Recent Applications of Internet-of-Things in Monitoring and Analysis

Edited by
Lini Lee
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Foreword

The Internet of Things (IoT) paradigm has grown by leaps and bound in the past years. IoT has given rise to many interesting applications and resulted in the development of new technologies that are designed specifically for IoT-oriented tasks. It continues to hold great promises in affecting our lives as this technology is utilised in a vast of applications which require monitoring and analysis.

Unlike other books on IoT that are available in the market, this book provides several undergraduate projects undertaken at Multimedia University. The authors have designed this book carefully so that it acts as a reference for further exploration of IoT-related projects. Rest assured readers will find this book resourceful leading to a new understanding and many innovative IoT projects in the future.

I would like to congratulate the editors, authors, and MMU Press for this wonderful effort, which is beneficial to the academic fraternity across all levels. Well done!

Prof. Ir. Dr. Hairul Azhar bin Abdul Rashid
Vice President
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2021

Preface

The Internet of Things (IoT) is a rapidly advancing area of research which underlies digital transformation. It holds great promise of effecting many positive changes in various aspects of life as this technology can be utilised in a myriad of applications which require monitoring and analysis.

This book is a compilation of several undergraduate projects undertaken at the Multimedia University on the applications of the IoT. Five exciting applications for monitoring and analysis are described in this book; these are useful as reference for further exploration on projects relating to the IoT. The technical depth is geared towards college and undergraduate students in science and engineering, although the book could serve as an interesting read for the general public as well. We believe that this book will provide the reader with a broad view of what can be achieved through digitalisation enabled by the IoT.

Happy Reading!

Lini Lee & Sin Liang Lim
Faculty of Engineering
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2021

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Introduction

The Internet of Things (IoT) is a connection of devices which are able to communicate through the internet so that data exchange can take place. These devices are equipped with sensors and appropriate software as well as unique identifiers such that the communication between these “things” can occur without human intervention. Data from the sensors go through one or more access control layers before being filtered, stored and passed to the end user for monitoring and analysis.

The proliferation of IoT has been partly spurred by advances in sensor technology. Low-cost sensors, low power consumption and little maintenance make IoT implementation very attractive. Examples of these are sensors which have become ubiquitous in wearable devices for healthcare monitoring. Home automation is another area which has benefited tremendously from the IoT. Here, the use of IoT is driven further by computing technologies such as image recognition and natural language processing.

In the enterprises, advances in cloud technology and the decrease in the cost of data storage have quickened the digital transformation. On the other hand, demand for automation have been fuelled by problems related to labour laws with some difficulties in managing labour-intensive factories especially during the pandemics. The lowering cost of intelligent devices increases the attractiveness of industrial automation based on IoT as a way of improving operational efficiency. Add on to that, data analytics serve as an important tool giving greater insights in the operations.

The combined advances in sensor technology, computing and cloud technology ensure that the IoT finds use in various diverse applications. This book describes five interesting applications, namely egg sorting, heartbeat monitoring, prayer monitoring, greenhouse monitoring and interactive kiosk. A synopsis of each chapter is given below.

Chapter 1 discusses the design and construction of a prototype egg sorter which can be used in the egg industry for determining the size of an egg. This is important for improving the efficiency of the egg production in differentiating the grade of the egg. The method is expected to be more reliable than the traditional way which is by human inspection. Image processing is used to extract the egg's features and its grade is determined based on the contour area covered by the egg.

In Chapter 2, a wireless intelligent Internet of Things for Tele-Healthcare Heartbeat monitoring system is designed as a useful e-health tool which can assist medical professionals in disease diagnosing, remote monitoring and medical treatment. The heartbeat measured on the patient using a pulse sensor is transmitted through Wi-Fi to a coordination layer which acts as the database/server to process and analyse the data collected. The system triggers an alarm if the heartbeat rate is beyond the threshold value.

In Chapter 3, the design of an assistive prayer monitoring system for elderly Muslims is described. The system comprises a smart prayer mat and a mobile application. By tracking the movements of the worshiper based on an infrared distance sensor and a pressure sensor, the system is able to display a *rakaah* (cycles of prayer) counter, amongst several other functions such as determining the correct direction of the *Qibla*. An Internet of Things platform is used to connect the smart prayer mat with a cloud storage and an Android mobile application is developed to retrieve and view the data stored.

Chapter 4 describes the design and construction of a greenhouse monitoring system. The temperature, humidity, light intensity and moisture in the soil are monitored in real-time. These sensor data are used to control a fan, a light and a water pump. This system uses two Arduino modules as transmitter and receiver platforms to process readings from the sensors and send signals to actuators through radio frequency communication. By accessing the laptop or mobile phone, the user can continuously monitor the conditions in the greenhouse via a ThingSpeak cloud account.

Chapter 5 explores the use of IoT for an interactive kiosk that serves as a smart locker. The system offers the users a locker to place their belongings securely and in the most efficient smart way with minimum required credentials. The kiosk will request the user for fingerprint before granting access to the locker. With the aid of Raspberry Pi and Arduino, the duration for storage can be set by the user. The system is intended for use especially at educational institutions to provide students with a smart campus experience.

1
Industrial Based Chicken Egg Sorter with Image Processing and Data Analysis

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Abstract - This project discusses the mechanical structure, application software, and controller design for an egg sorter which can be used in the egg industry. The machine will provide an alternative way of determining the size of an egg using image processing. This is important to improve the efficiency of egg production in differentiating the grade of the egg. The traditional way by human inspection and weight of the egg can be unreliable as outside factors can intervene in the process. Therefore, this project will study the egg's external behaviour and extract the egg's features to sort the egg. The camera attached to the Raspberry Pi is used to capture the image of the egg. The image processing occurs in the Raspberry Pi. The stepper motor is used to control the egg's motion, while servo motors are used in sorting the egg. A prototype of a chicken egg sorter has been built. When tested with eggs from three different grades, the prototype has performed satisfactorily, with an average error of 0.74% for the measured length and an average error of 1.57% for the measured width.

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INTRODUCTION

The IR4.0 based automation technology in industry diversification has increased its importance towards the rhythm in industrial pace and activities. Economical pressure and price competition have pushed the industries to grow the production line efficiency to survive in a competitive era. The automated production line has inspired the workers to shift a level up into more skilful labours. Current trends in automation have the advantages of letting the robots and mechanical arms do the hard labour jobs and the current labour can upgrade their skills to monitor and control the robotic arms. The new work styles not only reduce the health and safety hazard in the workplace, but they also upgrade the workers to become more skilful workers, to excel in the high-speed manufacturing era. This consistency in robotic and mechanical production lines has targeted the increasing demand for food, water, and basic necessities in life.

The agricultural industry has shown significant improvement throughout the years with the help of new technologies that are rapidly developing. The rise of demand and governance of food security has become a catalyst for implementing various technologies in the industry. As a result, high-definition imaging machines and monitoring sensors are increasingly applied in different kinds of food governance applications such as controlling, monitoring, and sorting. The technologies are used to ensure the consistency of producing high-quality products.

In the egg industry, the eggs have to pass through various quality control processes before they could be certified and placed on the shelf at grocery stores. The main processes of chicken egg farming are laying eggs, transporting, washing, candling and grading, packing, and marketing. The production line facilities require various procedures and technologies in order to produce eggs of the best quality. The production line process starts with the chicken laying eggs. After collecting the eggs, the next process is transporting or transferring the eggs from the farm to processing facilities. For small entrepreneurs, the eggs will be sold to other processing firms or companies. At the processing facilities, the eggs will be washed and cleaned. The eggs will be put on the conveyor and moved through brushes and underwater jets to remove dirt. The eggs will be blown by a fan for drying. After the eggs are cleaned, they will go through the candling and grading process. This process will determine the size and defects of the eggs. Any egg with a defect such as a cracked shell will be removed. Next, the eggs will be sorted depending on their grade, which is grade AA, B, C, and D. The eggs will proceed to the packaging process. They are packed commonly in a dozen or in a pack of 30 eggs. The eggs will then be ready to be transported to nearby local stores for sale to the consumers.

For the conventional method, which is mainly based on the classification of egg sizes through the egg weighing method, several problems arise when weight loss happens during different seasons of the year. This is especially obvious when the weather changes (Indirapriyadharshini et al., 2021).

PROBLEM STATEMENT

The classical approach of grading the eggs' quality based on their respective weights causes the production batch to be less appealing to the customers and frequently does not accomplish the standardised quality assurance in the sector. This is due to human bias or inconsistency in the grading selection process (Alphany & Val Irwin, 2018). Although guidelines are established, biasing exists occasionally due to differences in perspective towards the grading process. There is an urge for a better understanding of the eggs grading method via digital image processing in order to assure the quality of eggs production can be continuously improved from time-to-time (Valeriy et al., 2020). Essentially, the problem must be addressed so that a major setback such as inaccuracy in the grading of eggs can be resolved.

Two objectives have been defined in this project in order to overcome the aforementioned problem. Firstly, a grading classification method is to be developed by integrating the digital image processing and automation system for easier grading identification and modelling. Secondly, the features of the automation system in detecting the assigned products in accordance to their shape and size parameters are to be studied and analysed.

METHODOLOGY

This section contains descriptions explaining the project architecture, system, and methods that have been carried out to accomplish this project's goals. These involve the system design process, flowchart, analysis, and processes that are taken into consideration in the project. Hardware specifications, software algorithm, and its installation are discussed in detail.

The first part is the inserting section. This part is where the egg will be inserted and will be transferred to the next part. This part requires the user to put the egg on the plane or ramp at the prototype egg sorter. The process is started with a kick-start button which is attached to the controller. When the power supply is turned on, the controller will stand by in a ready mode that accepts triggering input from the button. Once the user excites the mechanical button, the system will be executed automatically. Several calculations are needed to determine the desired angle of the inclined ramp to allow the egg to roll and reach the next section. The inclined plane has a length of 30cm. The assumptions that are made are as follows:

a) the required force to break an egg is 25N,
b) the egg will stop at the end of the ramp,
c) the impulse time is 0.01s,
d) an egg has a mass of around 60g, and
e) the frictional force is neglected.

The following section is the processing section. In this part, the egg will roll into a slot of a cylindrical nylon block. This cylindrical block will be rotated and transfer the egg to the sorting section. The cylindrical block is attached to a stepper motor that controls its rotation and bearing on the other end as rotation and holding support. Besides, the block will stop perpendicularly to the camera to capture the image of the egg.

Figure 1.1 shows the mechanism of the sorting section. A corresponding photo of the prototype is shown in Figure 1.2. The egg is rolled into a slot, which will determine the grade of the egg; either it is A, B, or C. There are three slots, and the servo motor will control their opening and closing. The sorting slot is raised so that it is in an inclined position thus allowing the egg to roll into the slot due to gravity. The approximate angle of the inclination is about 30°.

Figure 1.1

Three-dimensional model of the prototype egg sorter

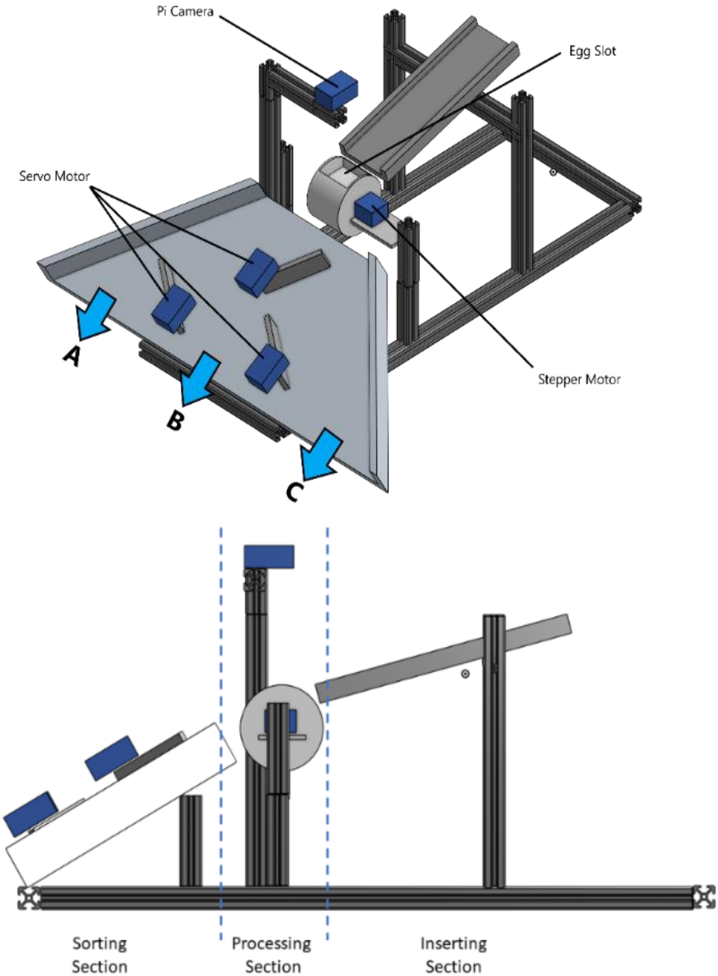


Figure 1.2

Mechanical prototype of the egg sorting section

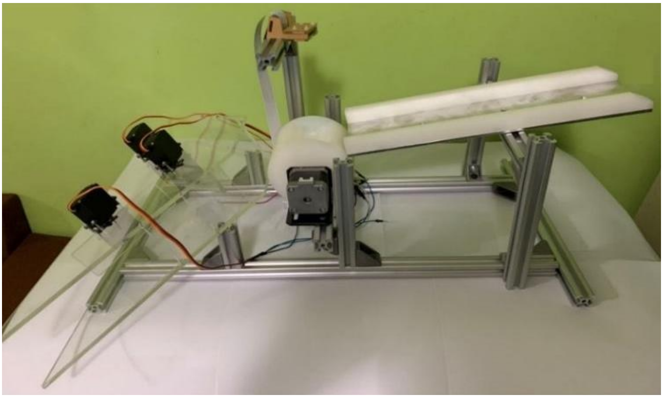
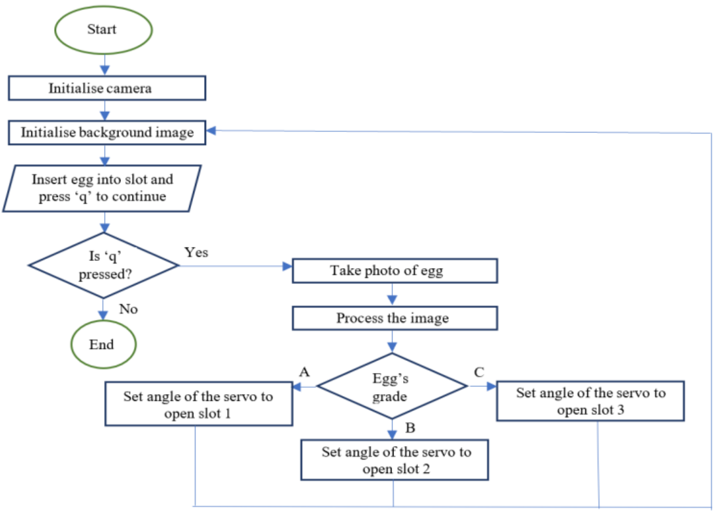


