DESIGN AND CONSTRUCTION OF A CROWD DENSITY ESTIMATION DEVICE

BY

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(2018/7144)

BELLS UNIVERSITY OF TECHNOLOGY, OTA

JULY, 2023

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A Project Submitted to the Department of Mechatronics Engineering, College of Engineering, Bells University of Technology, Ota in Partial Fulfilment of the Requirements for the Award of Degree of Bachelor of Engineering (B.ENG) in Mechatronics Engineering.

JULY, 2023

DECLARATION

I, hereby declare that this project was carried out by me under the supervision of Dr. Philip. A. Adewuyi of the Department of Mechatronics Engineering, Bells University of Technology, Ota, Ogun State, Nigeria. I attest that the project has not been presented either wholly or partially for the award of any degree elsewhere. All sources of data and scholarly information used in this Report are duly acknowledged.

....

Nwaubani Chizitere Nkenna

Date:……………………………….

CERTIFICATION

I certify this project titled ‘‘**DESIGN AND CONSTRUCTION OF A CROWD DENSITY ESTIMATION DEVICE**’’ is a project work carried out by **NWAUBANI CHIZITERE NKENNA** in the Department of Mechatronics Engineering, College of Engineering under my supervision. I have examined it.

…………………………….. ……………………………..

Dr Philip. A. Adewuyi Date

(Supervisor)

……………………………… ………………………………

Dr. Philip. A. Adewuyi Date

(Head of Department)

DEDICATION

I dedicate this project to the almighty God for the privilege given to complete my B Eng. degree.

ACKNOWLEDGEMENTS

I am hereby acknowledging the Vice-Chancellor Prof. Jeremiah O. Ojediran, the dean of college of engineering Prof. Ojo S. Fayomi and the entire management staff of Bells University of Technology for creating an enabling environment to carry out my project. My supervisor and head of department of mechatronics engineering, Dr. Philip. A. Adewuyi is also appreciated for his push and relentless efforts that helped to carry out this research and accomplished it in due time. Too numerous to mention are my course mate. I appreciate you all for standing by me all through the period of the programme.

To my caring parents, Mr & Mrs Nwaubani you are deeply appreciated for all support and encouragement all through the period of this programme. I appreciate all you have done for me, and may the almighty God continue to reward you.

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ABBREVIATIONS

IR-LED:	Infrared-Light Emitting Diode
BMS:	Battery Management System
LI-Ion:	Lithium-Ion
IOT:	Internet of Things
WiFi:	Wireless Fidelity

ABSTRACT

The human population is estimated to be above eight billion people. Human beings are social entities and then to move alone or in groups. Due to their behavioural patterns, humans gather together for different purposes like political rallies, music festivals, conventions, seminars and a lot of other reasons. This coming together and co-existence lead to there being a crowd of people. The gathering of a large crowd of people can usually become unruly and disturbing is there is no existence of trained crowd management system, it can lead to mass panic, stampede, pushing and crowd-crush which causes a control loss, accident, destruction of properties and even death. Crowd estimation and management techniques have resulted to prevent bad situations from occurring and the advancement of modern day technologies different techniques have been developed for crowd estimation, one of them is being discussed as a project topic. This project proposes the design and construction of a crowd density estimation device. The proposed system would consist of esp8266 NodeMCU open-source development board which has an ESP8266 wifi module, this board is for the designing of the ‘internet of things’. It also consist of an IR-LED sensor for accurate crowd density measurement. A channel relay module which protects the microcontroller from higher voltages. The ubidot is employed to control and automate the crowd density estimation. The site receives the data of number of visitors going into an enclosed area, the number of visitors already in the area and the number of visitors moving out of the area. Overall, this project presents a viable solution to the pressing issue of crowd density management and can be further developed and improved for commercial use.

Word Count: 288

Keywords: Ubidot, crowd, wifi, density, internet-of-things, NodeMCU, visitors, design, construction.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

A major difficulty experienced by individuals and organizations include amidst others, crowd density estimation. Crowd density is defined as the number and distribution of people within a specified geographical area at a given point in time. Crowd density estimation is the act or process of determining the number of individuals within a given area at a given point in time. In the days of old, Crowd density was estimated using a principle called Jacob’s method. When an area is divided into smaller sections, determining the population density in each one and calculating the average density allows one to infer the average population density of the entire area using the average density that has been calculated. One person per 0.25 square meters is already two mosh-pit densities according to Jacob's Method classification (Khalifa et al., 2022).

In recent years, researchers have been attempting to develop better systems that will solve this issue of crowd density. Convolutional neural network (CNN) is used to determine a more estimated density of people in public places. It is a detection-based approach which makes use of detectors such as the HC-SR04 ultrasonic sensor. The suggested model's performance versus single-CNN4 convolutional neural networks and switched convolutional neural networks (SCNN) is established through a density counting comparison study (Alashban et al., 2022).

With the crowd density estimation device, we can ensure public safety management. Due to the development of society and city, the crowd density is increasing in shopping malls, subway stations, tourist attractions, gymnasiums and other large-scale gathering places In this case, it is easy to lead to safety accidents, such as the stampede on the Bund of Shanghai on December 31, 2014, and the serious stampede on November 22, 2010 in Phnom Penh, Cambodia, which killed more than 500 people and injured more than 700 people. These accidents are all crowded stampedes caused by insufficient preparation for mass activities, poor on-site management and improper handling. They lead to major casualties and bad social influence. If we can make an accurate analysis of the degree of the congestion (Fan et al., 2021).

The crowd density estimation device offers intelligent monitoring. In the past, the crowd monitoring was usually done manually, and the users needed to observe multiple monitoring TVs for a long time. The long-time observation would make the users tired and lead to unnecessary security risks. The crowd density estimation system can give safety warning when the crowd density is too high, it can effectively prevent some problems in the school by automatically deriving data from the app and detecting the occupied percentage and send necessary warning. Lastly, the fact that the device is IOT based, makes the process of monitoring a whole lot easier and comfortable. The device sends real time data to database which will be fed into the app in real time. Parents can now stay at home and know their kids in school are having the necessary comfort and space within the classroom.

1.2 Statement of Problem

Crowd density estimation in wide areas is a challenging problem because of the high risk of degeneration, the safety of public events involving large crowds has always been a major concern. In this paper, we propose a crowd density estimation and prediction system for various area surveillance applications. The device makes use of two ultrasonic sensor two determine when individual walks across and the direction the individual moved in. The specific number of persons this system from the density of crowded areas. We can obtain predictions of a crowd's density almost immediately. The system has been used in real applications, and numerous experiments conducted in real scenes shows the effectiveness and robustness of the proposed method.

1.3 Aim of the Study

The aim of this project is to design and construct a crowd density estimation device which is based on Internet of Things.

1.4 Objectives of the Study

The objectives of the project are:

i. To develop a working circuit diagram for the project;

ii. To simulate the developed circuit diagram in (i);

iii. To construct the simulated diagram in (ii);

iv. To test and analyse the result in (iii).

1.5 Scope of Study

The scope of this study is to design and implement an IOT based crowd density estimation device capable of giving real time feedback to internet-connected devices thereby ensuring maximum monitoring. As a result of its usage of Wi-Fi technology, the system is very versatile. The address can be easily altered with ease at any moment, hence making its manageability guaranteed. The device is powered by a phone charger which makes it very energy efficient and portable.

1.6 Research Elements

The elements of this research are:

Chapter One: This chapter involves the introductory part of the project, which includes the statement of the problem, aim, objectives and scope of the study.

Chapter Two: Chapter two involves a literature review of past work on crowd density estimation using the internet of things by various authors and IOT practitioners.

Chapter Three: This chapter involves the explanation and description of material used to design and construct crowd density estimation device using the internet of things.

Chapter Four: Chapter four is based on the analyzing obtained from chapter three. It involves the tabulation of the results including graphical presentation and discussion.

Chapter Five: The conclusion of the study is achieved within this chapter, a summary of findings and necessary recommendations is covered in this chapter. This chapter has briefly introduced a crowd density estimation device using the internet of things and the advantages of implementing of the device.

CHAPTER TWO

LITERATURE REVIEW

2.1 Historical Background of Crowd Density

Crowd density estimation is a field that has emerged in recent years due to the increasing need for accurate crowd management and safety measures. But since the late 19th century, people have been studying crowd behavior and movement patterns. Gustave Le Bon, a French social psychologist, did one of the earliest investigations on crowd density in the latter part of the 1800s. He noticed that groups of people had a collective consciousness that was significantly distinct from the minds of its individual members. He observed that if crowds are not adequately controlled, they may prove both powerful and dangerous (Thonhauser, 2022).

2.2 Method of Capturing Crowd Density Estimate

The procedure of estimating crowd density involves counting the number of people in a given area to determine how crowded or congested it is. It is a more sophisticated method of counting the number of individuals in a specific location that also takes into account the space's size and layout. Researchers have recently focused on the issue of crowd counting and density estimation using a variety of techniques, such as detection-based counting, clustering-based counting, and regression-based counting dense (Sindagi & Patel, 2017).

Crowd density estimation is the process of measuring the level of congestion or crowding in a specific area based on the number of people per unit area. It is a more advanced form of crowd counting that takes into account not only the number of people in a given space, but also the size and layout of the area. It is important to note that Crowds may not always behave uniformly; they may congregate in certain areas and disperse in others.

Before going further, it will be important to define and try to understand what some terminologies like crowd density, estimation, crowd count is. According to the oxford dictionary a crowd is large number of people gathered in a place mostly in a disorganized or unruly way, following this train of thought crowd density refers to the determination of the number of people present in a particular area or space. It is expressed as the number of individuals per unit of area or people per square meter. Depending on the size of the area, the number of people available and the nature of the event, the crowd density may vary. High levels of crowd density may raise safety concerns as there is an increased risk of accident and panic possibility in case of emergency. One of the key issues addressed in a variety of applications, including surveillance, security, biology, and traffic, is the density of a crowded place (Alshaya, 2020).

2.3 Technologies behind Crowd Estimation

Crowd estimation comprises of different technology and techniques to get the estimate of number of people in a particular place. Some of these technologies includes image processing, mobile data analysis, video based analysis, sensor networks and machine learning. It also uses computer vision to detect movement in an area.

2.3.1 Video Surveillance

To capture the movement and density of the crowd, cameras are placed in strategic locations. The number of individuals present is then calculated from the camera feed using computer vision techniques. These algorithms are capable of finding individuals, estimating their locations, and combining the data to determine the size of the crowd as a whole. Security in crowded public areas refers to practically all types of aberrant incidents. Among these, detecting violence is challenging since it requires group interaction. Due to a number of practical limitations, analyzing anomalous or aberrant features in a crowd video scene is highly challenging (Sreenu & Durai, 2019).

