Potholes in concrete surfaces exceeding 20mm in depth shall be repaired within 3 days.
- Potholes are dents or holes in the concrete pavement surface.
- Pothole(s) with an area of 0.04m2 (i.e.,200mm x 200mm or 100mm x 400mm) or greater and a depth greater than 50mm shall be repaired within the timeframe of 3 days.
- Pothole(s) with an area of 0.04m2 (i.e.,200mm x 200mm or 100mm x 400mm) or greater and a depth from 25mm to 50mm shall be repaired within the timeframe of 7 days.

B. *Cracking*

- Corner cracks usually form a triangle with a transverse joint or a crack either at the center line or at the edge of the Travelled Portion.
- Cracks or raveled areas more than 40mm wide at joints shall be Reported to the District Office.
- Cracks in asphalt wider than 25mm shall be repaired within 14 days.
- Cracks in concrete wider than 6mm shall be Reported to District Office.

C.*Distortion*

- Distortions are any deviations of the concrete pavement surface from its original profile. These defects usually take the shape of a bump or depression and are noticeable in a moving vehicle.
- Bumps and depressions with a vertical differential of more than 50mm over 3m shall be Reported to the District Office.
- Slab by more than 100mm, shall be signed upon Detection and Reported to the District Office.

V. ALGORITHMS used & Roboflow

The crack and dent detection algorithm incorporates state-of-the-art computer vision techniques, such as deep learning and object detection methods, to automatically identify and localize defects in various surfaces. This algorithm efficiently reduces the need for manual inspection, ensuring swift and accurate detection of safety hazards and quality issues.

RoboFlow [7] significantly contributes to the crack and dent detection process by pre-processing and annotating large datasets of images, enabling the algorithm to learn from diverse examples and excel at recognizing defects in real-world scenarios. Its data management capabilities and model optimization techniques ensure that the algorithm achieves high precision and recall rates in detecting cracks and dents.

The seamless integration of RoboFlow with the algorithm streamlines the development and deployment process, resulting in an accurate and reliable defect inspection system that enhances safety and productivity across industries.

VI. CONCLUSION

In this paper we have proposed a solution of vehicle-mounted image acquisition device for infrastructure asset management. By using low cost hardware and advanced computer vision technique, our system effectively gathers image data from sidewalks. We accurately identified sidewalk defects and important features using machine learning methods in accordance with MQS-551 regulations.

By integrating real-time data analysis and cloud storage, our solution enables faster and informed decision-making for infrastructure maintenance. The proposed Raspberry Pi enclosure safeguards the components while ensuring easy accessibility.

Our work showcases the potential for technology to enhance infrastructure management, leading to safer and more efficient urban environments. Future efforts involve refining algorithms and conducting field trials for real-world validation. Embracing smart data collection can transform infrastructure maintenance and improve travel experiences for all.

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Suspension Energy Harvester Prototype

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Introduction

Current suspension systems excel in optimizing tire-road contact, increasing dynamic stability, and optimizing passenger comfort. However, to do this, the suspension system dissipates energy using dampers to remove unwanted vibration. Quarter car simulations show that modern passenger vehicles traveling on poor road surfaces at 13.4 m/s dissipate approximately 200 watts of energy from one damper alone [1]. In acknowledgement to this problem, the purpose of this research is to develop a prototype that can amplify vibrational energy on the lower control arm (LCA) using the physical phenomenon of mechanical resonance modes. This energy is then transduced to supply and store energy in a 12V auxiliary battery using linear electromagnetic induction through supporting power electronics.

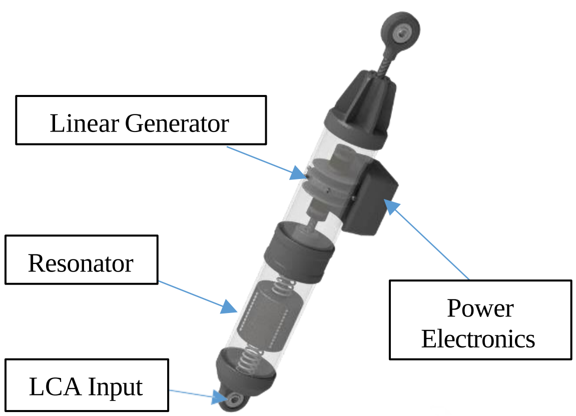

Figure 1: CAD Model of Damper

I. CONTENTS

A. *Technical contents*

The main objective of this research is to generate an output voltage of 14V DC to power a vehicle's auxiliary battery during average driving situations. For this to be accomplished, the system's efficiency must be optimized in the frequency range of 13-22Hz [2] on the LCA. When using techniques such as linear electromagnetic induction, operating efficiently in low frequency ranges can be difficult, especially as these frequencies lack the required vibration amplitudes and velocities to achieve high voltage outputs.