Figure 1.3

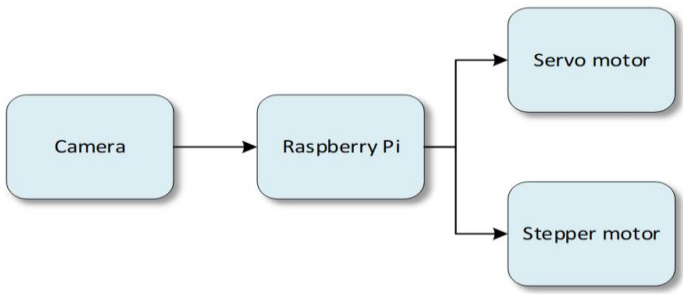
Flow chart of the chicken egg sorting process



The diagram in Figure 1.3 shows the sequence of operations of the chicken egg sorting machine. It starts with initialising the camera and other parameters. Next, a single photo of the slot without any egg is captured, converted, and saved as a reference image. Then, the machine is ready for the user to insert the egg into the camera slot. The user is required to press the ‘q’ key. The program will check for the inserted key. If the key inserted is ‘q’, the program will continue to capture the photo of the egg. Otherwise, the program will stop executing. After taking the photo, the image will be analysed and processed accordingly to determine the egg’s dimension and grade. When the egg’s grade and size have been determined, the angle of the servo motor will be set according to the designated slot. The egg will then be being sorted depending on its grade by getting into the right slot. The program is then repeated with initialising the image and requesting the user insert an egg.

Figure 1.4

Block diagram showing the connections between the camera, Raspberry Pi, servo motor, and stepper motor



The connections between the camera, Raspberry Pi, servo motor, and stepper motor are set up as shown in Figure 1.4. The Raspberry Pi is the platform for the elements to communicate with one another. It is also an element where image processing will take place. The camera is used to capture the photo of the egg, which then allows the Raspberry Pi to process the image in determining the dimension of the egg. The servo motor MG996R is used to open and close the slot according to the determined grade of the egg. For the servo motor, the signal wire is connected directly to the Raspberry Pi controller which provides a particular pulse-width modulation (PWM) signal to determine the angular position of the servo motor.

The model of the stepper motor used is 17HS8401. The stepper motor will transfer and control the motion of the egg from the ramp to the designated slot. The stepper motor is connected to a stepper controller of model TB6600. The stepper motor controller is linked to the Raspberry Pi controller which provides a pulse signal for triggering rotation with an angle of 1.8deg/step. Proper synchronisation of motion from the stepper motor and servo motor regulated by the Raspberry Pi controller ensures that the eggs slide smoothly into the particular slots according to their sizes.

DIGITAL IMAGE PROCESSING

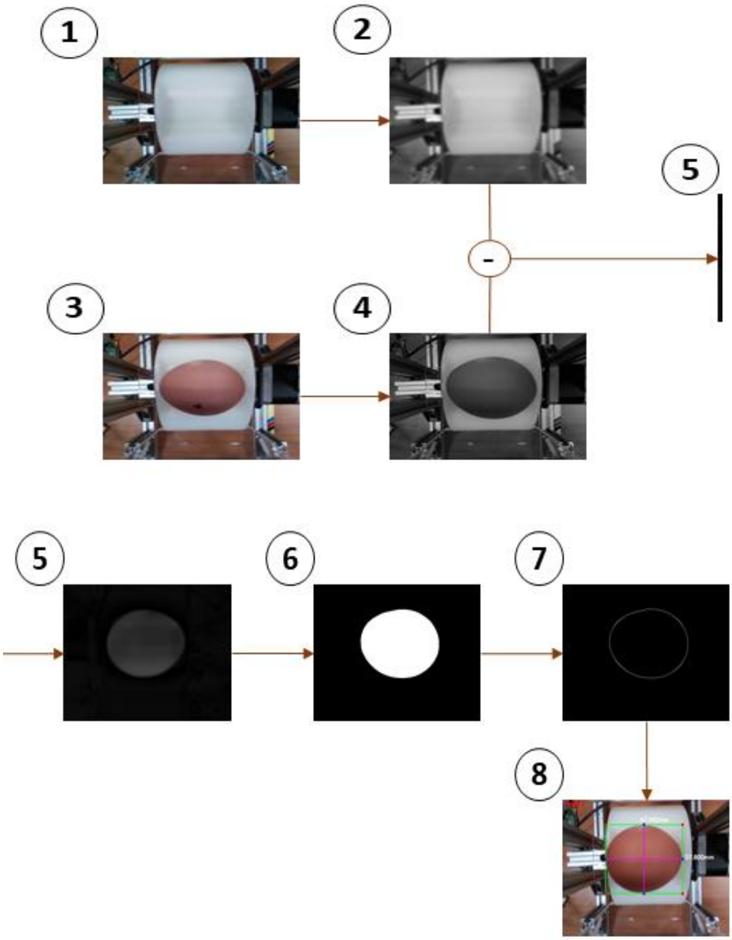
A technique of performing some operations on an image is called image processing. It is implemented in a system to beautify the image or extract useful information from it.

The output of this method may be a new form of an image or any other parameters which are relevant to the image and the system being implemented.

In this project, image processing is fully utilised in determining the grade of an egg. From the illustration in Figure 1.5, this process starts with image acquisition by taking an image of the empty slot. The image will act as a background image and be temporarily stored. The image is converted to a black and white image to avoid any hue that may interfere with determining the contour of the particular object and allow it to be processed faster. After the egg gets into the camera slot, image 3 and 4 require the same process as the first two previous steps before proceeding to the next process (Htet et al., 2020). Next, the images will undergo image segmentation. The black and white image of the egg is compared to the background image that is temporarily saved initially. By finding the absolute difference between both images, the background of the egg will be removed. This will leave an object of an egg, as shown in image 5. This approach of background subtraction allows the determination of the presence of the egg in the slot (Valeriy et al, 2020).

Figure 1.5

Illustration of the steps in the image processing

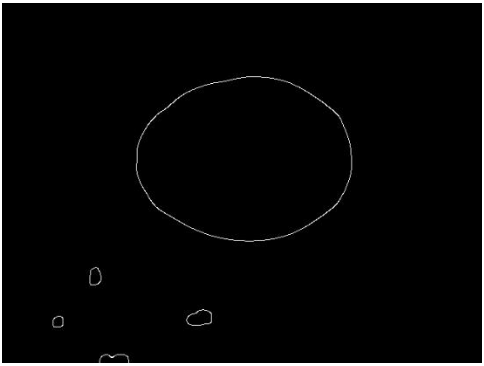


The image will further undergo image thresholding to increase the precision for the next process. After thresholding, a clearer and sharper image of the egg can be obtained in image 6 (Manikandan et al., 2021). The image thresholding process is essential to remove any noise around the object and to get a much more prominent object. In image 7, the contour of the object in the image will be found through the image contouring process. From the determined contour, its area is the feature that will be used to differentiate the grade of the egg (Valdez et al., 2017). To calculate the approximate length and width of the egg, a rotated bounding rectangle of the egg will be constructed, and the coordinates of all its corners will be extracted. After that, the midpoints of the sides of each bounding box will be calculated. The distances between the midpoints of the parallel sides will be computed, and they will represent the length and width of the egg in terms of pixels. The distance is calculated using the Euclidean distance which calculates the distance of a true straight line between two points (Srihari et al., 2020). By dividing those values with the ratio of pixel to the actual length, the approximate computed length can be obtained. In the end, the final image display will provide the egg's grade, length, and width (Kumaresan et al., 2020).

When the egg is placed into the camera slot, the image of the egg will be captured. The picture will go through several image processing steps: colour conversion, background elimination, image thresholding, edge detection process, and image contouring. The example result of a contoured image of an egg is shown in Figure 1.6.

Figure 1.6

Contour image of a scanned egg



From the contoured image, the full outline of the object detected can be seen in the image. The egg will produce a very large contour in a frame. This image can provide information about the object from the characteristics of the contour. The area of the contour of the egg is used to determine the right size and grading of the egg. The function cv2.contourArea() is used to extract the pixel area of the egg. For this experiment, a total of 3 samples are taken for each grade and the average value for the grade is tabulated. Table 1.1 shows the value of the pixel area occupied by the different grades of eggs.

Table 1.1

Average value of contour area of the eggs

Grade	Value 1	Value 2	Value 3	Average
A	55299.0	55087.5	55348.0	55244.8
B	51298.0	51288.5	51256.0	51280.8
C	47704.5	47604.5	47686.0	47665.0

DATA ANALYSIS

From Table 1.1, the different grades of eggs occupy different values of the contour area. The benchmark range is tabulated in Table 1.2. A Grade A egg has the highest value of the contour area, followed by a grade B egg and a grade C egg. This result is obtained because the egg has different sizes where grade A has the largest size, and grade C has the smallest size. The larger the size of an egg, the larger its contour will be in the picture. The larger the contour is, the higher the value of its contour area. This finding is substantially useful in determining the grade of an egg.

Table 1.2

Benchmark of range of contour for the eggs

Grade	Range of the value of contour area
A	More than 53500
B	Between 49000 and 53500
C	Less than 49000

The range of the contour area value for each grade of eggs is approximated by comparing the difference between the values for the different grades. The benchmark range is defined with reference to the range stated by Lubich et al. (2019). The given range will help in determining the desired slot depending on the grade of the egg. However, there are a few other contours of objects found during the process from the contoured image. This happens because noise and other unnecessary objects are captured into the frame during the capturing process. These are contoured due to a difference between the captured and the reference images (Waranusast et al., 2016). By obtaining the value of the contour of those unnecessary objects, it is found that the highest value of the contour area is approximately 3000 (Quilloy et al., 2018). Since the smallest contour area value for grade C is 47604.5, any contours with an area below 10000 will be neglected from being further processed (Mappatao, 2018).

The final image display is shown at each end of the sorting process with the given grade, length and width of the egg. If there is no egg present inside the slot, an empty slot with no egg status is shown. The final image displays for different situations are shown in Figure 1.7 and Figure 1.8. From the final image displays, the computed length, and width values shown are compared with the actual length and width values of the eggs. Table 1.3 shows the difference in the measurements.