2.3.2 Image Processing

Analyzing images taken by cameras or other imaging devices requires the use of image processing algorithms. Image processing techniques can determine the size and density of the crowd by locating and tracking specific individuals or groups within a particular area. To create the necessary density maps, it divides the input crowd image into patches and sends the image patches to different regression networks with different densities. It integrates the patch density maps in order to foresee the final density map (Zhu et al., 2020).

2.3.3 Computer Vision

Computer vision are employed to draw out relevant information from visual data. They entail the creation of algorithms capable of video or picture analysis and interpretation. Computer vision algorithms can find and follow people, identify their position and motions, and estimate crowd density based on the information gathered. This technique involves creating force time histories after tracking by employing optical flow-based methods for the crowd's displacement trajectories (Celik et al., 2018).

2.4 Performance Comparison of Crowd Estimation Machines

Comparing crowd estimate machine’s performance can be difficult since it depends on a variety of variables, including the technology utilized in each machine, the dataset used for training, the evaluation metrics used, and the scenario applied. By taking into account different crowd aspects, a lot of scholars attempted to provide thorough surveys and assessments of prior methodologies. The constructed low-level crowd traits are the major emphasis of these conventional methods for counting crowds. These low-level features are picked out, retrieved, and grouped into a structured input for the regression model that is employed for assessing and minimizing loss functions (Ilyas et al., 2019).

2.5 Typical areas of Deployment of Crowd Estimation Machines

When it comes to correctly assessing crowd size and density, crowd estimate devices, sometimes referred to as crowd counting systems, are used in a variety of settings. The following are some typical places where crowd estimating computers are used:

2.5.1 Event Management: To monitor and control crowd size, crowd estimating machines are frequently employed in event management. By pointing out regions of high density, they assist event planners in estimating the number of participants, monitoring crowd movements, and ensuring crowd safety.

2.5.2 Transportation: In transportation hubs including airports, train stations, crowd estimation devices are used. In order to enhance operational effectiveness and passenger experience, they assist authorities in monitoring passenger flow, optimizing crowd control, and identifying potential bottleneck locations.

2.5.3 Stadiums: In stadiums, crowd density estimation devices are used to predict the number of attendees for sporting events, concerts, and other large-scale gatherings, which can be used to plan crowd control strategies, maintain security in such areas and improving facilities and services can all benefit from this information.

2.5.4 Urban Planning: In order to comprehend population dynamics in public spaces, crowd estimating machines are used in urban planning. This aids the urban planners in creating and managing these areas efficiently so that they can accommodate anticipated crowds and promote easy circulation of resources in that area.

2.6 Shortcomings of Using Crowd Estimation Device

Although crowd estimation devices can be helpful in determining the population of a crowd or a public area, they also have several restrictions and potential drawbacks. Some of these drawbacks may include:

2.6.1 Limited Accuracy: Although crowd estimation devices can predict how many people are in an enclosed environment, their accuracy may be constrained. This can be affected by a number of variables, including the illumination, camera angle, and crowd density.

2.6.2 Highly Crowded Environment: In extremely packed situations when people are moving around and the crowd density is continually changing, such as at concerts or festivals, crowd estimating techniques might not be useful.

2.6.3 Dependence on The Quality of Materials Used: The precision of the crowd estimating model might be significantly impacted by the caliber of the materials that was used to capture the crowd. If for example, using a low quality camera can be impacted by poor lighting, low camera resolution, and other elements.

2.6.4 Limited Environmental Consideration: Devices used to estimate crowd density concentrate solely on counting the number of people present without taking environmental considerations into account. They might not take into consideration factors that could influence the crowd density or flow, such as the area's layout, its architectural features, or any impediments.

Therefore, it's possible that the estimates don't adequately account for the complexity of the crowd environment.

2.7 Future Trend of Crowd Estimation Device

The necessity for precise crowd management and analysis is increasing, and this is driving the area of crowd estimating devices forward. With the field of scene analysis and computer vision in general real-time crowd analysis is an active topic of study. Due to the extensive applications in population counting, managing public events, managing disasters, monitoring safety of individuals, and other areas in the past years, many methods for crowd management in real-time scenarios have drawn a lot of interest (Khan et al., 2020).

Cities with much population are mostly faced with security challenges especially when they frequently host large, or other types of people gatherings. Security forces are employed to monitor gatherings and ensure the safety of the attendees in order to reduce threat to lives and properties. The security forces can easily become overburdened when access to technology is restricted. Fortunately, the idea of intelligent monitoring systems is being adopted by more and more significant smart cities. In these circumstances, sophisticated crowd analysis techniques are needed for intelligent surveillance systems to adequately monitor crowd events (Zahra et al., 2021).

2.8 Application of Internet of things (IOT) Crowd Estimation Device

The accuracy, effectiveness, and utility of crowd monitoring are improved by incorporating IoT into crowd estimating equipment. It provides real-time data collecting, sophisticated analytics, and system integration, all of which improve crowd control, operational planning, safety, and security. This includes:

2.8.1 Data Gathering in Real-Time: The Internet of Things (IoT) enables the crowd estimate device to gather data in real-time from multiple sensors, cameras, or other connected devices. This makes it possible to keep an eye on the size, density, and behavior of crowds continuously.

2.8.2 Integration of Sensors: The Internet of Things (IoT) enables the integration of a variety of sensors into the crowd estimate device, including motion sensors, cameras, infrared sensors, and Wi-Fi trackers. These sensors can record a variety of crowd-related information, such as football, heat signatures, and Wi-Fi signals, giving a thorough picture of crowd dynamics.

2.8.3 Connectivity to Cloud Platforms: IoT enables the crowd estimating device to connect to cloud services, enabling centralized data processing and storage. Real-time uploading of crowd data to the cloud makes it possible to access it at anytime, anywhere, and for analysis.

2.8.4 Analytics and Visualization of Data: IoT-connected crowd estimate devices can use cutting-edge analytics approaches to analyse and analyze the gathered data. Algorithms for machine learning may be used to identify trends, patterns, and irregularities in crowd behavior. Effective decision-making is made possible by the use of visualization tools, which provide the facts in an intelligible fashion.

2.8.5 IoT-Connected Crowd Estimate: The devices may interact with mobile applications, giving consumers real-time updates on the crowd situation. Event planners, venue managers, and those who need to keep updated about crowd dynamics can all benefit from this tool.

CHAPTER THREE

METHODOLOGY

3.1 Project Workflow

The design and construction of a crowd density estimation device is to achieve the objectives which consists of three stages. At the first stage, the data collection dashboard will be designed using an internet of things development platform which is the ubidots. The second stage will involve the development of the code to perform the crowd density of the visitors using the arduino software. The last stage will be the testing of the circuit. The design and construction of a crowd density estimation device is also divided into three subsystems, which includes; the hardware, the software and the user interface. The hardware comprises of two IR-LED sensor, Esp8266, one channel relay module and an adaptable box that houses the other components. The software is developed using the arduino IDE.

The code is developed in such a way that the two IR sensor which one is designed as the ‘incoming visitor’ and the other is designed as the ‘outgoing visitor’ communicates with esp8266 wifi module, which then sends the collected data over a wireless connectivity to the user interface as shown in plate 3.1, which in this case is the ‘ubidots’ platform. The user interface which is the ubidot server as discussed earlier serves as a platform where the client receives the information produced by the hardware and software subsystems. The esp8266 wifi module serves as the link between the incoming visitor IR-LED sensor, the outgoing visitor IR-LED sensor and the ubidot server. A mobile data connection is used to transmit the data from the esp8266 wifi module to the ubidot server in real time.