To increase the effectiveness of power generation, the development of a tuned M and K system (mass spring system) can be applied to increase the output velocity and displacement during average road conditions through mechanical resonance. When evaluating the mounting point on the LCA as a base excitation model problem, the application of the amplitude ratio can be used to showcase the increase in output with respect to the input.

Amplitude Ratio (Base Excitation): $\frac{x}{y} = \sqrt{\frac{4\xi^2 r^2 + 1}{(1-r^2) + 4\xi^2 r^2}}$ (1)

The intentional tuning of $r = \frac{\omega}{\omega_n} = 1$ can be completed through the manipulation of the natural frequency of the system.

Natural Frequency: $\omega_n = \sqrt{\frac{k}{M}}$ (2)

By setting the $\omega_n = 15Hz$ as a design constraint, the expected operational LCA frequency range will fall between 13Hz to 22Hz. As a result, the theoretical displacement ratio (y-axis – Figure 2) increases in range of $0.866 < \frac{\omega}{\omega_n} < 1.46$ (x-axis – Figure 2).

To verify this phenomenon, calculation and simulation of the system response was completed at various frequency ranges to showcase the increase in displacement but more importantly the increase in output velocity (Figure 3).

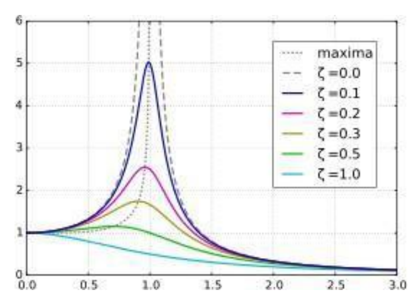

Figure 2: Steady State Variation of Amplitude with Relative Frequency

As the magnet output velocity is increased relative to the coil, electromagnetic induction is more efficient, thus generating more voltage in the system.

However, more damping can be expected as a result of the attached electromagnetic generator because of kinetic energy to electrical energy transduction.

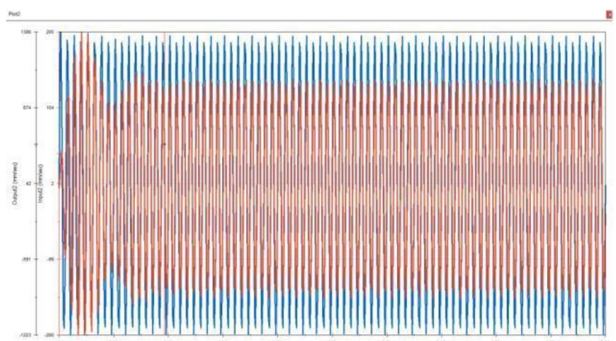

Figure 3: Air Damping Applied at 16Hz LCA Input.

Now that the harvester can manipulate the output frequencies to support optimal electromagnetic generation, it becomes critical to analyze Faradays law, (Equation 3), to ensure the generator is designed effectively.

$$\text{Voltage Generated} = -N\frac{\Delta(BA)}{\Delta t} \quad (3)$$

Faradays law demonstrates that induced voltage through electromagnetic induction is directly proportional to the number of coil turns and the change of magnetic flux [3]. From this understanding, the primary focuses of the generator design becomes the appropriate selection and arrangement of the magnets and coils.

To achieve high voltage outputs, the choice and placement of magnets should prioritize optimal field strength exposure to surrounding conductors during relative movement. Taking this into account, this design utilizes 4 radial Neodymium magnets as the primary source of generation, specifically due to its rare earth metal characteristics and ideal pole orientation (Figure 4).

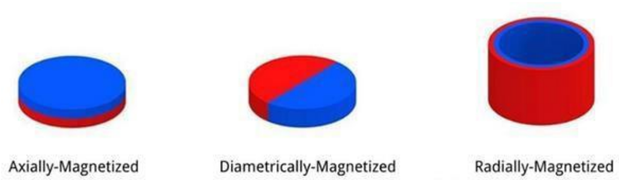

Figure 4: Magnet Configurations

Regarding the magnet arrangement, radial magnets are stacked with opposing polarities to establish a stronger magnetic field for the conductors to interact with. Additionally, axial magnets are positioned both above and below the radial magnet stack (Figure 5) to generate additional voltage and enhance safety measures, particularly when dealing with excessive oscillations. To address this concern, two axial magnets are placed on the top and bottom of the generator housing with the purpose of repelling the axial magnets on the radial magnet stack. This way, major oscillations could be dealt with, and momentum can be maintained within the system.