Figure 1.7

Final image displays for grade A egg (left) and grade B egg (right)

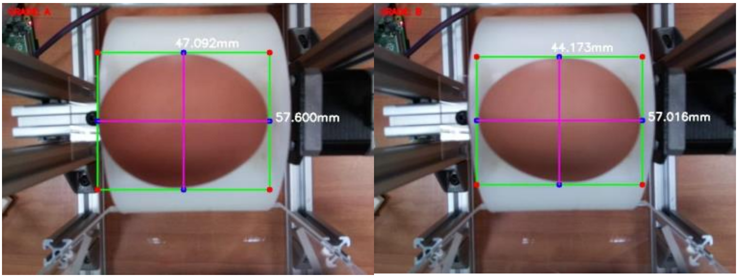


Figure 1.8

Final image displays for grade C egg (left) and no egg (right)

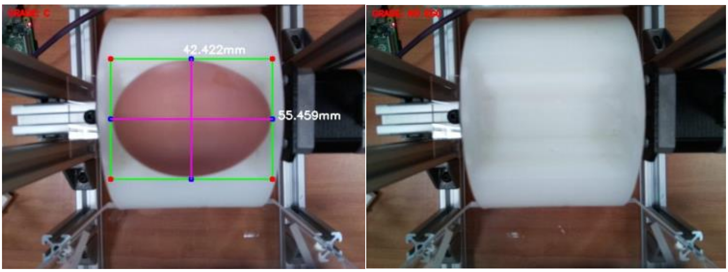


Table 1.3

Difference in the measurements between actual and computed length and width values

Grade	Measurement	Value (mm)	Difference (mm)	Percentage error (%)
A	Actual length	57.50	0.10	0.17
	Computed length	57.60		
	Actual width	46.30	0.79	1.71
	Computed width	47.09		
B	Actual length	56.70	0.31	0.54
	Computed length	57.01		
	Actual width	43.60	0.57	1.29
	Computed width	44.17		
C	Actual length	56.30	0.84	1.51
	Computed length	55.46		
	Actual width	41.70	0.72	1.70
	Computed width	42.42		

The analysed data of the measurements of the eggs show that overall, the percentage error of the computed value is higher for lower grade and smaller size of the eggs. A total of 3 samples are taken and the average value is obtained for four parameters which are the actual length, computed length, actual width, and computed width. The computed values are close to their actual values, and as the eggs become smaller, the computed values become lower. The highest percentage error is 1.71 % which is tolerable in this project.

CONCLUSION

A thorough analysis of the construction and process of the mechanical and electronic system design has been executed successfully in this project. In this application, image processing is a feasible method to be used in the sorting of the chicken eggs depending on their grade or size. The results of the average values of the contour area of 55244.8, 51280.8, and 47665.0 for grade A, grade B, and grade C eggs, respectively. This allows the determination of the range of values of the contour area for each grade. It also helps to construct the optimal algorithm for differentiating an egg, based on its grade. Then, the sorting process can be done correctly and successfully by giving the correct angle for the servo motor to open or close the sorting slots. In this project, the study on obtaining the approximated length and width of the egg has been successfully implemented. The small percentage error which is lower than 2% shows the relevance of using the technique in determining the grade of the egg and provides high accuracy on the dimension of the egg. This gives the farmer or entrepreneur the information to verify the classification and sizing of the egg.

There are some limitations for this chicken egg sorter which is currently only a prototype. The number of eggs which can be scanned and filtered is limited by the time requirement of 3 seconds for each egg. The speed of image capturing and processing is limited by the amount of random-access memory (RAM) in the Raspberry Pi controller. For a chicken egg farm, the eggs are passed down on a conveyer belt, and many eggs roll down simultaneously. A soft surface and an improved chicken egg sliding mechanism are necessary to avoid the eggs from being broken.

Future work that is of great interest is implementing machine learning to determine the volume or mass of the eggs. On top of that, the features of detecting the freshness of the egg using artificial intelligence will enable the user to examine the quality and defects which are not obvious from the observation by naked eyes. The user can also differentiate the rotten or cracked eggs and filter them out before proceeding to the next stage.

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2
Internet-of-Things for Tele-Healthcare Heartbeat Monitoring System

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Abstract - Advances in computer and communication technology, the deployment of Internet of Things applications and services is accelerating across the world. New revolutionary healthcare service is developed with the integration of modern biomedical instrumentation, computer and communication technologies, and a conventional healthcare approach. This work proposes and develops a wireless intelligent Internet of Things for Tele-Healthcare Heartbeat (IoT-THH) monitoring system. The system architecture of the IoT-THH consists of four layers, i.e., perception layer, network layer, coordination layer, and application layer. The heartbeat measured on the patient using the pulse sensor (perception layer) is transmitted to the coordination layer through Wi-Fi (network layer). The coordination layer acts as the database/server to process and analyse the heartbeat data collected. The alert system in the application layer is triggered once the heartbeat rate collected is beyond the threshold value. The IoT-THH monitoring system is designed to assist medical professionals in disease diagnosing, remote monitoring, and medical treatment. The modernised healthcare approach helps to optimise healthcare efficiency, improve human health status and reduce fatality rates by providing early diagnosis and medical treatment to the patients. A prototype that consists of an electric imp002 microcontroller, a Pulse Sensor Amped, and a green LED light is developed. Extensive experimental works are carried out to evaluate the performance of the IoT-THH prototype with the commercial Medisana heartbeat measurement device. The

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accuracy of the IoT-THH is comparable with the commercial Medisana heartbeat measurement device.

INTRODUCTION

According to American Heart Association (AHA)'s 2015 Heart Disease and Stroke Statistic, 8 million people died of cardiovascular diseases, 3.7 million people died of heart disease, 1.2 million people died after a stroke, 1.1 million people out of 7.5 million people killed by heart attack and about 7.9 million people experience disability due to stroke in the United States (American Heart Association, 2015). Heart disease is the leading global disease that causes death. Worldwide, 17.9 million death cases were reported in 2019 due to heart disease (World Health Organization, 2021). 8.6 million death cases happened to women annually due to heart disease instead of cancers. As reported by American Heart Association, the number of death cases due to heart disease is expected to rise to more than 23.6 million cases per year by 2030 (Mozaffarian et al., 2016; Smith, 2012).

Early diagnosis of heart and cardiovascular diseases brings a better and healthier life. Research is focused on information and communication technology for the development of new intelligent tools or devices for healthcare services. A computer-based monitoring system is designed to support real-time remote monitoring on the patients, assuring a better quality of healthcare services and reducing the fatality rates by providing in time medical treatment (World Health Organization, 2017).

In this work, an Internet of Things for Tele-Healthcare Heartbeat (IoT-THH) monitoring system is proposed for real-time heartbeat monitoring for early diagnosis of heart and cardiovascular diseases. The general information of the healthcare system is presented in the section “Healthcare”. In the section “Architecture of IoT-THH”, the overall system architecture of IoT-THH is presented. The experimental results taken by the IoT-THH monitoring system are presented in the section “Experimental Results”. Ultimately, a conclusion is drawn in the last section.

HEALTHCARE

The world population is increasing day by day, leading to the high demand for healthcare services and more options for healthcare facilities and technologies. Advances in computer networks and communications led to the development of a new revolutionary medical healthcare referred to as e-health. There is a breakthrough in healthcare with the implementation of an at-home health service to patients rather than an in-hospital health service. An ambulatory system that allows real-time remote monitoring of the patient’s condition is in demand. Combining modern biomedical instrumentation, computer, and telecommunication technologies, a patient monitoring system should be capable of monitoring, gathering, recording and transmitting the physiological data measured from patients remotely. Many studies are carried out to evaluate the potential of tele-healthcare, especially during the COVID-19 pandemic (Krishnamoorthy et al., 2021).

Wearable intelligent healthcare devices have gained much interest in recent research (Lee & Lee, 2020; Matthew et al, 2021). Singh and Jain (2015) proposed that a wireless physiological monitoring system be introduced to measure a patient's body temperature, oxygen saturation, and heart rate. The physiological data measured on the patients are transmitted to a smartphone via Bluetooth for data analysis. A wireless body area network for healthcare monitoring has been implemented (Wahanea & Ingole, 2017). Many health sensors can be added to the wireless health system to monitor the patient's health condition. The physiological data measured on the patient are transmitted to an Arduino microcontroller that acts as a base station via ZigBee communication technology and eventually to a Structured Query Language (SQL) database via a Wi-Fi network (Wu et al., 2017). The medical records can be examined by the medical experts or consultants remotely for early medical diagnosis and treatment. Wi-Fi is used as a communication network by IoT-THH systems as it is more economical and widely used in the world rather than ZigBee and Bluetooth.

ARCHITECTURE OF INTERNET OF THINGS FOR TELE-HEALTHCARE HEARTBEAT

A real-time heartbeat monitoring healthcare device is introduced for real-time monitoring, early medical diagnosis, and medical examination. As shown in Figure 2.1, the architecture of the IoT-THH system consists of 4 layers, i.e., perception layer, network layer, coordination layer, and application layer.

Figure 2.1

The Architecture of the Internet of Things for Tele-Healthcare Heartbeat (IoT-THH) system

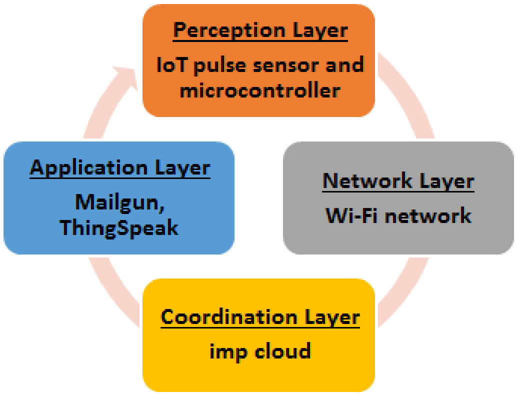
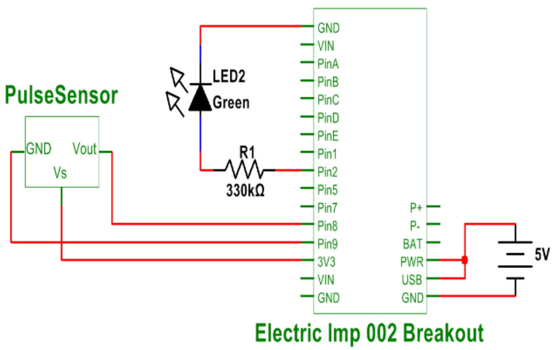


Figure 2.2

Circuit of IoT-THH monitoring system

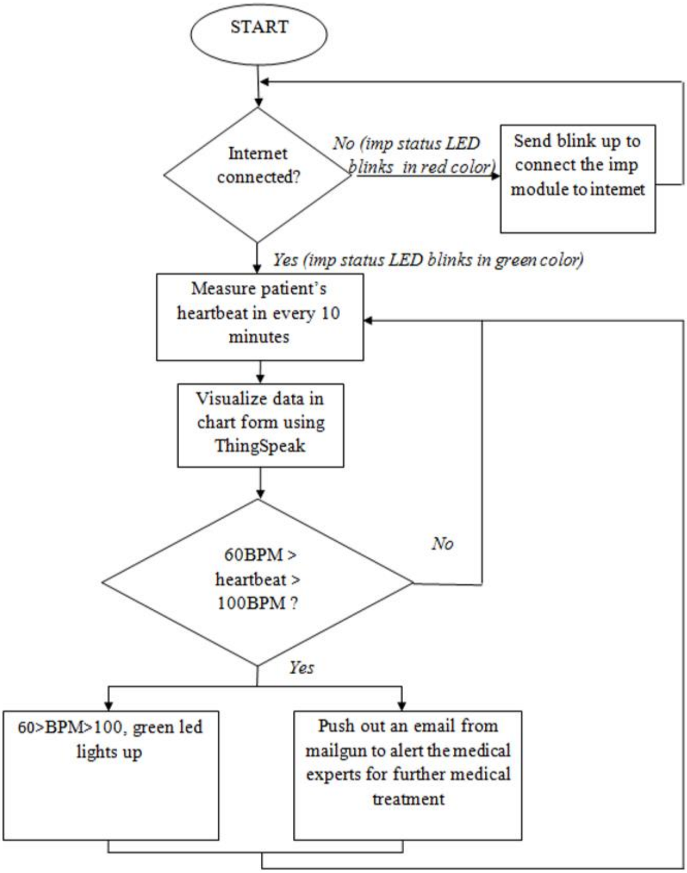


The circuit of the IoT-THH system designed is shown in Figure 2.2. The IoT-THH system measures the patient's heartbeat continuously every 10 minutes and its operation flow chart is shown in Figure 2.3.

The pulse sensor is attached to the measurement site, i.e., ear, axilla, hand, and finger, where the heartbeat can be taken. The heartbeat taken from the patient is measured and gathered continuously every 10 minutes and sent to the imp cloud via a local area wireless network. The heartbeat data are transmitted and stored in ThingSpeak that can be visualised in a graphical format to have a better view for inspection. The server will trigger a signal or alarm to the patient and medical experts when the heartbeat data collected are out of the norm. An email is pushed out from the Mailgun email automation service to the medical experts to alert them for further medical treatment. A red light-emitting diode (LED) is lighted up to alert the patient on his/her critical condition when an abnormal heartbeat rate is detected. Whenever the heartbeat measured from the patient is abnormal, outside the range of 60 beats per minute (BPM) to 100 BPM, a green LED is lighted up, and an email is pushed out by the server to alert the patient and the medical experts. With the implementation of the cloud-based system, the patient's heartbeat readings are accessible on various types of smart devices uniformly and ambiguously.

Figure 2.3

The Operation flow of the IoT-THH monitoring system



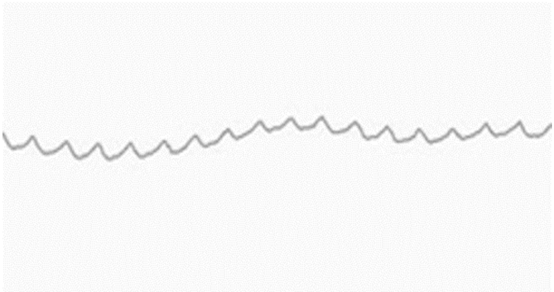
The perception layer of the IoT-THH consists of the microcontroller and pulse sensor. The pulse sensor measures the heartbeat pulse. The Electric imp002 module is used as a microcontroller to digitise and convert the analogue output obtained from the pulse sensor to the heartbeat data. Wi-Fi (network layer) is used in the IoT-THH system to transmit the heartbeat data from the perception layer to the coordination layer. A Blinkup command is used to configure the Wi-Fi details to the imp Wi-Fi module for wireless network connectivity. The coordination layer is used to coordinate the pulse sensor and the database. The heartbeat measurements taken from the patient are uploaded and stored in ThingSpeak (database). The data stored are presented in a graphical format to the end-users. An email will be sent by Mailgun to the medical expert once the heartbeat rate of the patient measured is beyond the threshold value (60 BPM to 100 BPM). Medical experts can access the heartbeat rate remotely~~,~~ and hence provide immediate medical advice.