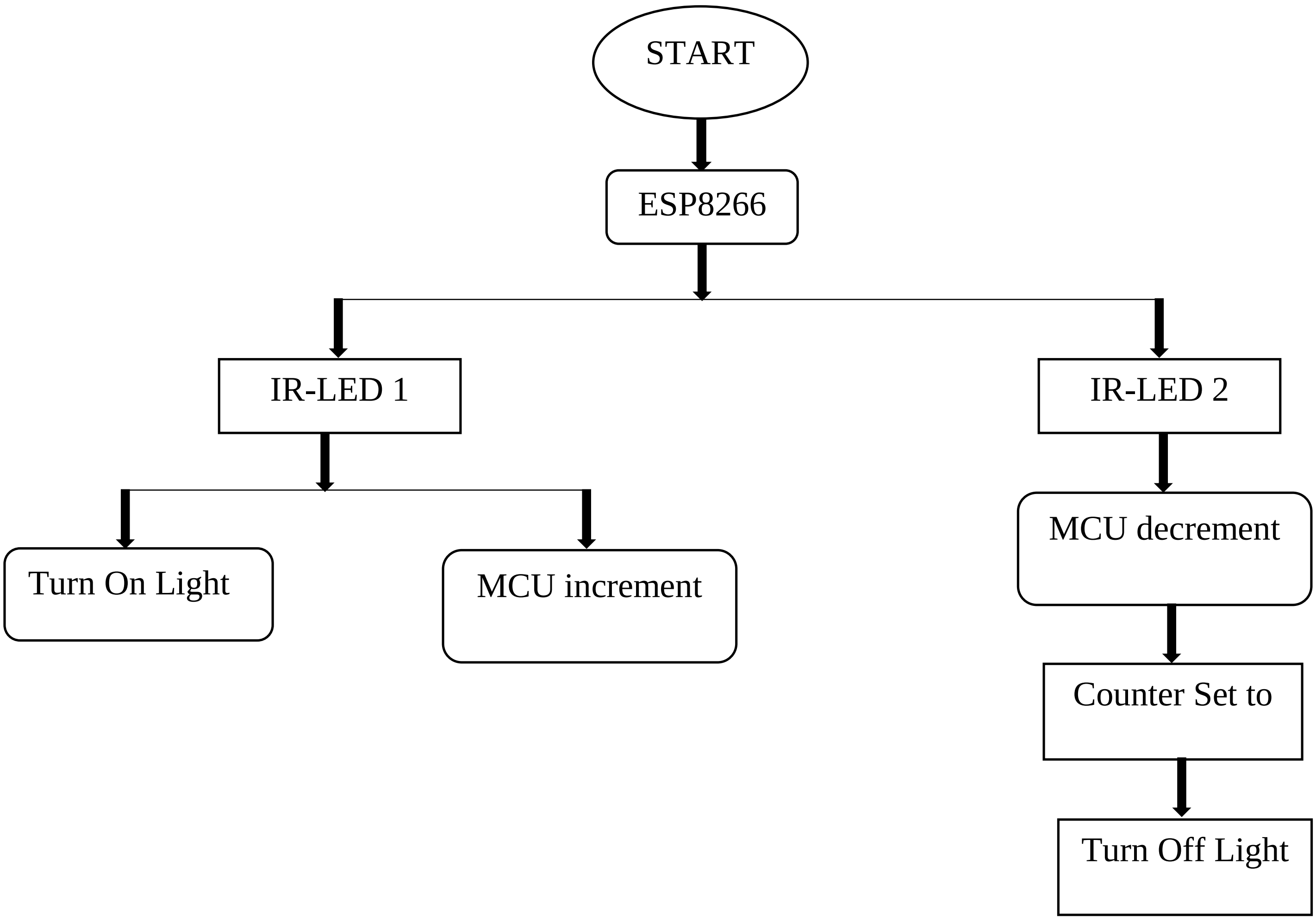

Plate 3.1: Workflow Diagram

3.2 BLOCK DIAGRAM

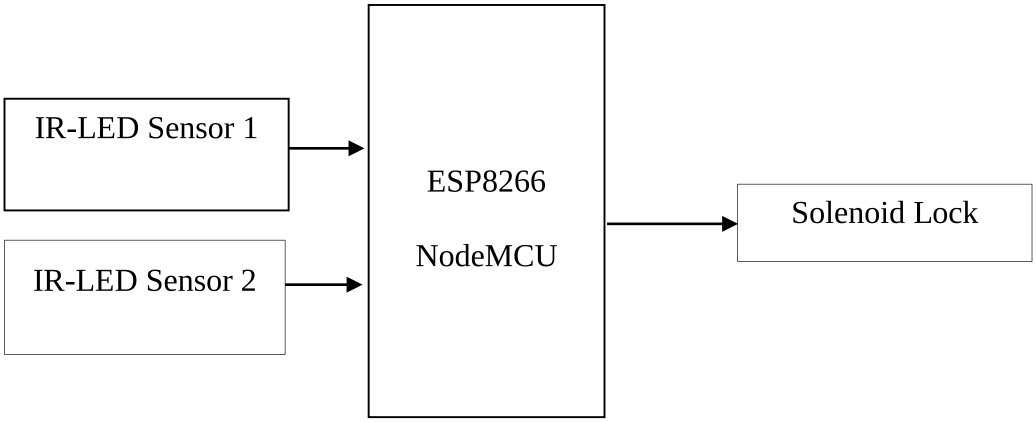

Plate 3.2: Block Diagram of a Crowd Density Estimation Device.

3.3 Circuit Diagram

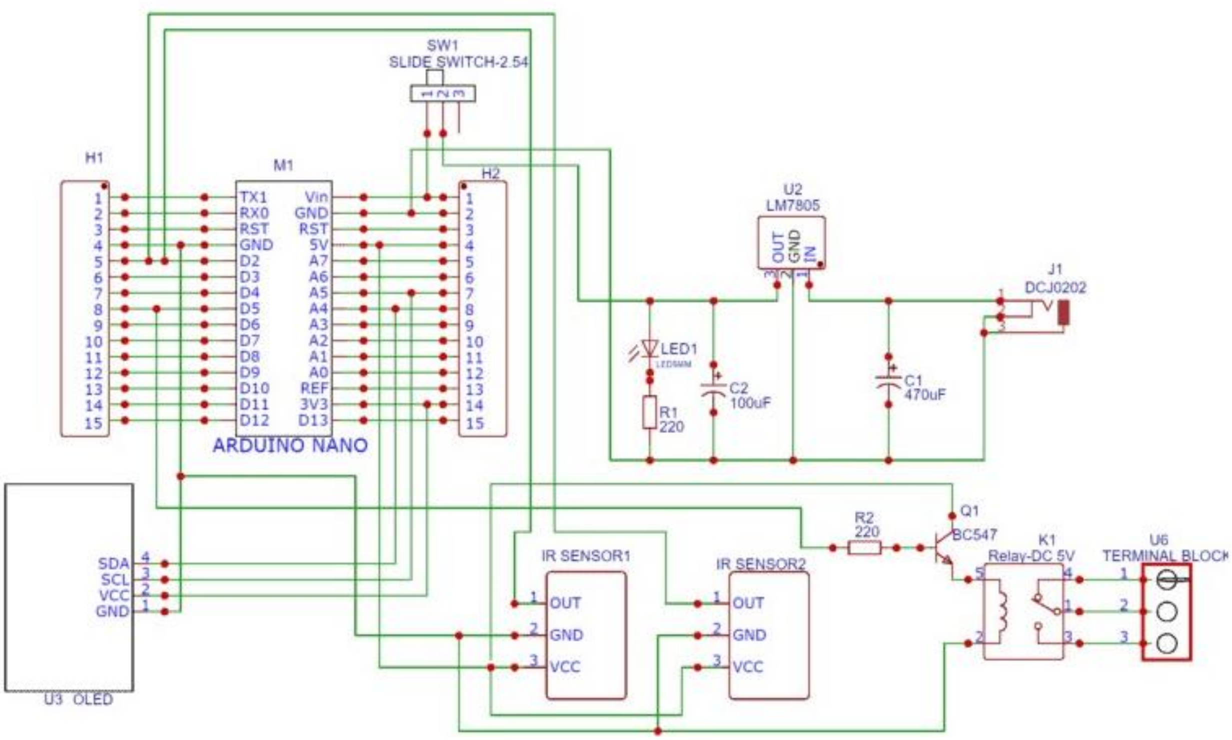

Figure 3.1: Circuit Diagram of a Crowd Density Estimation Device.

3.4 Design Calculation

Speed of the IR-LED Sensor, S is distance/time

i.e d/s in m/s.

i) The distance between the visitor and IR-LED sensor is 2cm, which is 0.02m.

ii) The time taken for the IR-LED sensor to detect (count) the visitor is 800milliseconds which is 0.8 seconds.

iii) The speed of the IR-LED sensor to transmit the data collected is given by distance/time; d/s = 0.02/0.8 = 0.025m/s.

3.5 Materials Used

The materials used for this design involves both hardware and software components. The hardware components required for this system are:

i. Esp8266 NodeMCU

ii. IR-LED Transmitter (Infrared Light Emitting Diode)

iii. One Channel Relay Module

iv. Li-Ion Battery

v. BMS (Battery Management System)

vi. Jumper Wire

vii. Adaptable Box

viii. Solenoid Lock

3.5.1 Esp8266 NodeMCU

The ESP8266 NodeMCU is a popular open-source development board that is based on the ESP8266 Wi-Fi module. It is designed for building IoT (Internet of Things) projects. The ESP8266 NodeMCU comes with built-in Wi-Fi connectivity, which allows it to connect to the internet and communicate with other devices over a wireless network. The NodeMCU is powered by the ESP8266 microcontroller, which is a low-cost, low-power, and high-performance system-on-a-chip (SoC) that integrates a CPU, Wi-Fi, and other components on a single chip.

The NodeMCU can be programmed using Lua, a lightweight scripting language that is easy to learn and use, making it an ideal choice for beginners. The NodeMCU has a number of GPIO (General Purpose Input/Output) pins, which can be used to connect to external sensors, actuators, and other components. The NodeMCU comes with a USB interface, which can be used to power the board and upload firmware updates. Figure 3.2 shows the image of an esp8266 which is a versatile and affordable development board that provides a powerful platform for building a wide range of IoT projects. Its built-in Wi-Fi connectivity, GPIO pins, and support for Lua programming make it an ideal choice for implementing this project.

The ESP8266 is a flexible Wi-Fi module that combines a microcontroller with Wi-Fi capabilities. It can connect to the internet or local networks, communicate with other devices, and carry out a variety of activities when given instructions by the user, who frequently uses AT commands or the Arduino IDE to configure the device. Due to its simplicity of use and low cost, it is frequently employed in IoT applications.

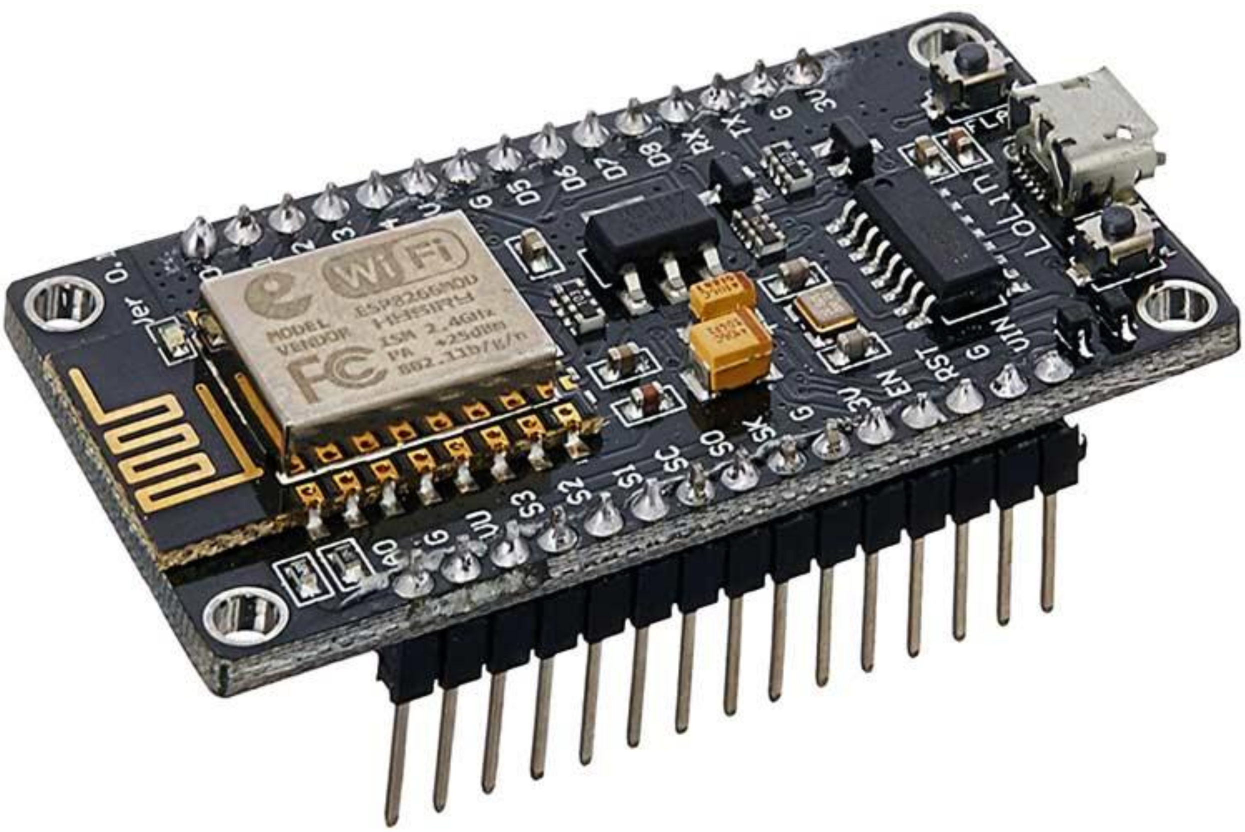

Figure 3.2: Esp8266 NodeMCU (Alshaya, 2020)

3.5.2 IR-LED Transmitter

It is a device that emits infrared light in the form of pulses. It is frequently utilized in a wide range of applications, such as proximity sensors, data communication, remote controls, and several other electronic systems that call for wireless communication or object detection. According to the electroluminescence theory, an IR-LED transmitter emits light in the infrared spectrum when an electric current flows through a semiconductor material that has been particularly formulated for this purpose. An IR-LED is built similarly to a regular LED, with the exception that it is made to emit light in the infrared spectrum.