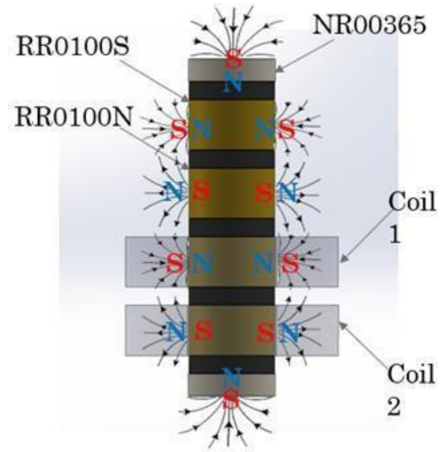

Figure 5: Magnet Arrangement Diagram

Coil windings in this linear generator design utilize two sets of 28-guage copper wire, primarily due to its excellent conductivity and small cross-sectional diameter. The use of a small cross-sectional diameter ensures minimal space is occupied per turn, allowing for a higher number of turns within the available area (Figure 6). Furthermore, the number of coil windings is deliberately outnumbered by the number of magnets. The rationale behind this decision is to ensure that all magnets can pass through the coil twice per sequence and their AC currents are in phase.

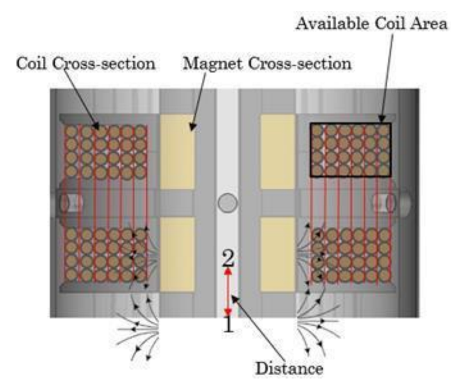

Figure 6: Coil Area Cross-Section

The electrical energy generated will be in the form of alternating current. The power electronics circuit will need to rectify the AC current to ensure a clean electronic signal to the point where the system can output 14V DC.

A key component to smooth rectification is the use of a switching power supply. Switching power supplies use pulse width modulation to control the average power delivered by the input signal and are designed for high efficiency and small size. They incorporate a switching regulator to convert electrical power efficiently. Switching DC power supplies regulate the output voltage through a process called pulse width modulation (PWM). This allows for the use of rectifier bridges and buck/boost converters which are key to the functionality of our power electronics system. [5] They are ideal for high frequency output which is ideal within our design given the space constraints and the need for frequency amplification.

The rectification circuit is the primary element of the PCB board. The rectifier in the circuit is comprised of 4 diodes arranged in a Full-Wave Diode Bridge configuration producing a positive AC output. The capacitor acts as the filter in this circuit by reducing the noise of the signal and filters the signal resulting in a DC output. The goal was to use the least number of components possible to improve efficiency and reduce the number of voltages drops throughout the circuit.

Voltage regulation is key for the functionality of a buck-boost converter. Buck-boost converters are devices that can step-up and step-down voltages using PWM and induction. The buck boost converter can receive a wide variety of input voltages and produce an output. Based on this feedback voltage value the PWM duty cycle for the built-in N-Channel MOSFET is adjusted to control the output voltage.

The final design objective was to fit all electronics to one PCB while using the space as efficiently as possible while eliminating excessive wiring or breadboards. The functionality of the pulse width modulation capability allows for reduction of size of the power supply. This can be achieved by increasing the power density which is possible by decreasing the size of the passive/energy storage components such as the inductors, capacitors. We can also decrease the size of these components by increasing the switching frequencies. Compared to linear power supplies a switch power supply uses much smaller magnetic systems versus the large transformers and heat sinks present in linear power supplies.

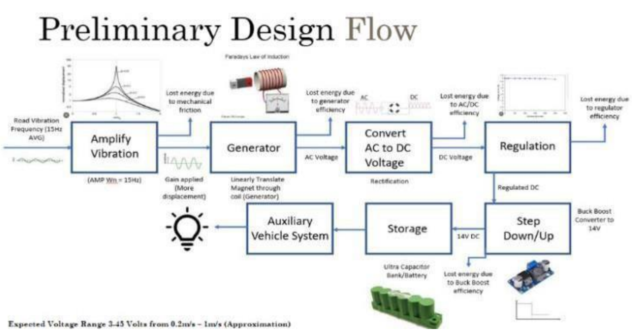

Figure 7: Power Electronics Design Diagram

*B. **Conclusion***

The paper proposes a potential solution to recapturing and optimizing the mechanical vibrations received by the LCA to convert into electrical energy. The research provided highlights a proposed prototype which amplifies frequencies in the range of 13-22Hz [2], generates AC electrical voltage through electromagnetic induction, and converts generator AC to usable DC power for the auxiliary systems. Potential applications include implementation in EVs (Electric Vehicles) for range extension and power supplementation which would otherwise be taken from the PPS (Peak Power Source) of the vehicle.

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