Heartbeat Measurement

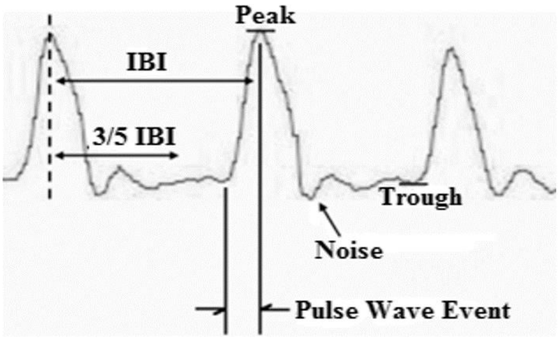
Pulse Sensor Amped is an enhanced version of the pulse sensor which is designed with a noise filtering and amplification circuit to amplify the raw signal obtained from the older version of the pulse sensor (Figure 2.4).

Figure 2.4

Saw-tooth raw signal (a) and amplified signal (b)



(a)



(b)

Pulse Sensor Amped normalised the signal to around the midpoint of the supplied voltage. It works with the principle of photoplethysmography, which measures the pulse corresponding to the relative changes of light intensity that can be detected by a light sensor. The blood vessel becomes opaque when the blood is pumped from the heart to the body, and less light is reflected to the light detector. The decrease in reflected light intensity would increase the resistance of the light detector. Hence the output voltage is higher. The signal value remains at the midpoint of the voltage when the amount of light intensity detected by the light detector remains constant. The signal goes high and beyond the midpoint voltage when the reflected light is low due to the high density of blood flowing through the blood vessels. The green LED light used in Pulse Sensor Amped; Avago APDS-9008 light detector has peak sensitivity towards electromagnetic radiation of 565 nm wavelength (Gitman & Murphy, 2018). The 16 bits analogue to digital converter (ADC) of electric imp is equalled to 65536. Hence, the midpoint of the voltage and the initial threshold amplitude are set to 32768. According to the National Institute of Health, humans have a normal maximum resting pulse rate of 100 BPM corresponding to 1 beat in 0.6 s. Referring to this, an initial interbeat interval (IBI) describing the time between heartbeat in milliseconds is set to 600 corresponding to 0.6 s to start up the Pulse Sensor Amped.

High resolution increases the reliability and the accuracy of a measurement. A regular sample rate of 500 Hz is set with a beat to beat timing resolution of 2 ms. When the electric imp is powered up with the running Pulse Sensor Amped, it constantly reads the waveform value at every 2 ms and the time since the last beat (TSLB) is calculated as shown in Figure 2.5. The peak and trough of the pulse are kept on track to measure the heartbeat accurately as shown in Figure 2.6.

Figure 2.5

Code for getting the time since last beat (TSLB)

```
for (local i = 0; i < length; i +=2) {
local sample = (buffer[i+1]<<8) || buffer[i];
local noiseMargin = IBI * 3/5;
sampleNumber++;
local TSLB=(sampleNumber -
lastBeatSample)*1000/SAMPLE_RATE;
```

Figure 2.6

Code for initialising the waveform peak and trough

```
If ((sample < thresholdAmp) &&
(TSLB > noiseMargin) &&
(sample < waveformTrough)) {
waveformTrough = sample;
}
else if((sample>thresholdAmp) && (sample>waveformPeak)) {
waveformPeak = sample;
}
```

Suppose the current waveform sample value of the pulse detected is smaller than the initial start-up threshold amplitude. In that case, the trough of the waveform is initialised to the current waveform sample value provided that the TSLB is greater than the noise margin of 3/5 IBI. The waveform peak is contrary to the current waveform sample value if the waveform sample value is greater than the initial start-up threshold amplitude. The threshold amplitude adaptively changes during operation relative to 50% of the pulse amplitude. This aims to increase the accuracy of the measurement.

The measured pulse must fulfil the minimum conditions in order to be taken for BPM calculation. The TSLB of the measured pulse must be greater than 250 ms (minimum IBI with reference to the maximum pulse rate of 240 BPM) (Gitman & Murphy, 2018). Secondly, the amplitude of the measured pulse must be greater than the threshold value so that the IBI can be calculated. Instead of using the first beat that may not be accurate due to instability, the second beat is used to seed the array in order to get a more accurate BPM. Ten sets of IBI values are obtained, and the average value is computed. The BPM is computed by dividing 60000 with the average value of the IBI, as shown in Figure 2.7.

When the waveform signal is decreasing and crosses the threshold amplitude, it indicates that the pulse is over. The Boolean pulse is cleared for the next pulse and the amplitude of the new passing by waveform signal will be measured. The threshold amplitude is updated with the new threshold amplitude relative to 50% of the signal amplitude obtained from the new passing by waveform signal. The peak and trough of the waveform are then reinitialised to the new threshold amplitude as shown in Figure 2.8, and the next beat begins. When there is no beat detected for 2.5 s, the Boolean pulse and the variables stored for heartbeat measurement are all reinitialised to the primary start-up value, ready for the next heartbeat measurement.

Figure 2.7

Code for inter-beat-interval (IBI) and beats per minute (BPM) calculation

```
If ((TSLB>250) &&
(sample>thresholdAmp) &&
(pulseFlag == false) &&
(TSLB > noiseMargin)) {
pulseFlag = true;
IBI = TSLB;
lastBeatSample = sampleNumber;
if (firstBeat) {
firstBeat = false;
secondBeat = true;
continue;
} else if (secondBeat) {
secondBeat = false;
for (local i = 0; i < 10; i++) {
intervalArray[i] = IBI;
}
}

//Calculate the average IBI from the array
//and current value

localaverageIBI = 0;
for (local i = 0; i < 9; i++) {
intervalArray[i] = intervalArray[i+1];
averageIBI += intervalArray[i];
}

IntervalArray[9] = IBI;
averageIBI += IBI;
averageIBI /= 10;
beatsPerMinute = 60000 / averageIBI;
```

Figure 2.8

Code for reinitialising the waveform peak and trough with new threshold amplitude relative to 50% of new passing by waveform signal amplitude

```
else if ((sample < thresholdAmp) && (pulseFlag == true)) {
        pulseFlag = false;
        thresholdAmp = (waveformPeak + waveformTrough)/2;
        waveformPeak = thresholdAmp;
        waveformTrough = thresholdAmp;
        }
```

Data Visualisation

ThingSpeak is an application platform that provides various services, exclusively for the implementation of IoT design. It provides access to a broad range of embedded devices and web services. It combines them into a single system and acts like a cloud that communicates the neighbouring devices across the internet to perform tasks or services. ThingSpeak enables a user to collect, store, analyse, visualise, and retrieve the data collected from physical objects, such as sensors and microcontrollers. ThingSpeak can store up to 12 fields of data in which 8 fields store any type of data, 3 fields store location data such as longitude, latitude and elevation, and 1 status field describes the data stored in the channel. The channel can be set to either private view or public view.

In private view, the channel's feed and charts can only be viewed by the channel owner. The other users can only view the channel's feed and charts by using the Read

API key generated when the channel is created. However, if the channel is set to public view, the channel's feed and charts can be viewed by the public through the specific Uniform Resource Locator (URL). In order to grant access to perform some tasks or services, a Write Application Programming Interface (API) key must be included and called in the developers' program.

Figure 2.9

Program in imp agent platform to transmit and update the physiological data to ThingSpeak via HTTP

```
local thingspeakUrl = "http://api.thingspeak.com/update";
local headers = {"Content-Type":
"application/x-www-form-urlencoded",
              "X-THINGSPEAKAPIKEY":
"3YKJ404NGAL5TSFP"};
local field = "field1";
function httpPostToThingspeak (data) {
            local request = http.post(thingspeakUrl, headers, data);
            local response = request.sendsync();
            return response;
}
device.on("updateBPM", function(BPM) {
            local response =  httpPostToThingspeak(field
+"="+BPM);
            server.log(response.body);
});
```

As shown in Figure 2.9, the ThingSpeak API key is included in the programing code in the electric imp agent platform. The program written in the imp agent platform is responsible for transmitting and updating the heartbeat data in ThingSpeak via Hypertext Transfer

Protocol (HTTP). The http.post is used by the electric imp to send out a request to ThingSpeak to store and update the channel feed continuously at an interval of 10 minutes when the heartbeat is measured. Figure 2.9 shows the encoding and inserting of the ThingSpeak username and password, ThingSpeak URL, and the Write API key into the http.post function. ThingSpeak acts as a database in which the heartbeat data can be stored and retrieved in a comma-separated values (CSV) file format.

Alarming System

Mailgun is an automatic email service established by Rackspace. It is a cloud-based email delivery service that can be programmatically integrated into a cloud application, enabling email sending, receiving, and tracking. Mailgun uses HTTP to send an email to the web application referred to as a mailbox that is accessible by the medical experts. The authorisation is needed in order to access Mailgun. The API key obtained in Mailgun gives authentication to the Mailgun API.

Figure 2.10 shows the details of the http.post function with the Mailgun URL (sender's address), mailbox URL (recipient's address), API key, and the content of the email message. An email is triggered by Mailgun to the medical experts when the patient's heartbeat reading is beyond a normal threshold reading (60 BPM to 100 BPM). The email triggered by Mailgun to the medical expert consists of the URL that links to the physiological data visualised in ThingSpeak. An LED light is used as an indicator to alert the patients on their abnormal heartbeat reading. Patients can seek medical help or treatment in case they have been left out by the medical consultants, hence preventing unnecessary delay in disease diagnosis and treatment.

Figure 2.10

Program code for triggering an email using http.post

```
local from =
“postmaster@sandbox772d9dd608b24c9fa9aa1059131b10fcmailgu
n.org”;
local to = “mmuhospital@gmail.com”;
local apikey = “key-ac7082878a8cbebb17a73elde297a533”;
local domain =
“sandbox772d9dd608b24c9fa9aa1059131b10fcmailgun.org”;
local request = http.post(“https://api” + apikey +
“@api.mailgun.net/v3/” + domain + “/message”, {“Content-Type”:
“application/x-www-form-urlencoded”}, “from=” + from + “&to=”
+ to + “&subject=” + subject + “&text” + message);
local response = request.sendsync();
server.log(“Mailgun response:” +response.body);
```

EXPERIMENTAL RESULTS

The IoT-THH system design consists of an electric imp002 microcontroller, a Pulse Sensor Amped, and a green LED light (Figure 2.11). The experiment was carried out on 2 participants by taking their heartbeat measurement using different heartbeat measurement devices. The measurement was taken for 20 minutes (with a time step of 1 minute) by using the commercial (Medisana) heartbeat device for 20 readings. The experiment was repeated by using a Pulse Sensor Amped to measure the heartbeat rate. Table 1 summarised the heartbeat measurements taken on 2 participants.

Figure 2.11

Prototype of the IoT-THH system

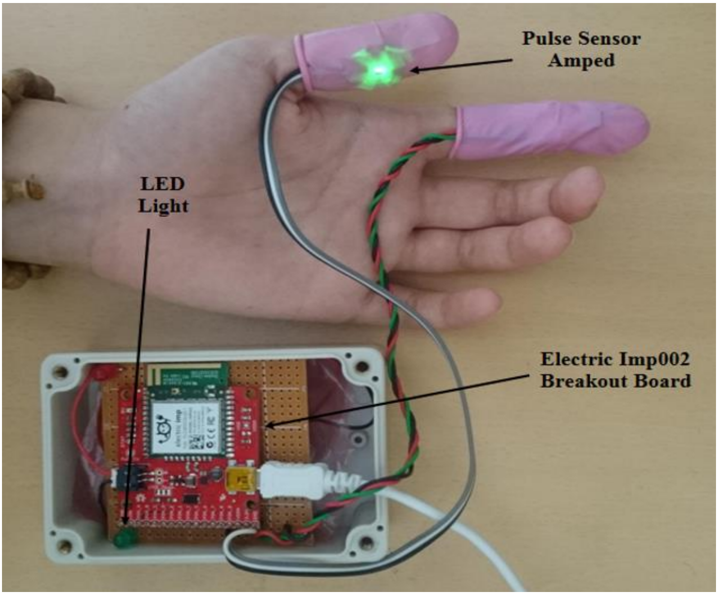


Table 2.1

Heartbeat measurement taken on participants A and B using Pulse Sensor Amped and the reference commercial Medisana heartbeat measurement device

Participant A Heartbeat rate (BPM)		Participant B Heartbeat rate (BPM)	
Pulse Sensor Amped	**Medisana**	**Pulse Sensor Amped**	**Medisana**
84	84	86	84
74	73	85	79
78	69	86	83
78	71	84	84
71	79	87	85
77	73	80	84
79	71	88	82
85	66	83	79
71	75	79	83
76	84	83	78
78	79	84	82
73	78	82	85
74	76	87	86
75	73	80	78
75	81	83	87
71	75	84	70
72	78	82	80
75	71	88	89
71	80	88	84
67	76	89	83
Average 75.2	Average 75.6	Average 84.4	Average 82.7

The heartbeat rate of participants A and B are shown in Figure 2.12 and Figure 2.13, respectively. The heartbeat measurements taken by both devices are within the range of 65 BPM to 85 BPM for participant A and 75 BPM to 90 BPM for participant B. The measurement discrepancy of the two different devices for participants A and B is shown in Figure 2.14. The highest reading discrepancy is 19 BPM, and the lowest reading discrepancy is 0 BPM.