The IR-LED emits infrared light with a certain wavelength when a current is supplied to it. The wavelength generally lies within the 700 nm to 1 mm region of the near-infrared spectrum. While this wavelength range is undetectable to the human eye, it may be picked up by electronic devices and sensors that are made to pick up infrared signals. Figure 3.3 shows the labelled image of an IR-LED transmitter which are used in a wide range of applications including; proximity sensor, remote control, data communication, object detection among others.

A wide number of applications that improve convenience, security, and efficiency are made possible by IR-LED sensors, which are essential parts of contemporary electronics. They are essential in a wide range of businesses and standard household items due to their capacity to detect infrared light and react to environmental changes. IR-LED sensors will probably play a bigger part in creating our linked environment as technology advances.

Figure 3.3: IR-LED Transmitter (Naeem, 2020)

3.5.3 One Channel Relay Module

A channel relay module is an electrical device that enables control of high-power circuits via low-power signals, also known as a relay board or relay module. It functions as a switch, making it possible to regulate electrical loads that need larger voltages or currents than a microcontroller or another low-power device is capable of handling directly. The Internet of Things (IoT) and automation systems, robots, household appliances, and industrial equipment are just a few examples of the many applications where channel relay modules are often utilized.

A PCB (Printed Circuit Board) with numerous relays installed on it makes up a conventional channel relay module as shown in figure 3.4. Each relay functions as an individual electromagnetic switch. Depending on the particular requirements of the application, a module may include a few to dozens of relays. A relay's driver circuitry turns on the relay coil when a control signal is provided to the input terminal. This produces a magnetic field that, depending on the kind of relay, draws the contacts of the relay together or releases them. When the contacts shut, the load attached to the output terminals completes the circuit and turns on. The load is detached and it shuts off when the connections open, on the other hand.

A switch that can be remotely operated by a low-power signal is a one-channel relay module. When triggered or deactivated, it opens or closes a high-power circuit by physically shifting the position of its switch contacts through the use of an electromagnetic coil. When electrical isolation or remote control of high-power equipment is necessary, a number of applications frequently exploit this feature.

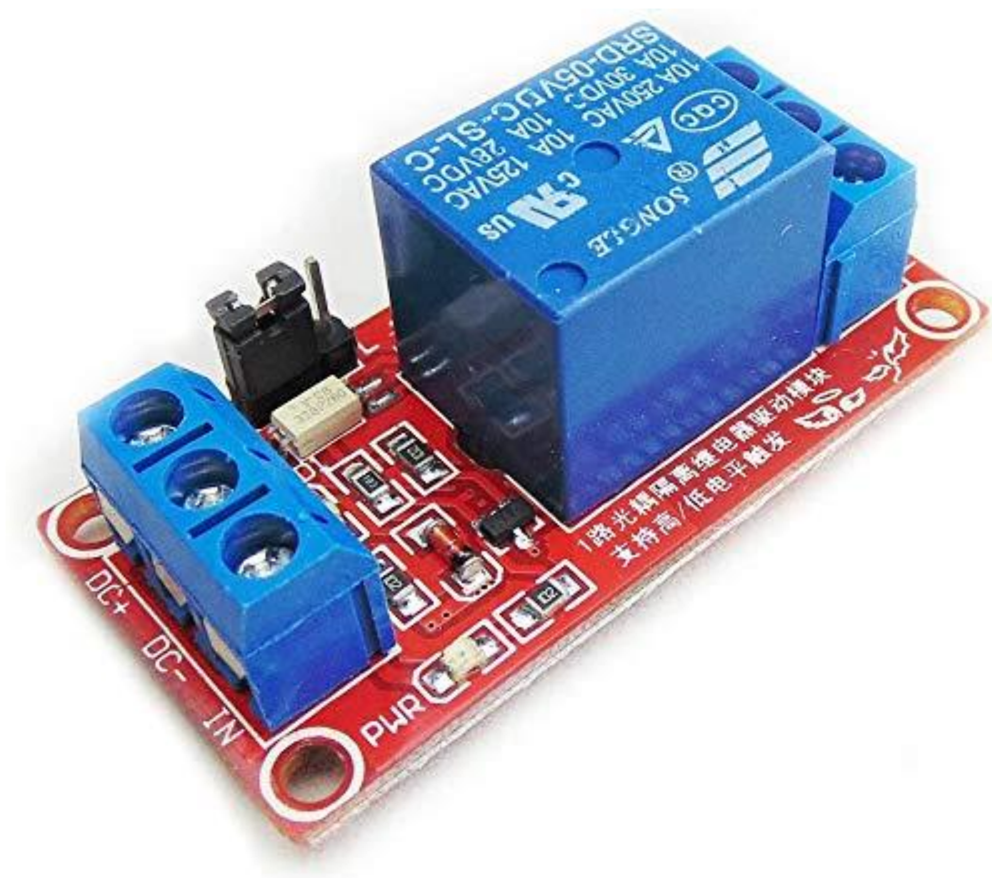

Figure 3.4: One Channel Relay Module (Saeed, 2020)

3.5.4 Li-Ion Battery

Rechargeable energy storage technologies known as lithium-ion (Li-ion) batteries have transformed the portable electronics market and are now extensively employed in a wide range of applications, from smartphones and laptops to electric cars and renewable energy storage systems. Compared to other types of rechargeable batteries, Li-ion batteries have several benefits, such as high energy density, lightweight construction, extended cycle lives, and low self-discharge rates. Li-ion batteries are the best option for powering our contemporary products because of their qualities. In order to store and release electrical energy, Li-ion batteries are made up of a number of essential parts.

The separator, electrolyte, cathode, and anode are the major parts. Common lithium-based materials used to make cathodes include lithium cobalt oxide (LiCoO2), lithium iron phosphate (LiFePO4), and lithium manganese oxide (LiMn2O4). Graphite, the most prevalent carbon-based material, is often utilized as the anode. Lithium salts mixed in organic solvents make up the electrolyte of Li-ion batteries, which is generally a non-aqueous solution. While serving as a barrier to stop direct contact between the cathode and anode, the electrolyte permits the conduction of lithium ions. In order to avoid short circuits and permit the movement of lithium ions, the cathode and anode are physically separated by a separator, which is typically formed of a porous polymer material. Figure 3.5 shows the image of a 3.7V Li-Ion battery.

Figure 3.5: Li-Ion 3.7V Battery (Jabba, 2019)

3.5.5 BMS (Battery Management System)

A battery management system (BMS) is an electrical device that maintains and regulates rechargeable batteries. Voltage, current, temperature, state of charge (SOC), state of health (SOH), and other characteristics of battery performance are monitored and controlled using a combination of hardware and software components. The BMS as shown in figure 3.6 prevents the battery from being overcharged, discharged, or running outside of its safe operating parameters, ensuring safe and effective battery performance. The BMS regularly assesses the battery's performance and general health by checking important factors including voltage, current, and temperature. Accurately estimating the battery's state of charge, health, and remaining capacity is made possible with the use of this information.

By carefully monitoring and managing numerous parameters, improving performance, prolonging battery life, and eliminating potentially dangerous circumstances, a battery management system assures the safe, effective, and dependable functioning of battery packs. When it comes to controlling the efficiency and security of rechargeable batteries, such those used in electric cars and portable gadgets, a battery management system (BMS) is an essential tool. Its main operating concept entails keeping an eye on, managing, and safeguarding the battery pack. Each cell in the battery pack is continually monitored by the BMS. Measurement parameters for this include voltage, temperature, and occasionally current. It makes sure that cells are functioning in a safe and ideal range.

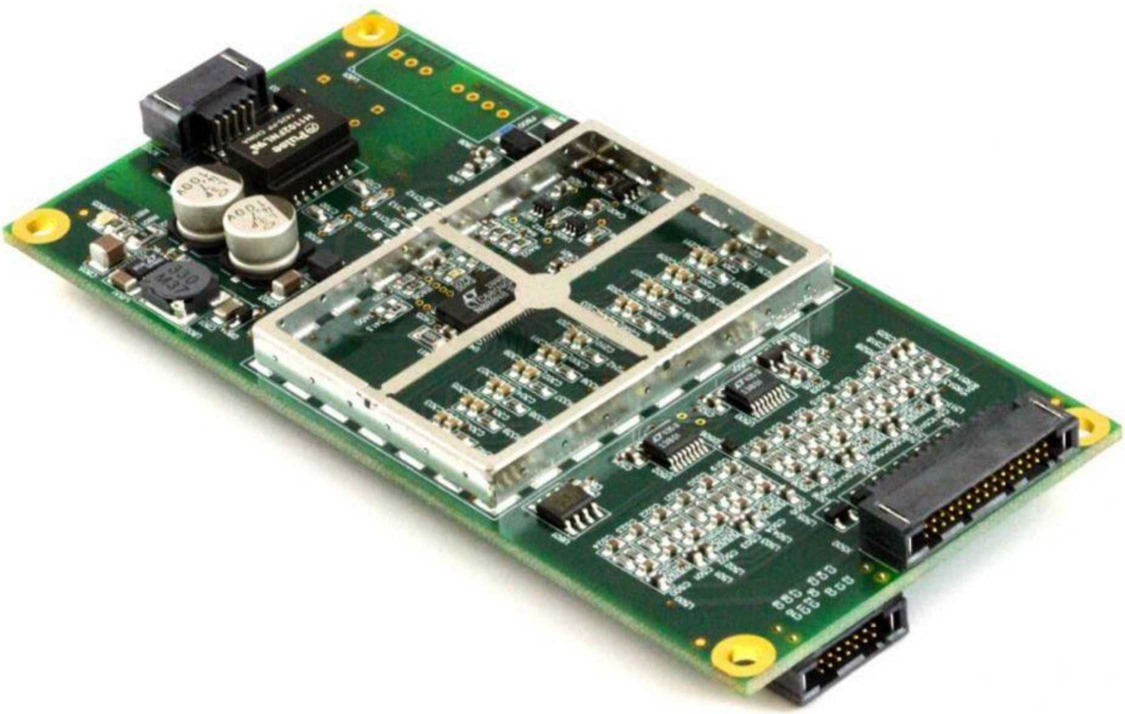

Figure 3.6: Battery Management System (Vasan, 2020)

3.5.6 Jumper Wire

Jumper cables, usually referred to as jumper wires or simply jumpers, are a crucial part of electronic and electrical circuits. They're employed to provide connections between various locations on a circuit board or between other circuit boards. When breadboarding, prototyping, and debugging electrical circuits, jumper wires are indispensable. They can be solid jumper wires, standard wires, male-to-male jumper wires, male-to-female jumper wires and female-to-male jumper wires. The image shown below in figure 3.7 is the male-to-female jumper wire. A jumper wire is a basic electrical part that connects two locations in an electrical or electronic circuit momentarily.

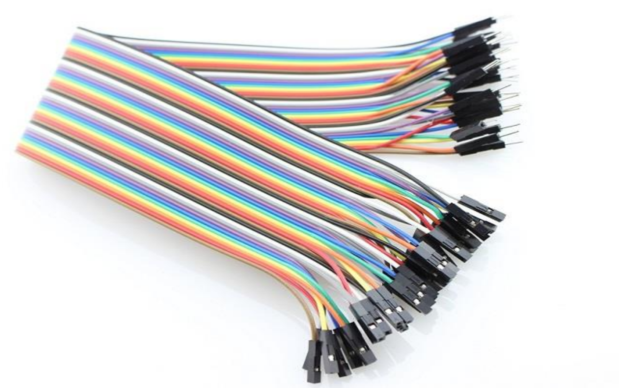

Figure 3.7: Male-to-Female Jumper Wires (Ullah, 2021)

3.5.7 Adaptable Box

Various electronic components and equipment can be housed and protected in an adaptable box for electronics, which is a flexible and adaptable solution. It provides flexibility in terms of size, design, and customization possibilities, making it simple to integrate and modify as necessary to meet the unique demands of the electronics being housed. Due to the rapidly changing nature of technology and the wide variety of electronic devices and components that are currently accessible, it is essential to have a box or enclosure that can meet these shifting requirements. Any application, from simple consumer electronics to intricate industrial systems, may benefit from the versatility that an adjustable box offers to handle various sizes and shapes of electronics. In this project I will be making use of the adaptable box to house my electronic components. The typical example of an adaptable box is shown in figure 3.8.

Figure 3.8 Adaptable Box

3.5.8 Solenoid Lock

When controlled access and security are crucial, electromagnetic locking mechanisms like solenoid locks are frequently utilized in a variety of settings. Using the principles of electromagnetic, it is intended to lock down doors, gates, cabinets, or other physical obstacles. For its dependability, simplicity, and ability to work with electronic access control systems, solenoid locks are frequently used and it is shown in figure 3.9.

Two basic parts make up a solenoid lock which comprises of a solenoid and a locking mechanism. An electromechanical device called a solenoid uses electrical energy to produce linear motion. A coil of wire is twisted around a ferromagnetic core, often comprised of iron or steel, to create this device. The coil produces a magnetic field around the core when an electric current flows through it. The core is moved by this magnetic field, retracting or expanding depending on the design. The movement of the core directly affects how the locking mechanism works.

The solenoid coil produces a powerful magnetic field when an electrical current is introduced to it, which magnetizes the iron core. The plunger or bolt is pulled into the core of the solenoid coil by the force of the magnetization acting on it. The door or latch is physically stopped from moving while the plunger or bolt is drawn into the coil, locking it. The strength and security of the lock are determined by the magnetic field's intensity and the locking mechanism's design. Electric current must be released from the coil in order to open the solenoid lock. When the current ceases, the magnetic field vanishes, releasing the plunger or bolt from the grip of magnetism. By doing this, the door or latch may be unlocked and the locking mechanism can return to its initial position.

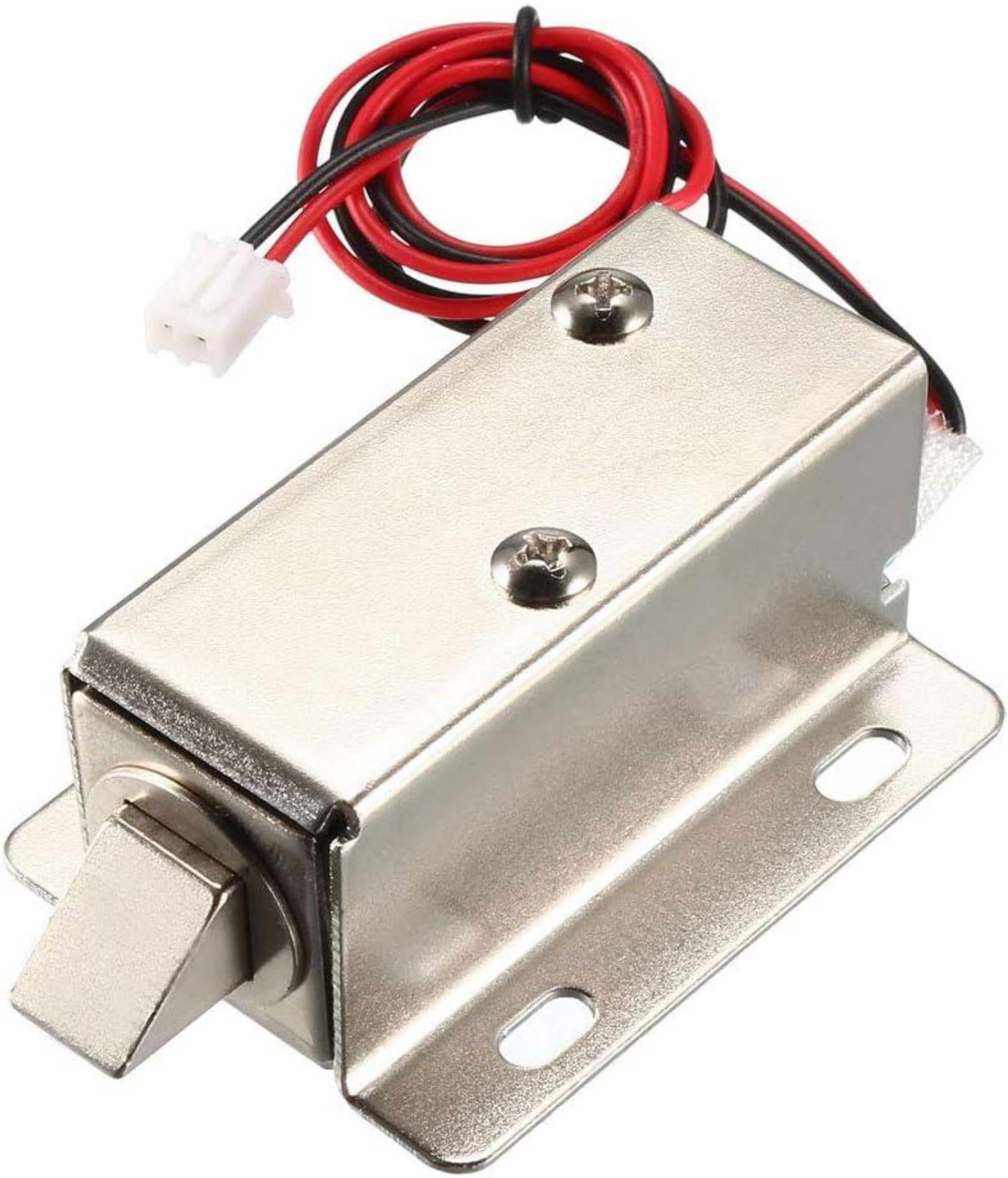

Figure 3.9: Solenoid Lock (Orchi, 2018)

3.6 METHODS

3.6.1 Steps Taken to Connect the Electronic Components (Hardware)

Step 1: Connect the SDA and SCL pins of the 0.96" OLED display to the D2 and D1 pins of the NodeMCU.

Step 2: The output pins of the two IR sensors should be connected to NodeMCU's D5 and D6.

Step 3: The entering visitor counter will be controlled by one of the IR Sensors, and the departing visitor counter by the other.

Step 4: Connect a 5V relay module in a similar manner to NodeMCU's D4 pin.

Step 5: The Relay Module and IR Sensors both operate at 5V VCC. Either the Lolin NodeMCU VU Pin or the Amica NodeMCU Vin pin may give 5V.

Plate 3.3 below shows the hardware set ups which are explained in the steps above.

3.6.2 Steps Taken to Create the Ubidot Dashboard

Step 1: Log in to ubidot.com server with your email address and password.

Step 2: Get your api token and upload to the arduino IDE code.

Step 3: Write the variables to be transmitted into the ubidot app which in this case is the incoming visitor, outgoing visitor and current visitor.

Step 4: On the ubidot platform, click on the ‘dashboard’ icon at the upper left corner of the user interface.

Step 5: Click the ‘create’ button.

Step 6: Assign the variables to the dashboard and then configure.