Figure 2.12

Heartbeat rate readings taken on participant A

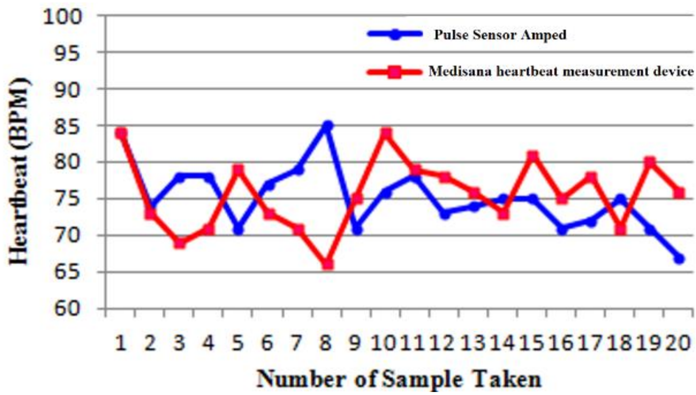


Figure 2.13

Heartbeat rate readings taken on participant B

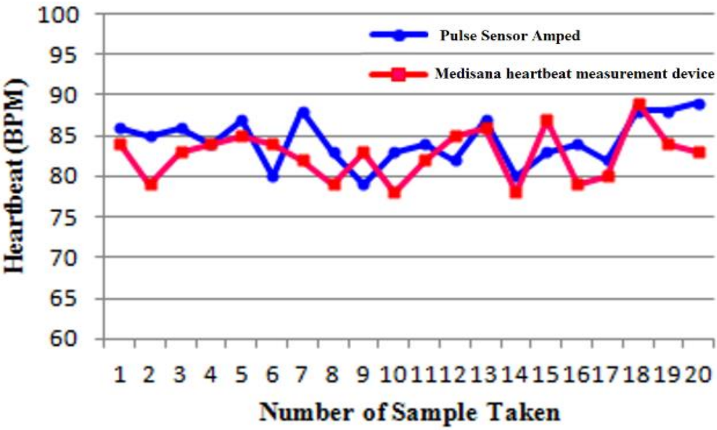
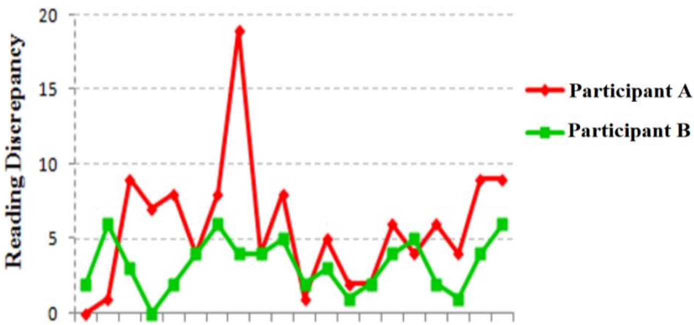


Figure 2.14

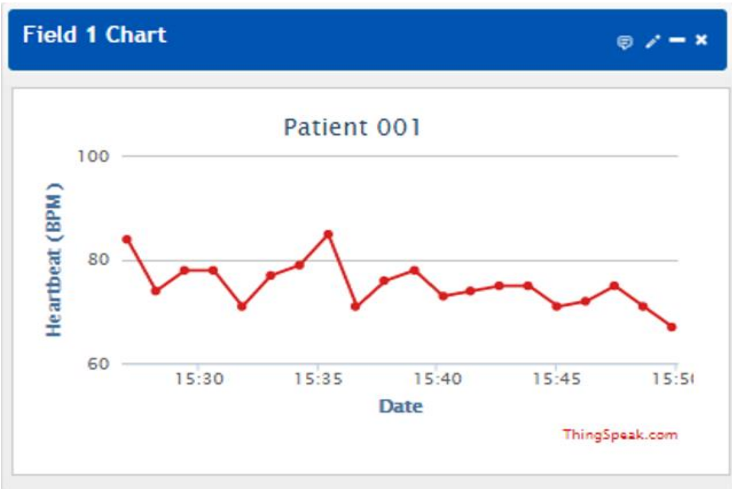
Reading discrepancy of the measurements taken on both participants A and B



The accuracy of Pulse Sensor Amped has not been defined in the datasheet. However, the accuracy of the Pulse Sensor Amped is very similar to the accuracy of the Medisana heartbeat device. ThingSpeak displays the heartbeat measurement data by visualising it in a graphical format, as shown in Figure 15. The measurement readings can be viewed through any smart device with the URL provided.

Figure 2.15

Visualisation of heartbeat data in ThingSpeak



For alerting purposes, an email is pushed out by the Mailgun email automation service when the heartbeat reading goes beyond the normal reading of 60 BPM to 100 BPM. An experiment is carried out with the heartbeat set to 70 BPM to verify if the program is functioning as expected (Figure 2.16). Real-time monitoring and diagnosing are enabled anywhere, anytime with internet availability without needing the medical experts to be on site with the patients. A green LED is lighted up when the heartbeat goes beyond the normal heartbeat range when the heartbeat reading measured from the participants exceeds the threshold reading (Figure 2.17).

Figure 2.16

Sample email pushed out by Mailgun

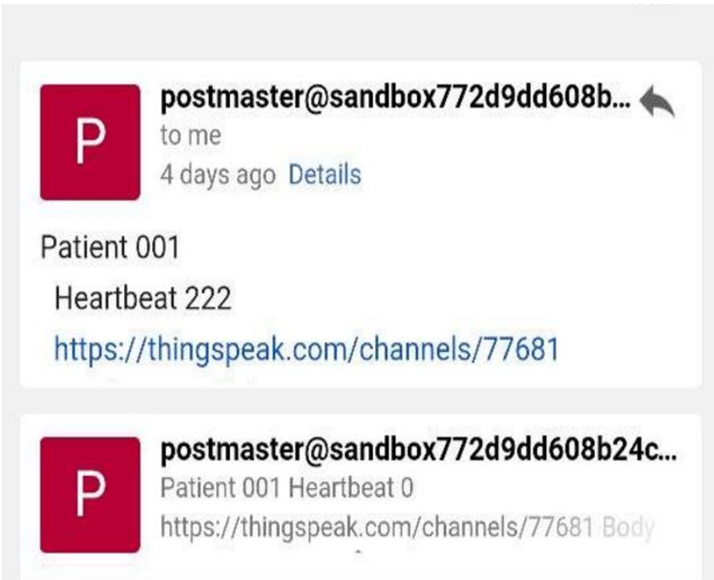
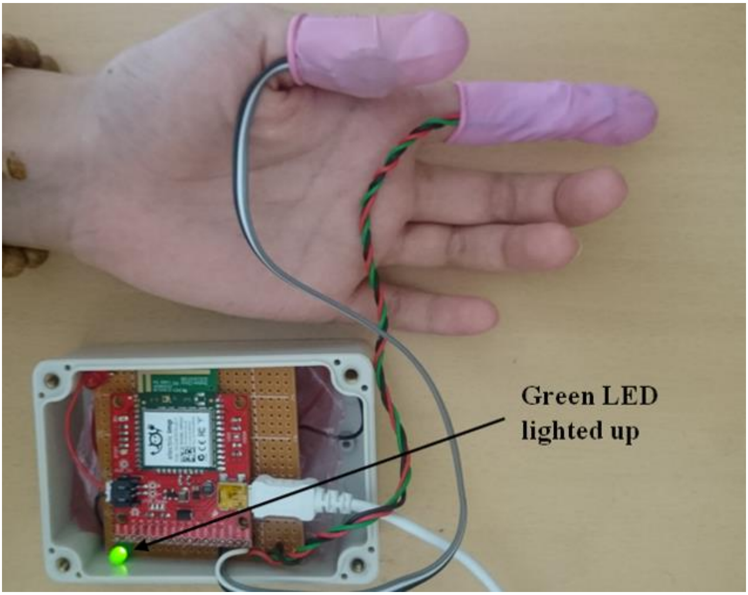


Figure 2.17

Green LED is lighted up when heartbeat goes beyond normal heartbeat range



CONCLUSION

The low cost and easy to use wireless IoT-THH system is proposed in this work to monitor a patient’s heartbeat. The IoT-THH system is capable of measuring, gathering, analysing, and processing the heartbeat of the patient continuously and consistently. The IoT-THH system consists of 4 layers, i.e., perception layer, network layer, coordination layer and application layer. The pulse sensor in the perception layer is used to measure the heartbeat of the patient. Wi-Fi is used as a transmission network for the data transmission among the perception layer and coordination layer. The heartbeat data gathered are sent to the server (coordination layer) that acts as a database. The data gathered are analysed and processed by the coordination layer. An alarming signal will be triggered by the coordination layer to the application layer. The LED light is lighted up, and an email is pushed out to alert the patient and medical experts on the patient's condition once the heartbeat reading of the patient is beyond the normal threshold reading. An extensive experiment has been carried out to study the accuracy of the pulse sensor. The accuracy of the Pulse Sensor Amped is comparable with the commercial Medisana heartbeat monitoring device. Extra sensors such as temperature, blood pressure, etc. can be added to collect and monitor more health data in future.

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3
Assistive Prayer Monitoring System for Elderly Muslims

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Abstract – Elderly Muslims face several challenges in performing daily prayers such as forgetting the number of *rakaah* (cycles of prayer), prayer recitation, and even the prayer times. In this work, a prayer monitoring system is proposed in the design of a smart prayer mat to track the movements of the worshiper based on an infrared distance sensor and a pressure sensor. In addition, it has the ability to determine the correct direction of the *Qibla*. Audio and visual effects have been added too to make the system more effective. Finally, an Internet of Things platform connected the smart prayer mat with cloud storage, and a mobile application was developed to view the data. The system was tested by an elderly man for four consecutive days, and the results indicated the effectiveness of the proposed system. The designed prayer monitoring system has the ability to track the movements of the user while praying, upload the prayers data to the cloud and monitor the prayer activities through an Android application.

INTRODUCTION

According to the statistics by the United Nations, life expectancy in Malaysia has increased from 67.9 years in 1980 to 76.2 years in 2020 (Macrotrends, 2021). The population of people aged 65 years and above has grown over the years. Globally, the older population is expected to increase from 9.3 percent in 2020 to around 16 percent

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in 2050 (United Nations, 2020). Therefore, there is a greater need for a support system for older people choosing to remain in their own homes.

With the advancement of electronic devices and the internet, assistive technologies have gained interest among the older population. There are several existing assistive technologies to support independent living of the elderly such as mobility assistance (Shishehgar et al., 2019), medical adherence system (Sherif et al., 2020), and home monitoring system (Sherif et al., 2019; Tabbakha et al., 2019). A comprehensive list of assistive technologies for the elderly can be found in Soar et al. (2020). From the literature, most smart tools focus on helping the elderly in their daily tasks and activities. Yet, very few focus on religious and spiritual aspects (Ismail et al., 2014). Religious activity, such as prayer, is one of the spiritual aspects needed by the elderly to support their emotional well-being.

Solat (the Islamic prayer) is very important in Islam, which is one of five pillars in the faith of Islam. It is an obligatory religious duty for every Muslim. In addition, several studies have shown that *Solat* benefits health (Chamsi-Pasha & Chamsi-Pasha, 2021) and provides emotional support to Muslim patients (Akhmad, 2017; Yucel, 2007). *Solat* consists of several physical movements and Quran recitals and needs to be performed five times daily at specific times. Elderly Muslims, especially those with cognitive impairment, face several challenges in performing daily prayers. They may have difficulties remembering the number of *rakaah* (cycles in

Solat), the Quran recitals, and the prayer times. An assistive prayer technology will be useful for elderly Muslims in guiding them to perform daily prayers.

In this chapter, a smart prayer monitoring system has been designed to assist elderly Muslims in praying. In the preliminary study, a design of a prayer adherence system has been proposed for Muslim children (Mansor et al., 2019). Based on this preliminary work, the system design has been extended to suit the needs of the elderly. Specifically, this project developed a prayer monitoring system using the Internet of Things (IoT) platform, which is able to assist and monitor the daily prayers of elderly Muslims. The designed system is composed of three main parts: i) a smart prayer mat to provide audio and visual assistance to users while praying; ii) cloud storage to store the prayer activities for monitoring purposes and iii) a mobile application to display the prayer performance based on the information stored in the cloud storage.

RELATED WORKS

Web and mobile applications are experiencing a technology boom, especially with the arrival of IoT technologies. Applications have migrated to another level, where the development is focused on assisting the daily need of users. In the context of Islamic applications, Muslim consumers use a unique set of applications daily, such as prayer time reminder, *Qibla* direction, Quran companion, and Halal Food locater (OnePath Network, 2019; The Center for Global Muslim Life, 2017). The most popular app for *Solat* activities is “Muslim Pro”

(Muslim Pro, 2021), which provides the *Solat* times, *Azan* audios, and *Qibla* direction. “QamarDeen” is another popular Islamic app to track the *Solat* progress and other good deeds, but it requires the user to manually enter the data (Faris, 2021).

The advancement in computer vision techniques has motivated researchers to explore more on automated recognition of the *Solat* activity and position. Earlier work by Muaremi et al. (2013) used wearable sensors to detect the *Solat* activity among a large crowd of pilgrims. Another work (El-Hoseiny & Shaban, 2009) used a video processing technique for prayer action recognition. Other interesting works (Al-Ghannam & Al-Dossari, 2016; Ali et al., 2018) utilised the accelerometer sensors in mobile phones to recognize the *Solat* activity. They found that mobile phones can be used to detect the *Solat* activity and evaluate the correctness of the *Solat* position.

The most related work to the proposed system are studies on smart prayer mats. A research work led by Kasman (Kasman & Moshnyaga, 2017) has introduced a smart prayer mat to assist Muslims in praying. This smart prayer mat is embedded with electronic parts (controller and sensor) and has several functions such as *Qibla* locater, Azan reminder, and *rakaah* counter. A liquid crystal display (LCD) screen is placed on the prayer mat to display *Qibla* direction, prayer times, and *rakaah* counting information. Later, they used this smart prayer mat to identify the various human postures while praying (K. Kasman & Moshnyaga, 2017). Another work by Ismail et al. (2015) has included a mini MP3 player to the smart prayer mat. The player will prompt sound for each *rakaah* of prayer, which is useful to assist the elderly with cognitive impairment. Unlike the previous smart prayer mat (Kasman & Moshnyaga, 2017), this ‘textile-based smart prayer mat’ will record the log data of *Solat* activities in a micro SD card. However, both proposed smart prayer mats are not connected to the internet. Therefore, they do have any monitoring mechanism to keep track of daily *Solat* activities.

Besides a smart prayer mat, a smart carpet system was developed to monitor people with dementia (Tanaka et al., 2015). The system was programmed to detect the position of the person whether they are walking, lying, or sitting on the floor. The smart carpet is embedded with an array of pressure sensors. Signals produced from these sensors are sent wirelessly to an online server, where they will be decoded to identify the position of the patient. In this way, a caregiver is able to monitor the patient’s condition remotely. The designed system in this project has a similar system architecture to this smart carpet system (Tanaka et al., 2015).

BACKGROUND

Praying in Islam (*Solat*)

Solat is an Arabic term that is commonly used to describe Islamic prayer. It is fundamental ritual worship for every adult Muslim. *Solat* is performed five times daily at designated times and facing *Qibla* (the holy city of Mecca). The five prayers are known as *Fajr*, *Zuhur*, *Asar*, *Maghrib and Isya*. Each prayer has a specific number of cycles, which is also referred to as *rakaah*. Each *rakaah* consists of a sequence of physical movements: standing, bowing, prostrating and sitting. Figure 3.1 shows the sequence of prayer positions for one full cycle (*rakaah*).

Figure 3.1

A sequence of prayer positions for one full cycle (rakaah)

The sequence (*rakaah*) as shown in Figure 3.1 must be repeated several times, and the worshipper needs to recite passages from Quran for each cycle. Table 3.1 shows the number of *rakaah* required for each prayer. In short, each prayer has a different prayer time and number of *rakaah*. Therefore, elderly Muslims often face problems in remembering the number of *rakaah* while praying.

Table 3.1

Muslim prayer times and number of rakaah

Prayer	**Prayer time**	**Number of *rakaah***
Fajr	Dawn	2
Zuhur	Mid-day	4
Asar	Afternoon	4
Maghrib	Sunset	3
Isya	Night	4

Internet of Things (IoT)

The IoT describes a situation where physical devices are connected to the internet without or with minimal human intervention. This establishes communication between devices and online storage, where data are collected from devices to be stored online. The basic architecture of an IoT system consists of three essential elements: devices/sensors, online servers, and applications, as illustrated in Figure 3.2. Devices are physical objects such as smartphones, appliances, and cars which are embedded with sensors. This type of device is commonly referred to as an IoT device. Data acquired from sensors will be transferred to an online server using wireless communication such as Wi-Fi. The transmitted data are stored and processed within the cloud storage. Data analytics will be performed on the recorded data, and these provide better decision-making for the IoT device and system. Applications are sets of visualisation tools used to view the process data, such as mobile applications and web applications.

Figure 3.2

The basic architecture of an IoT system

Advantages of using IoT are easier access to information, better communication, and automation. Popular IoT applications are smart home, smart city, smart healthcare, industrial IoT, and smart waste management (Kumar et al., 2019). In addition, IoT technologies have been integrated with assisted living solutions for the elderly, such as health tracking and automated home control (Maskeliūnas et al., 2019). For example, medical adherence applications have been developed to monitor medication intake, report missing dosages, and remind patients to take their medicines at the correct time (Sherif et al., 2020; Silva et al., 2018). The medication adherence system was proposed to assist elderly people in using IoT systems in a smart home. Its success implies that an adherence system could be easily set up to monitor repetitive activities in daily life. Motivated by the good performance of the medical adherence system, a similar system architecture has been extended to the application of monitoring the daily *Solat* activities.

SYSTEM ARCHITECTURE

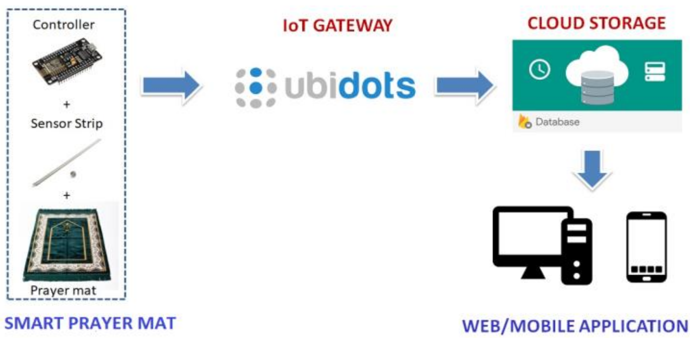
Figure 3.3 illustrates the system architecture of the proposed prayer monitoring system. The designed system consists of two main parts: a) smart prayer mat (hardware) and b) mobile application (software).

a) Smart prayer mat: A prayer mat is embedded with several electronic components such as multi-touch sensors, LCD, speaker, and controllers. The function of the controller is to manage the input/output devices and to connect to the internet. The multi-touch sensors are used to recognise the *Solat* activities and the information is sent to the server. LCD and speaker provide visual and audio assistance to the user while praying.

b) Mobile application: A mobile application was developed to keep track of *Solat* activities based on the information stored in the server. The user is able to view and monitor the progress of daily prayers.

Figure 3.3

The system architecture of the prayer monitoring system



Integration of smart prayer mat and web application was developed using an IoT platform. This project uses Ubidots, a popular IoT platform that provides an interface for the IoT testing environment (Ubidots, 2021). It uses MQ Telemetry Transport (MQTT) messaging protocol, which is faster and more reliable compared to the Hypertext Transfer Protocol (HTTP) protocol. For cloud storage, Firebase has been chosen for online storage. Firebase is a platform owned by Google since 2014 (Firebase, 2014). It provides real-time database service, which is easy to handle and suitable for beginner developers. Firebase is one of the popular IoT platforms because of its easy integration with web and mobile applications. In short, a similar system architecture in the preliminary work (Mansor et al., 2019) is utilised, but the smart prayer mat has been redesigned to provide visual and audio assistance to the user (as described in the next section).

SYSTEM DESIGN

Smart Prayer Mat

A smart device is an electronic device that can be connected to the internet and is capable of sending and/or receiving information. Smart devices make life more convenient because data can be transferred to cloud storage without or with minimal human intervention. The smart prayer mat has a similar characteristic to other smart devices, where the data from Solat activities can be automatically collected and recorded. Specifically, the smart prayer mat is designed with the following objectives:

- To give the direction of *Qibla*
- To give information on the time of prayers
- To display *rakaah* counter

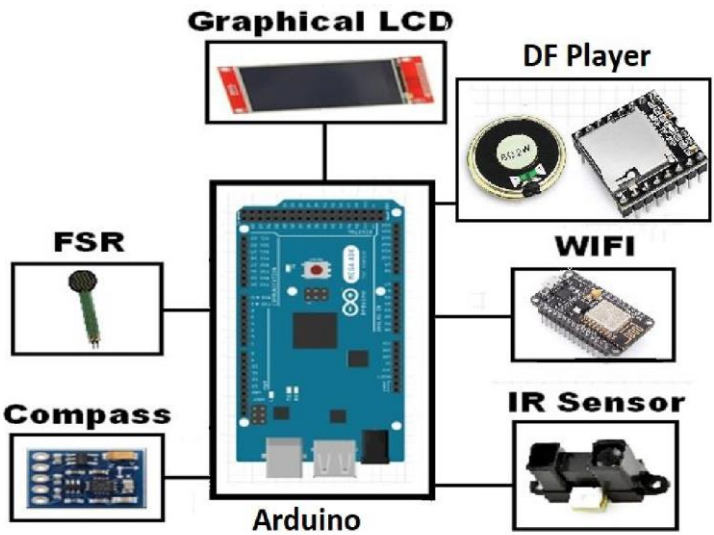
- To assist elderly with Quran recitation while praying
- To collect information on time and date of praying, and send to the online storage

Embedded Unit

To fulfil the above characteristics of a smart prayer mat, an embedded unit is developed using a set of electronic components, as shown in Figure 3.4. These components are the Arduino microcontroller, graphical LCD, force-sensitive resistor (FSR), infrared (IR) sensor, Wi-Fi module, audio player and compass module.

Figure 3.4

Electronic components of the embedded unit



The Arduino Mega was chosen as the smart prayer microcontroller because it has high capabilities and large memory. In addition, it has a high number of general-purpose input/output (GPIO), and thus it is capable of connecting a large number of input and output devices. Three input (FSR, IR sensor, and compass) and three output (LCD), audio player, and Wi-Fi) devices are connected to the Arduino Mega for the smart prayer mat. This microcontroller acts as the processing unit to manage the input and the output devices.

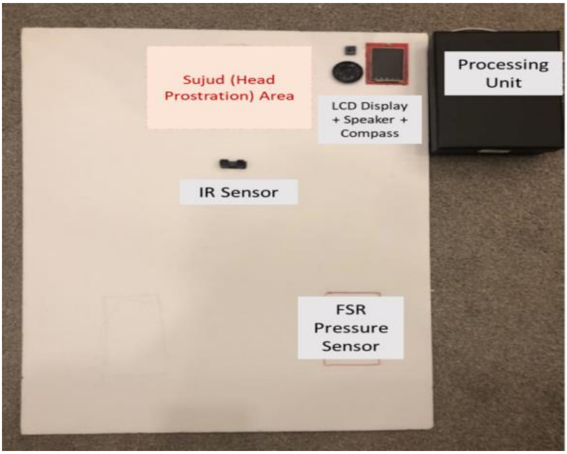
Three sensors were utilised for the smart prayer mat: FSR pressure sensor, IR distance sensor, and digital compass. Both FSR and IR sensors are used to detect all *Solat* positions (as illustrated in Figure 3.1), and a digital compass is used to determine the *Qibla* direction. The LCD screen is a touch screen to display the information of *Solat*, and the DF player is a mini MP3 player to play the Quran recitation. NodeMCU is used as a Wi-Fi module to connect the embedded unit with the internet.

Prototype

A prototype of a smart prayer mat has been developed in the project, as illustrated in Figure 3.5.

Figure 3.5

A prototype of a smart prayer mat



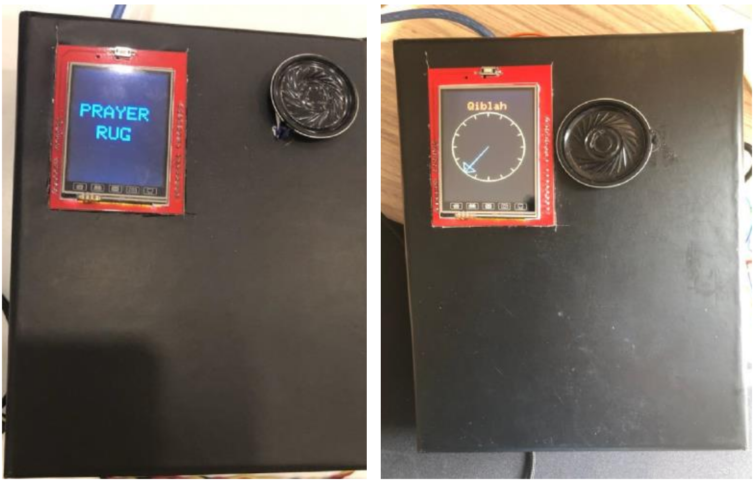
When the processing unit is turned on, the LCD panel displays a welcome message, as shown in Figure 3.6(a), and the Islamic greeting ('*Assalamualaikum*') is played on the speaker. The system starts to operate when the user stands on the FSR pressure sensor area (refer to Figure 3.5). The compass unit determines the angle of deviation and shows the correct *Qibla* direction on the LCD screen, as illustrated in Figure 3.6(b).