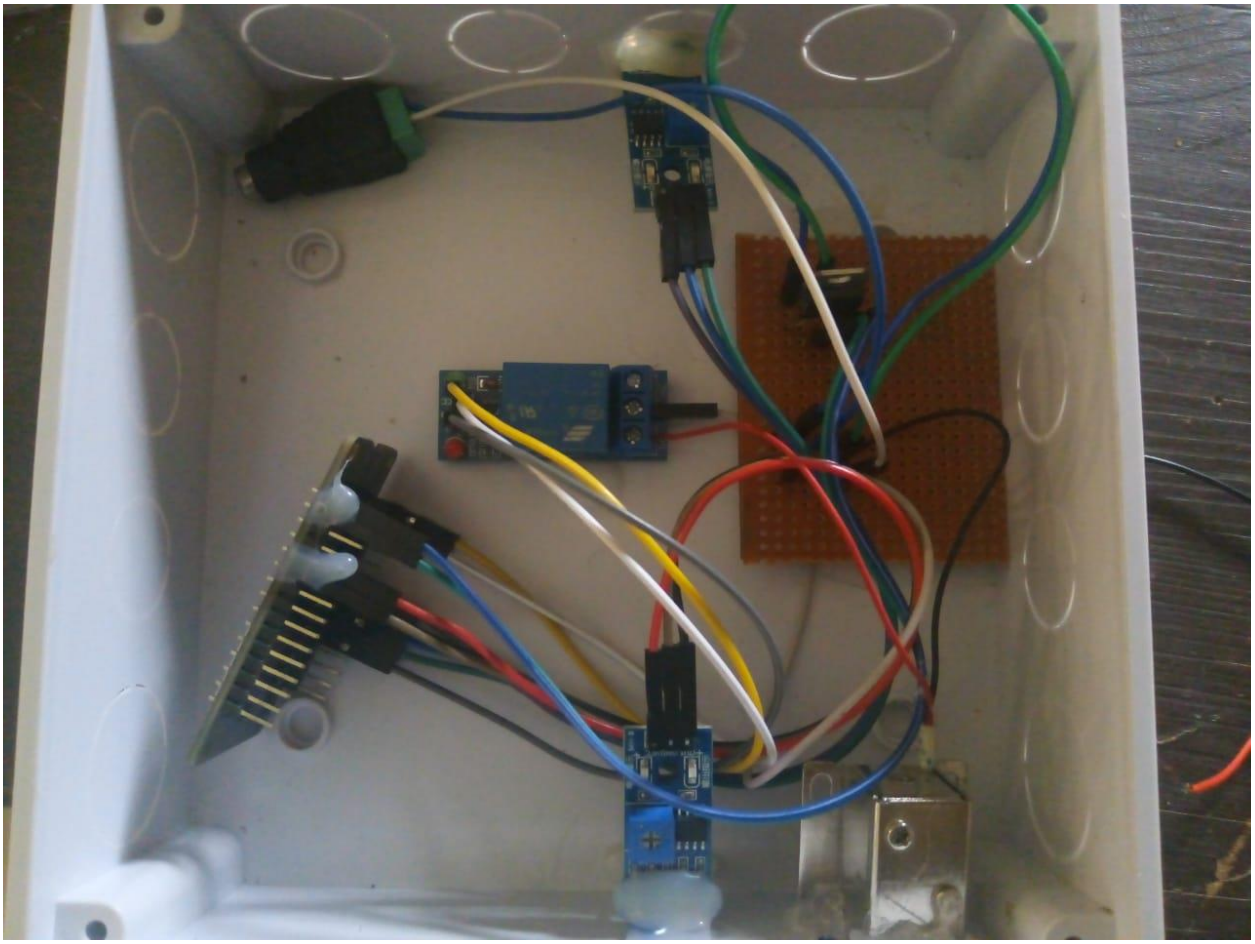

Plate 3.3: Complete Hardware Setup.

3.6.3 Use of Ubidots Internet of Things Development Platform

This system was designed to collect data of the number of visitors going into an office, the number of visitors already in the office, to shut the door of that office when the number of visitors in the office is exactly twenty (20) and to know the number of visitors leaving the office. The wifi module will act as the mode of transmission of data between the IR-LED sensor and the ubidot Internet of Things development platform.

The ubidot dashboard was designed to perform the following;

i. Display the data of the incoming visitors.

ii. Display the number of current visitors in real time.

iii. Display the number of outgoing visitors.

iv. Display the door status when the number of visitors is twenty (20) or more than 20.

v. Display the Visitors frequency.

Plate 3.4 shows the typical view of the ubidots dashboard which is designed to display the incoming visitors, outgoing visitors, current visitors, the door 'off' status and the visitor's frequency. In the dashboard, the value of the incoming visitors is fifty four while the value of the outgoing visitor is thirty nine. The current visitors plate in the dashboard shows that the current number of visitors is fifteen, this which is gotten by the difference between the incoming visitors and the outgoing visitor. When a visitor enters the room, the value is updated. If the visitor leaves the room, whatever that is left is the number of the current visitor. Since the door status is set to turn on whenever the current number of visitors is twenty or more, the current number of visitors in this case is fifteen, therefore the door status is indicating off.

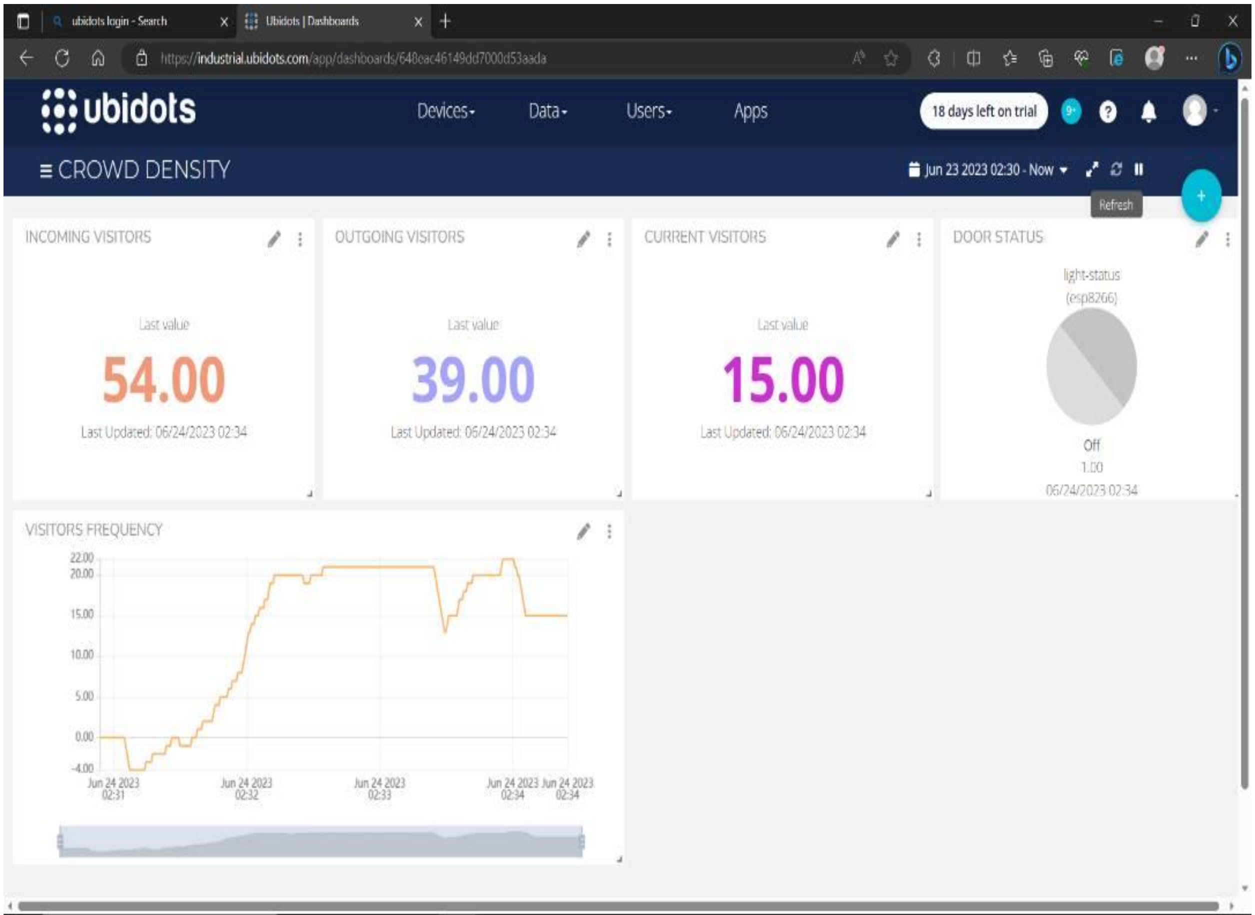

Plate 3.4: Ubidots IoT based Crowd Density Estimation Dashboard

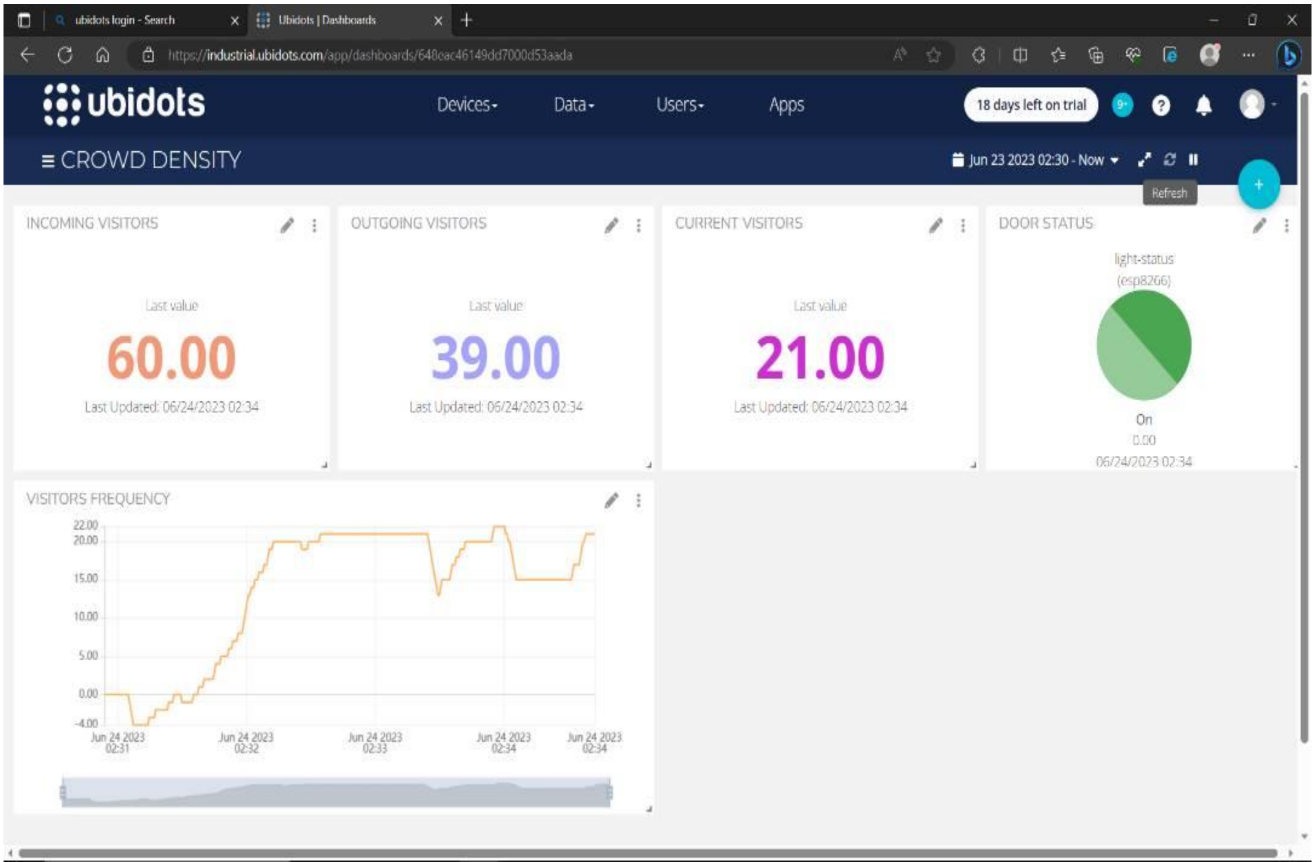

Plate 3.5: Ubidots Platform displaying the data collected.

Plate 3.5 shows the data collected from the hardware and software subsystems of this project. The door status which is represented below at top-right corner of the ubidots dashboard displays a green light which shows that the current number of the visitors exceeds twenty, which in this image is twenty one. The difference between the number of the incoming visitor and the number of the outgoing visitor is the number of the current visitor, which in this case is twenty one. Since the door status is set to turn on whenever the number of the current visitor is twenty or more, the current number of visitors is twenty one, therefore the door status indicates on.

CHAPTER FOUR

RESULTS AND DISCUSSION

This chapter consists of the various results and observations of the project work. A viable and economical method for monitoring crowd density in numerous applications is crowd density estimation utilizing an ESP8266 and two IR-LED sensors. It uses infrared sensors to find individuals and analyzes their reflections to calculate the crowd density in real time. The ubidot IoT platform which its aim is to display the estimate of the number of individuals in a particular environment by receiving the data through the two IR-LED sensor (Incoming and Outgoing). The code to make the device perform such operations was developed using the arduino IDE. When the project has been completed, the prototype was analyzed and the final results are shown below.

4.1 CROWD DENSITY ESTIMATION

The design comprises of two IR-LED transmitter, with one of them collecting data for the incoming visitor and the other collecting data for the outgoing visitor. The ubidot platform tends to display the data that both IR-LED sensor transmits. The ubidot dashboard is designed in such a way that the data for incoming visitor, current visitor, outgoing visitor, door status and the visitors frequency are displayed differently for easy understanding. The arduino IDE code was developed so that when the number of visitors going into an enclosed area is exactly twenty (20), the solenoid lock should close and the light status on the door status on the dashboard of the ubidot should indicate on by displaying a green light.

Table 4.1: Crowd Density Estimation

TIME	CURRENT NUMBER OF VISITORS
08:15	0
08:48	1
09:27	2
09:38	3
10:01	5
10:03	6
10:37	9
10:42	11
10:49	14
10:55	15
11:10	17
11:13	19
11:15	20

Table 4.1 above shows the data of the number of current visitors entering into the office at a specified time. The table was developed, when the ubidot server collected the data from the esp8266 in real time and should only allow only twenty visitors in the room by 11:15. This was done by setting the door status to turn on when the number of visitors is exactly twenty. From the above table, at 8:15, the counting of visitors in the room started and until 8:48, only one visitor entered the room. The visitors kept entering till 11:15 when the number of current number of visitors is exactly twenty.

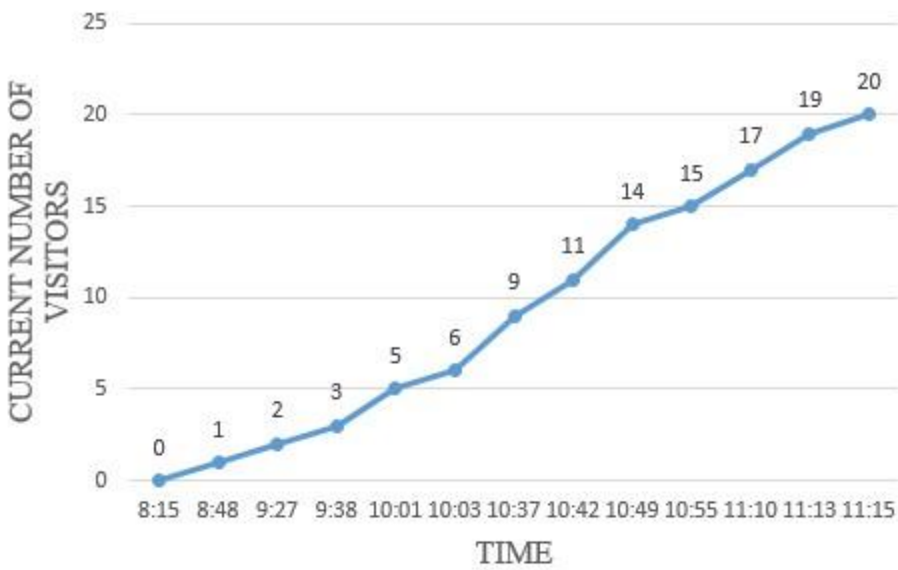

Plate 4.1: Crowd Density Estimation Chart

The image shown above in plate 4.1 shows the chart of the current number of visitors plotted against the time they entered into the office which the values were gotten from table 4.1. From the chart, the counting started at 8:15 and the current number of visitor was zero. The first visitor came in at about 8:48 which is shown in the chart. The line on the chart kept ascending because the number of visitors were increasing until 11:15, when the predetermined maximum number of visitors in the room to be twenty was achieved.

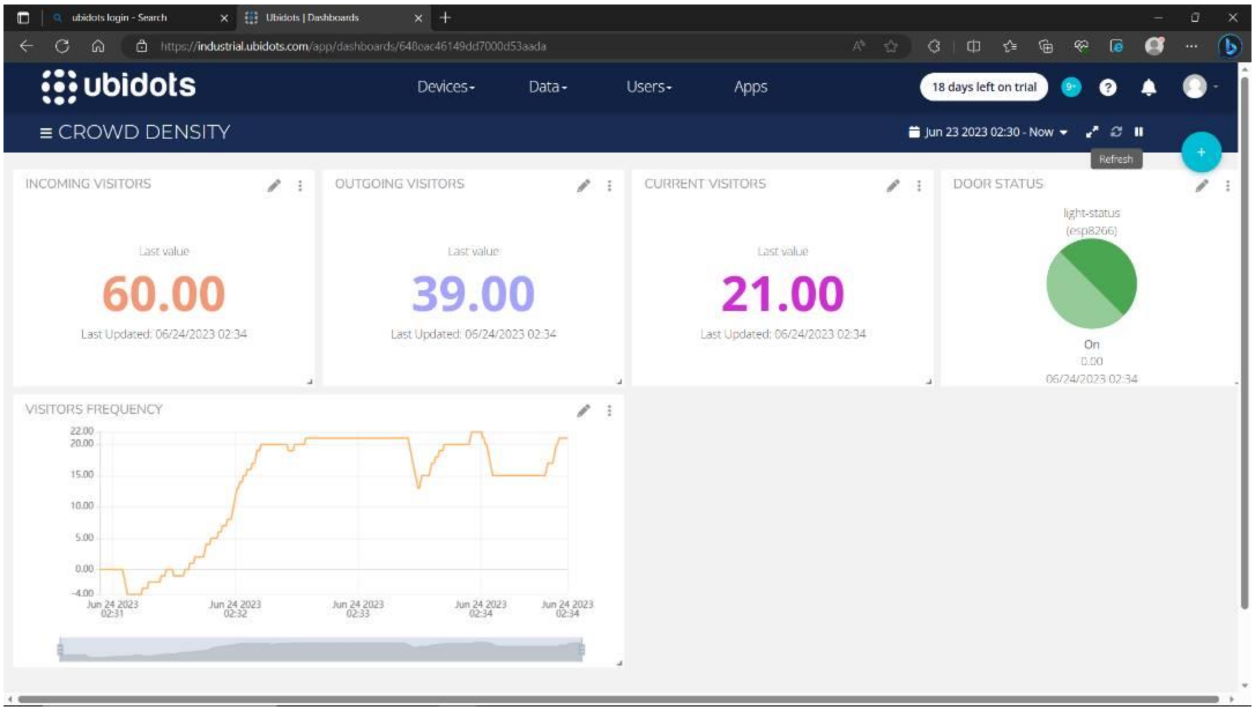

Plate 4.2: Ubidot Dashboard Showing the Data of the Crowd Density of Visitors with Door On Status

Plate 4.2 above is showing the number of incoming visitor as sixty, the number of outgoing visitor as thirty nine and the current number of visitors which is the number of visitors left in the room when visitors stopped coming in and going out of the room. It is the difference between the number of incoming visitor and the number of the outgoing visitor. The door status was set to turn on whenever the number of the current visitor is equal to twenty or more than twenty. In the image above, the number of the current visitors is twenty one, therefore the door status indicated on.

4.2 TESTING AND RESULTS

This device is tested so as to evaluate the functionality of the crowd density when the number of individuals entering into an office is twenty or more than that, the door status indicates 'ON', otherwise the door status will indicate 'OFF' which is shown in table 4.2 below. This device is made up of two pairs of IR-LED sensor, esp8266 wifi module and a solenoid lock. The device was designed to have two modules which includes the client and the server where the data is collected. Wifi network named 'Zitere' was created. This would send the data collected from the both IR-LED sensor to the client unit, which in this case is the ubidot platform.

Table 4.2: Testing and Results

Time	Incoming Visitor	Outgoing Visitor	Current Visitors	Door Status
08:15	3	0	3	Off
08:48	9	0	6	Off
09:27	17	0	17	Off
09:38	20	0	20	On
10:01	23	3	20	On
10:03	27	7	20	On
10:37	32	12	20	On
10:42	35	15	20	On
10:49	0	20	0	Off

Table 4.2 shows the collecting of the data of visitors entering and leaving the room in real time. In the table, there is a column for the time the visitors entered the room in real time as well as a column for the number of the incoming visitor, number of the outgoing visitor, current visitor and the door status. As explained earlier, the number of current visitor is the difference between the number of the incoming visitor and the number of the outgoing visitor. The current number of visitors was set so as not to exceed twenty. Subsequently, the door status was set to indicate on when the number of the current visitor is exactly twenty which is shown in plate 4.3 below and off when the number of the current visitor is less than twenty.