Afterwards, the display screen will display the five daily prayers for the user to choose the prayer (*Fajr, Zuhur*, *Asar*, *Maghrib*, *Isya*) to be performed, as shown in Figure 3.7(a). The user can now begin his/her prayer. The LCD screen will display the *rakaah* counter and list the steps in *Solat*, as shown in Figure 3.7(b). The infrared sensor, which is placed in the centre of the prayer mat, will detect all the *Solat* positions (standing, bowing, prostration and sitting). Whenever a new *Solat* position is detected, the LCD screen will highlight the related step, and the speaker will play the required Quran recitation. In this way, the system is able to assist or remind the user on Quran recitation and the *Solat* steps while praying.

The number of *rakaah* will be updated on the LCD screen once the user has completed one full cycle. The smart prayer mat system will continue to monitor the actions of the worshiper during the prayer until completion. At the same time, the information of *Solat* activity will be sent to the online database for record and monitoring purposes.

Figure 3.6

LCD of (a) welcome message and (b) Qibla direction



(a) (b)

Figure 3.7

LCD of (a) prayer selection and (b) list of Solat steps

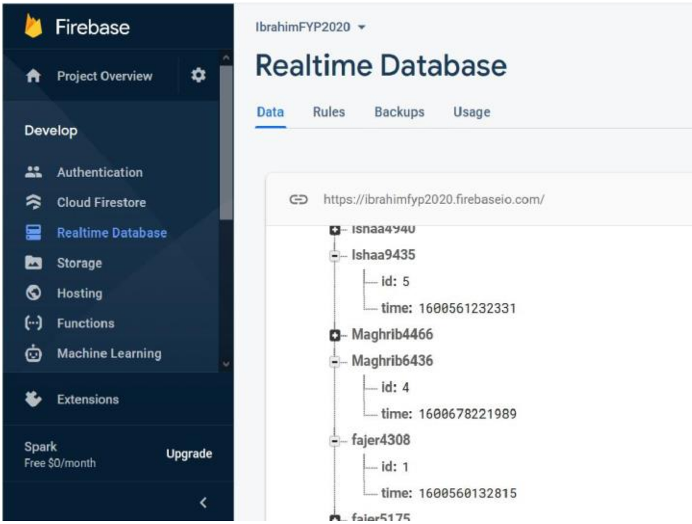
(a) (b)

Mobile Application

When the user starts praying, the processing unit will send the relevant information on *Solat* activity to the Cloud storage. For this prototype, Arduino sends two types of data: 1) ID number of prayer and 2) date and time of *Solat* performed by the user. Figure 3.8 shows an example of the data stored in the Firebase database.

Figure 3.8

An example of recorded data on the Firebase database



An Android mobile application was designed to retrieve and visualise the data from the cloud storage (Firebase). Figure 3.9 shows the user interface of the mobile application. It displays the information of the date and time of *Solat* activity and the performance status (either complete or not complete). The user may select a specific date to view the *Solat* performance on that day. Figure 3.10(a) shows the date selection, and Figure 3.10(b) shows the results of *Solat* activity on the selected date. The usage of cloud storage and mobile application has enhanced the reliability of the system from a smart prayer mat to a smart prayer monitoring system.

Figure 3.9

A user interface of Smart Prayer mobile application

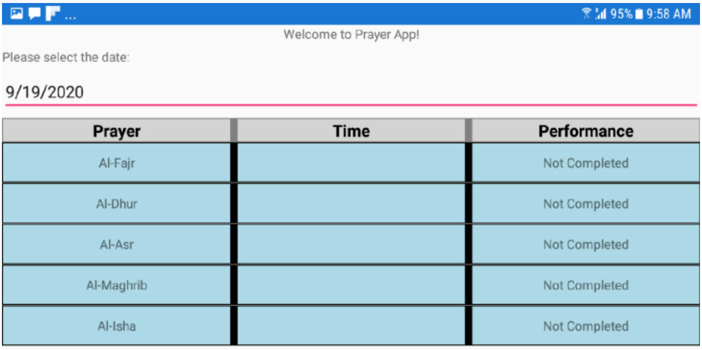
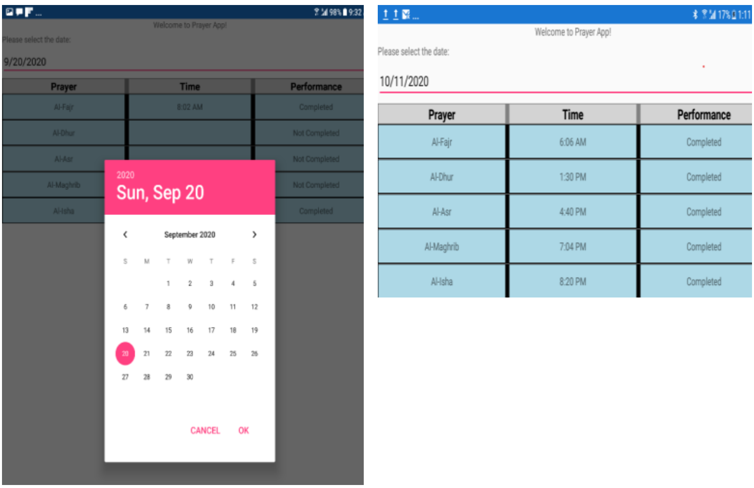


Figure 3.10

Mobile application: (a) selection of date and (b) Solat performance on the selected date



(a) (b)

SYSTEM EVALUATION

An elderly Muslim has tested the prayer monitoring system for four consecutive days. The results show that the designed system has high efficiency because it can track the movement of the worshipper and detect all *Solat* positions correctly (i.e. with 100% accuracy). The tester also gave a positive response towards the system as he found that the system would be a useful assistive technology for elderly Muslims. The *rakaah* counter and the audio assistance provide good support for the user to remember or learn about the steps in performing *Solat*.

CONCLUSION

In this project, a new assistive prayer monitoring system was proposed and designed to help elderly Muslims in performing daily prayers. The proposed system has two main elements, a smart prayer mat and a mobile application. The smart prayer mat effectively tracks the positions of the user while praying, shows the direction of *Qibla*, provides *rakaah* counter, and assists in Quran recitation. The IoT technology was implemented in the system, which makes it easier for the mobile application to retrieve data from the prayer mat. In short, the smart prayer mat provides audio and visual assistance to the user in praying, while the mobile application monitors the performance of daily prayers.

For future work, a GPS device and a prayer reminder could be added to the system to enhance their functionalities. This system could be utilised as a health tracker for elderly Muslims with dementia. Caretakers can view the progress of *Solat* performance from the mobile application, and an alert can be sent to the application if no *Solat* activity is detected for the whole day.

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CONFLICTS OF INTEREST: The authors have no conflicts of interest to declare.

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4
Internet-of-Things based Greenhouse Monitoring System

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Abstract - A greenhouse monitoring system with radio frequency (RF) signal support was designed and built. The combination of the hardware and software used in the greenhouse system is an embedded system. Intelligent systems have been implemented to overcome the environmental factors adversely affecting the greenhouse system. To attain maximum growth of the plant, continuous supervision and checking are crucial. Controlling the environmental factors such as temperature, humidity, light intensity, and moisture in the soil will help increase plant growth. This system uses two Arduino modules as transmitter and receiver platforms to process the readings from the sensors and send them to actuators through an RF signal. Furthermore, the Internet of Things has been implemented to monitor and control the system in real-time. All environmental factors recorded by the sensors will be sent to the client account (ThingSpeak) via a Wi-Fi module, which would be connected to the users' Internet Protocol (IP) address and the internet to send the data. By accessing the laptop or mobile phone, the user can continuously monitor the data measured by the greenhouse sensors. For analysis of the plant condition, all sensor information can be used to assess the environmental factors in the greenhouse, which are measured by 1 day, 1 week, and 4 weeks respectively. Four sensors were used to measure temperature, humidity, light intensity, and soil moisture, and it gives a perfect result of greenery conditions. For optimal outcomes, these data are essential for controlling the greenhouse climate.

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Senthilpari, C., & Arumugam, H. (2021). Internet-of-things based greenhouse monitoring system. In L.N. Lee, & S.L. Lim (Eds.), *Recent applications of internet-of-things in monitoring and analysis* (pp. 79-101). MMU Press.

INTRODUCTION

The growing of crops offers a considerable challenge, with crops often vulnerable to adverse weather conditions. In evaluating the rate of crop production, weather and climate conditions play an essential role. However, there is no room for a limitation when world food security depends heavily on crop production. Therefore, the quest for a solution led to agricultural management activities involving agriculture in a regulated environment. Greenhouse agriculture in a protected environment and atmosphere is one of the essential variants in agriculture. Greenhouse farming cultivated plants with a clear or partly clear substance under sheltered structures (Parvez et al., 2020). Greenhouses are primarily built to provide optimal cultivation conditions and protect crops against adverse weather and various pests. According to Kodali et al. (2016), greenhouse cultivation is a practice that has helped improve farmers' efficiency while improving product quality and isolating them in micro-ecosystems that are perfect for plants to grow strong, healthy, and safe. Therefore, greenhouse cultivation needs to provide sufficient light, water, air ventilation, humidity, and an adequate temperature.

PROBLEM STATEMENT

In agriculture, a significant problem is the imbalance of the environment, which damages and slows plant growth. Plant growth is affected due to excessive or inadequate temperature, humidity, water, and light. Greenhouse farming uses a greenhouse structure with walls and roof that helps to improve crop production, vegetables, fruit, etc. The work by Kumar et al. (2016) illustrates that a greenhouse has to be constructed in such a way so it can effectively control the microclimate. Sensor data are used to monitor greenhouse conditions. Greenhouses control environmental parameters in two different ways, either manually or remotely. However, given that there are drawbacks to manual intervention, such as loss of productivity, loss of resources, and labour costs, these methods are less effective. According to Kumar and Jatoth (2015), intelligently supervising a sensible greenhouse through the Internet of Things (IoT) embedded systems can control the climate condition. This obviously can remove or reduce human intervention. According to Bseiso et al. (2015), various sensors measuring the environmental parameters can provide data to regulate the environment in a smart greenhouse to be consistent with plant requirements. A cloud server assists in data processing and maintains a control assessment of the greenhouse. This design provides farmers with minimal to essentially no manual interference with effective and cost-effective solutions.

A large-scale provision of a greenhouse monitoring system will solve many problems in farming. A greenhouse can be designed to be inexpensive and easy to use. Thus, the main aim of this chapter is to design an intelligent system for the greenhouse and to construct a simple greenhouse system with Arduino equipped with a radio frequency (RF) signal transmission. The greenhouse has a continuous supervision system that controls and maintains the greenhouse climate. The greenhouse system is constructed with little cost. There are two major units: supervising and checking units. The supervising unit consists of a light intensity detector, soil moisture detector, humidity, and temperature sensors to measure the environmental data. For transmitting data to the cloud, a Wi-Fi module is used. The controlling unit consists of a cooling fan, water pump, and light to control the system and to implement an RF signal module to transmit and receive data from the monitoring section to the controlling section. The data from the ThingSpeak account can be used for future reference to develop the greenhouse. Furthermore, this chosen architecture will allow multiple greenhouse systems to be controlled using a single controlling unit.

OBJECTIVE

The first purpose is to contrast a simple greenhouse system with Arduino using a radio frequency signal transmission. The objective is to build a greenhouse system with little cost and test the system model to show the basic idea of how a greenhouse can be implemented. This helps to monitor greenhouse conditions, and the sensor's data is used to analyse the greenhouse. The data from the ThingSpeak account can be used for future reference to develop the greenhouse. Greenhouse farming is a structure that helps to improve crop production, vegetables, fruit, etc. Greenhouses control environmental parameters in two different ways, either manually or remotely. However, given that there are drawbacks to manual intervention, such as loss of productivity, loss of resources, and labour costs, these methods are less effective. According to Kumar and Jatoth (2015), intelligently supervising a sensible greenhouse through IoT embedded systems also can control the climate condition. This obviously will remove all human intervention criteria. According to Bseiso et al. (2015), the various sensors measure the environmental parameters consistent with plant requirements to regulate the environment during a smart greenhouse. A cloud server then creates a system when connecting via IoT remotely. The cloud server assists in data processing and maintains a control assessment in the greenhouse. This design provides farmers with minimal to essentially no manual interference with effective and cost-effective solutions.