At 8:15, three visitors entered the room and no visitor left, therefore the current number of visitors in the room is three and the door status indicated off because the number of the current visitor is three which is less than twenty. At 9:38, twenty visitors has entered the room and no visitor left the room, making the number of current visitors in the room to be twenty, the door status indicated on. At 10:01, twenty three visitors entered the room and three visitors left, the number of the current visitors became twenty and the door status indicated on. By 10:42, thirty five visitors has entered the room and fifteen visitors has left, the number of the current visitors is twenty and the door status is on. At 10:49, no visitor entered the room, twenty visitors left the room and the number of the current visitors is zero therefore, no visitor is in the room and the door status indicated off.

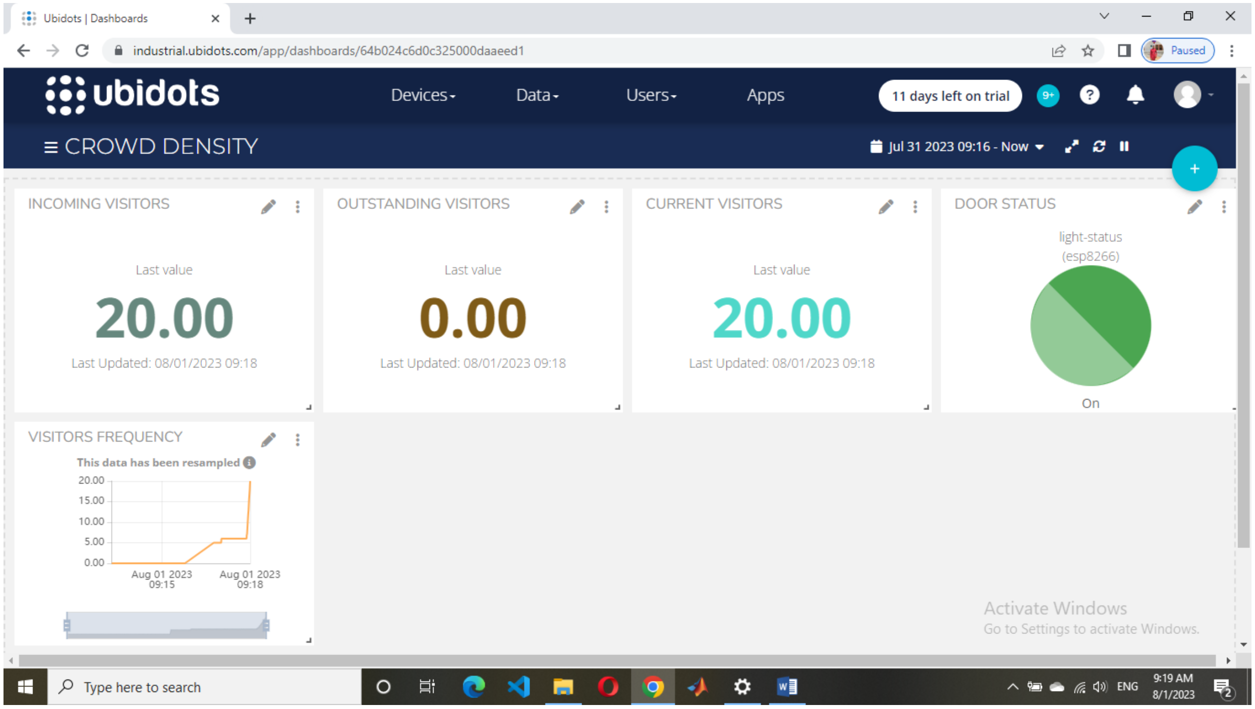

Plate 4.3: The On Door Status Indicated When the Current Number of Visitors were Exactly Twenty

4.3 OBSERVATION

A crowd density estimating device may be shown in action managing crowds effectively, improving safety, and maximizing resource allocation in diverse contexts. It exemplifies the integration of physical sensors with cutting-edge data processing technology to deliver useful real-time insights. In the process of getting the estimation of number of individuals that were entering into an office, I encountered some difficulties and the following observations were made:

4.3.1 Poor Mobile Network

Network issues were one of the major challenges I faced while the ubidot platform was trying to collect the data from the two IR-LED sensor over a wifi and displayed on its dashboard using a mobile network. I noticed that when the mobile network is strong, the data is displayed on the ubidot platform faster and more accurate in real time. Some of the network providers have poor network service which affected the general working process of the device in terms of transmission.

4.3.2 Connection to the Server

The ubidot platform was not able to receive the data from the IR-LED sensor on time. This delayed the data to be displayed on the platform. The IR-LED sensor also had similar issue in transmitting data to the ubidot sever. The best practices for preventing connection problems with the server may include routinely checking the health and performance of the server, keeping up secure and dependable network connections, updating client setups and software and putting in place failover and redundancy solutions for crucial connections.

Table X: Bill of Engineering Measurement and Evaluation

S/N	DESCRIPTION	QUANTITY	UNIT PRICE, N	COST, N
1	Esp8266	1	9,000	9,000
2	IR-LED sensor	2	7,000	14,000
3	One Channel Relay Module	1	2,500	2,500
4	Adaptable Box	1	5,000	5,000
5	Battery management system	1	7,000	7,000
6	Solenoid Lock	1	8,000	8,000
7	Li-Ion Battery	1	4,500	4,500
	Total			50,000

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

I obtained a successful crowd density estimation that is based on internet of things. It successfully transmitted data from one unit of the project to the other. When the data is sent to the ubidot platform by the two IR-LED transmitter over a wifi network, this reading is accessible to the client. This device entails the possibility of getting an estimate of crowd density in offices, industries, schools, medical centers, stadiums and many other places where its application is useful. It can be used to control overcrowding and places where number of individuals should not exceed a predetermined count. Further research of this prototype can be employed to get an improved crowd density estimation to carry out tasks in where its use is needed.

5.2 Recommendation

Based on the observations and results of the prototype of an IoT based crowd density estimation, the following recommendation should be considered for improvements and research.

i. Implement real-time data processing to give quick updates on the density of the crowd.
ii. Create more complicated algorithms to handle scenarios with many crowds, erratic crowd forms, and dynamic movement patterns.
iii. Integrate machine learning techniques to improve the system's capability to recognize different people and minimize false readings.
iv. Implement wireless communication protocols to make it easier for the devices to sync and share data.

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APPENDIX ONE

GANTT DIAGRAM

Project Duration

S/N	CHAPTER	JAN	FEB	MAR	APR	MAY	JUN	JUL
1	Introduction	•	•					
2	Literature review		•	•	•			
3	Design and Methodology					•	•	•
4	Result and discussion						•	•
5	Conclusion and recommendation							•

APPENDIX TWO

UBIDOT NODEMCU CODE

```
#include "UbidotsESPMQTT.h"

#include <SPI.h>

#include <Wire.h>

#include <Adafruit_GFX.h>

#include <Adafruit_SSD1306.h>

#define TOKEN "BBFF-yI90uhPG1nUTOjSit3oMXcJQfQDE0s" // Your Ubidots TOKEN

#define WIFINAME "Zitere" //Your SSID

#define WIFIPASS "zitere627" // Your Wifi Pass

#define SCREEN_WIDTH 128    // OLED display width, in pixels

#define SCREEN_HEIGHT 64    // OLED display height, in pixels

#define OLED_RESET -1       // Reset pin # (or -1 if sharing Arduino reset pin)

Adafruit_SSD1306 display(SCREEN_WIDTH, SCREEN_HEIGHT, &Wire, OLED_RESET);

#define inSensor 14

#define outSensor 12


#define relay D4


int inStatus;

int outStatus;


int countin = 0;
```

```
int countout = 0;


int in;

int out;

int now;


Ubidots client(TOKEN);


void callback(char* topic, byte* payload, unsigned int length)

{

  Serial.print("Message arrived [");

  Serial.print(topic);

  Serial.print("] ");

  for (int i = 0; i < length; i++)

  {

    Serial.print((char)payload[i]);

  }

  Serial.println();

}



void setup()

{
```

```
  client.setDebug(true); // Pass a true or false bool value to activate debug messages
  Serial.begin(115200);
  client.wifiConnection(WIFINAME, WIFIPASS);
  client.begin(callback);
  display.begin(SSD1306_SWITCHCAPVCC, 0x3C); //initialize with the I2C addr 0x3C
(128x64)

  pinMode(inSensor, INPUT);
  pinMode(outSensor, INPUT);
  pinMode(relay, OUTPUT);
  digitalWrite(relay, HIGH);

  Serial.println("Visitor Counter Demo");
  display.clearDisplay();
  display.setTextSize(2);
  display.setTextColor(WHITE);
  display.setCursor(20, 20);
  display.print("Visitor");
  display.setCursor(20, 40);
  display.print("Counter");
  display.display();
  delay(3000);
```

```
}

void loop()
{
  if (!client.connected())
  {
    client.reconnect();
  }

  inStatus =  digitalRead(inSensor);
  outStatus = digitalRead(outSensor);
  if (inStatus == 0)
  {
    in = countin++;
  }

  if (outStatus == 0)
  {
    out = countout++;
  }

  now = in - out;
```

```
if (now <= 0)
{
  digitalWrite(relay, HIGH);
  display.clearDisplay();
  display.setTextSize(2);
  display.setTextColor(WHITE);
  display.setCursor(0, 15);
  display.print("No Visitor");
  display.setCursor(5, 40);
  display.print("Light Off");
  display.display();
  Serial.println("No Visitors! Light Off");
  delay(500);
}
else
{
  display.clearDisplay();
  display.setTextColor(WHITE);

  display.setTextSize(1);
  display.setCursor(15, 0);
  display.print("Current Visitor");
```

```
display.setTextSize(2);
display.setCursor(50, 15);
display.print(now);

display.setTextSize(1);
display.setCursor(0, 40);
display.print("IN: ");
display.print(in);

display.setTextSize(1);
display.setCursor(70, 40);
display.print("OUT: ");
display.print(out);

display.display();

Serial.print("Current Visitor: ");
Serial.println(now);
Serial.print("IN: ");
Serial.println(in);
Serial.print("OUT: ");
Serial.println(out);
delay(500);
```

```
  }


  if(now>= 20)
  {
    digitalWrite(relay, LOW);
  }
  else
  {
    digitalWrite(relay, HIGH);
  }
  int relaystatus = digitalRead(relay);
  client.add("in", in);
  client.add("out", out);
  client.add("now", now);
  client.add("Light Status", relaystatus);
  client.ubidotsPublish("ESP8266");
  client.loop();
  Serial.println();
  delay(100);
}
```