METHODOLOGY

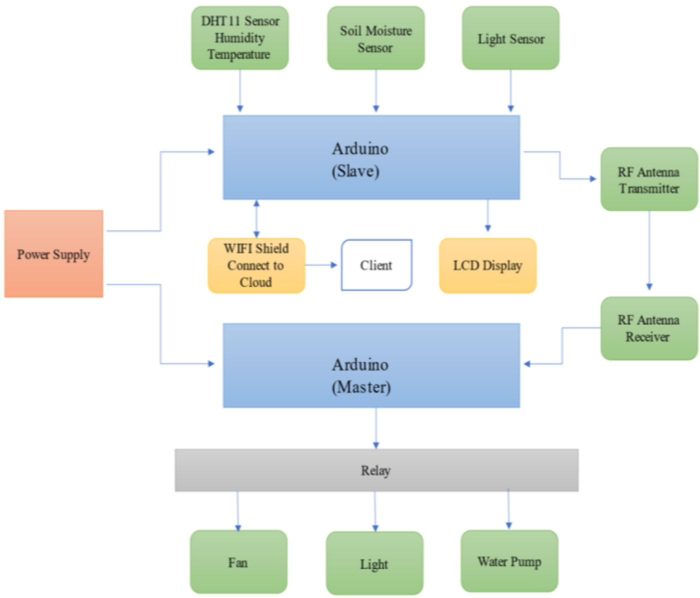
The design of the greenhouse and the construction of the circuit are the main components of this project. Compared to industrial products selling on the market, the budget costs for setting up the greenhouse are lower. The construction of the greenhouse model was tested and ran manually without an internet connection. This chapter concentrates on two parts: the greenhouse and RF signal transmissions from one Arduino to another. The greenhouse is implemented in the IoT system with four sensors for sensing data: temperature, humidity, soil moisture, and light intensity. A second Arduino as master receives input data from the first Arduino as a slave through an RF signal. The Wi-Fi shield attached to the slave Arduino connects and sends the data to the cloud.

Two Arduino modules are used in the project as input (sensors) and output (equipment). The Arduino Mega 2560 microcontroller of ATmega2560 module is used, with 54 digital outputs/inputs, 16 analogue outputs, a universal serial bus (USB) connection, a power jack, an In-Circuit Serial Programming (ICSP) header, 4 universal asynchronous receiver-transmitters (UARTs), a 16 MHz oscillator, and a reset button. The operating voltage of Arduino Mega is 3.3V to 5V, and the input voltage is 7V to 12V. A Wi-Fi shield is attached to the transmitter (slave) Arduino to establish an internet connection and upload the data from sensors to the cloud (Mei-Hui Liang et.al 2018). The Arduino Wi-Fi shield establishes a wireless specification for an Arduino board to access the internet based on an HDG204 wireless local area network (LAN) 802.11b/g. An AT32UC3 offers a Transmission Control Protocol (TCP) and a User Datagram Protocol (UDP) network as an Internet Protocol (IP) stack. The Wi-Fi library is used to write the sketches and connect to the internet through the shield. Wi-Fi is attached to the Arduino board using the shield-long wire-wrap headers. This retains the pin structure intact and allows for stacking on top of it.

The Arduino slave is the transmission sensor, receiving information signals from humidity, soil moisture, and light sensors. In the greenhouse supervision system, the power supply is 12V to power up Arduino, supported by 3.3V to 5V. Castro et al. (2019) found that a voltage regulator constructed in the motor driver board can supply 5V maximum, supporting the Arduino (master) and relay to power up equipment that supports 12V. The fundamental concepts in Figure 4.1 and Figure 4.2 show that multiple greenhouse supervision systems can be implemented with single output as a receiver to control the equipment unit in all greenhouses. Sensors such as DHT11 to measure temperature and humidity, soil moisture sensor to measure soil pH and water level, light-dependent resistor (LDR) sensor to measure light intensity will be connected to the Arduino (slave).

Figure 4.1

Greenhouse system block diagram



Arduino modules A_1, A_2, and A_3 in Figure 4.2 will receive the sensors' input values and send the data via RF transmitters (slaves) to the RF receiver (master). The RF (master) will receive data from the RF (slaves) and send the input data to Arduino B. Output data from Arduino modules A_1, A_2, and A_3 will be processed in Arduino B; which will send the command to the equipment for the output task. Data processed from Arduino modules A_1, A_2, and A_3 in Figure 4.2 will be sent to the cloud, and the end-user can receive the cloud data, which can be monitored via ThingSpeak. This data can be viewed on a liquid crystal display (LCD) as well.

The method uses a modular design to form the prototype's construction and design framework. Multi-client interface access should be provided with the system architecture that can be connected to a communication system. The system shall contain an effective operational expert. In particular, permitted users may adaptably use it, and unapproved users cannot access it.

Figure 4.2

Diagram of multiple systems

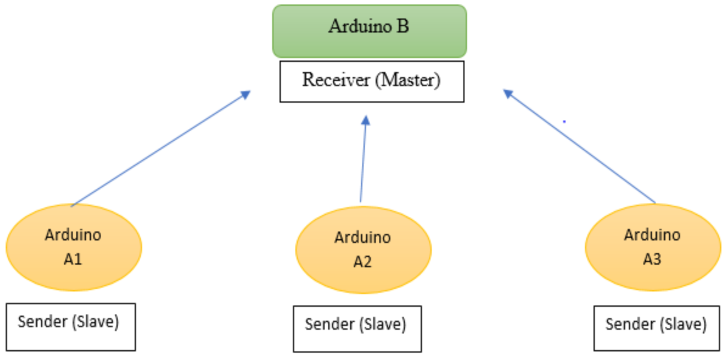
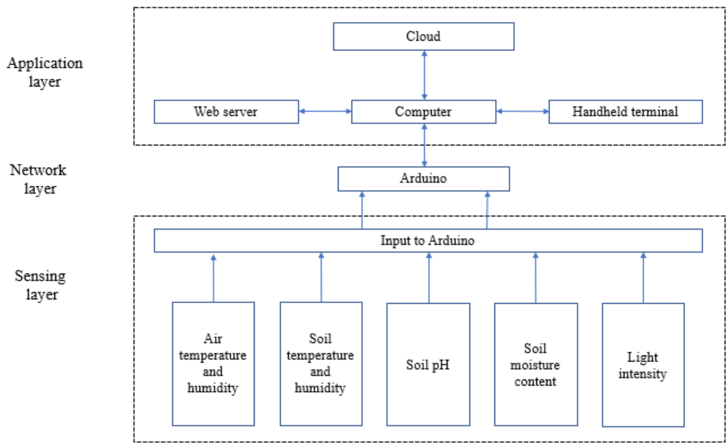


Figure 4.3

System program design



For the program design, the information required for plant growth has been collected in 3 separate layers. These layers are combined with the sensor, Wi-Fi information, and other major technologies (Ayaz et al., 2019). The equipment and software are known for remote control and intelligent management. The device is primarily equipped with a sensor, network component, and application component, shown in Figure 4.3.

The sensing layer uses sensors to detect sensor readings. The network layer is a LAN-based and Wi-Fi-based communication system, which constrains data communication. The application layer is at the system's highest level; it is the functional centre of basic leadership.

SENSING LAYER

The detection level is often employed to get data, such as farmland data, for natural microclimate control. The sensor layer comprises a range of sensors that measure the environmental parameters in real-time. The DHT11 sensor is selected for humidity and temperature measurements. The DHT11 humidity and temperature sensor values are given in Table 4.1.

Table 4.1

Parameters of humidity and temperature sensor

Parameter	Value
Humidity	0-100%
Temperature of air	-30-70^{o}C
Output current	4-20mA
Functional voltage range	12-24V_{DC}
Response time	<1s
Settling time	1s
Temperature range	-35-75^{o}C

For light intensity measurement, the light intensity calculation methodology is split into two sections: a thermometric impact assessment and a photoelectric impact assessment. The Light Intensity Module was used for this device. The key light intensity parameters are illustrated in Table 4.2. The light intensity sensor operating voltage is between 12-24V, which is taken from the power supply voltage. The sensing temperature varies from -40°C to +80°C.

Table 4.2

Parameters of light intensity sensor

Parameter	Value
Range	0-200000lx
Operating current	4-20mA
Operating voltage	12-24V_{DC}
Temperature range	-40-80^{o}C
Humidity range	0-100%

The pH is a measure of acidity and alkalinity in soil and influences soil fertility and nature. The parameters of the soil sensor are described in Table 4.3.

Table 4.3

Parameters of soil sensor

Parameter	Value
Range of measurement	0-14pH
Output current	4-20mA
Input voltage	12-24VDC
Operating time	<10s (in water)
Operating temperature range	0-80°C
Operating humidity range	0-95%

NETWORK LAYER AND APPLICATION LAYER

This circuit of the system is the "neural system channel", which sends data to the processor. It defines whether the data collected from the front end can be adequately transmitted to the "unit brain", the host personal computer (PC) observational application subject. Focus data testing equipment offers a step option; the entire system server-side is the application layer observation focus. It has several capabilities across the entire observational system involving, for example, mailing, display, customer login, and information retention. This framework's application layer PC has a stable server architecture. The server design is as follows, along with the requirements of setup programming and horticultural field planting.

- Client account (ThingSpeak IoT)
- The host has an IP address

Data control of the application layer focuses on remote observation of agricultural plantation sites. Important figures related to the application are progressively monitored for agricultural yield production. These are presented in simple but informative images for visualisation. A critical component of this framework is report development. It stores local data in an organised structure, tracks ongoing or stored data, and outlines the ecological supervision guidelines for improvement.

The wireless transceiver module is nRF24L01, which is easy for transferring the RF signal. A single nRF24L01 module will actively hear up to six different modules at the same time. The nRF24L01 transceiver module operates at 2.4GHz with an operating voltage from 2V to 3.6V. The RF24Network library can be used to build a network arranged in a tree topology, where one of the nodes is the base, and all the others have children. Each node can have five children, which means that it can construct a network of 3125 nodes. The sensors and equipment work simultaneously by communicating from Arduino (slave) to Arduino (master). The data collected from Arduino (slave) sensors are automatically uploaded via Wi-Fi shield to the cloud account (ThingSpeak). From the cloud account, users can view and monitor the environmental factors of the plant. All the sensor data will print out in the 16×4 LCD.

A steady power supply at a range of 5V~12V is used in this system. The battery power is stepped down using a voltage regulator with a bridge rectifier filtered by a capacitor of around 470uF to 1000uF. The LM7805 regulator is used to get a constant dc voltage of 5V. The voltage requirements of each sensor and equipment are listed in Table 4.4.

Table 4.4

Voltage and current ratings of sensors and equipment

No	Sensor/Equipment	Required voltage (V)	Current (A)
1	DHT11 sensor	3V to 5.5V	0.5mA to 2.5mA
2	Soil moisture sensor	5V	<20mA
3	Light intensity sensor	3.3V to 5V	15mA
4	Water pump	12V	Current with load (<320mA)
5	Cooling fan	12V	0.5A
6	Light	12V	20mA

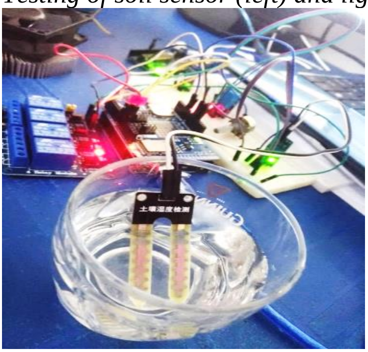
All sensors were checked first, and readings were obtained. The data were used to calibrate sensor accuracy. This test was done before the full design was assembled to prevent any failure. The baud rate was set to 9600 baud for all sensors. These tests were conducted many times to check the sensors' possibility of failing. All sensor values were recorded from the serial monitor. The sensors showed some errors in the readings due to unavoidable circumstances, for example, thunder, power failure, or the sensors being interrupted with other signals. Hence a diagnostic was performed to make the sensors work perfectly.

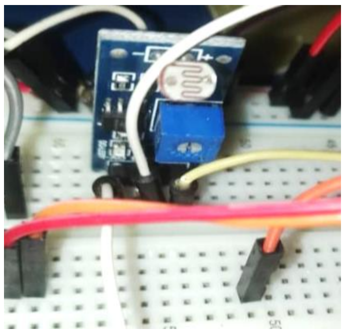
Water content plays a vital role in groundwater recharge agriculture and soil chemistry in soil science, geophysical science, and agricultural science. Once the wet content of the soil is perfect for plant growth, plants will absorb soil water. Not all of the water contained within the soil is obtainable to plants. A lot of water remains with the soil as a thin film. The soil water dissolves salts and forms the soil solution, which is vital for supplying nutrients to the growing plants. Figure 4.4 (left) shows the picture of a soil sensor being tested.

Figure 4.4 (right) shows the light intensity sensor being tested with the light on and light off. The sensor worked in a very good condition without any error occurring. By measuring the radiant energy that exists in a very narrow range of frequencies, called light, ranging in frequency from infrared to visible to ultraviolet light spectrum, a light sensor produces an output signal that indicates the intensity of light.

Figure 4.4

Testing of soil sensor (left) and light intensity sensor (right)





RESULT AND ANALYSIS

The greenhouse system was tested and run for four weeks. Two samples of the plant were used for the evaluation.

The growth of the plant depends on the environmental factors that occur surrounding it (Shirsath, D.O et.al 2017). Thus, environmental factors surrounding the plant should be put into serious consideration to enhance plant growth. Climate control for the plant is very important. When a seedling starts growing, the plant's seed will close its stomata to prevent water loss. Furthermore, a high humidity level will affect the plant's condition because it uses stomata to breathe. This may cause the plant to suffocate. The plant will close its stoma when the weather is warmer to avoid water loss since the stomata is a cooling system. High humidity also helps the growth of mold and bacteria, which can cause the plants to grow in unhealthy conditions. Water and nutrients are vital to the plant. Nitrogen, phosphorus, and potassium are most important for plant growth, helping them make healthy and strong green leaves and roots. The plant needs sunlight as energy to make food by a process called photosynthesis. The light is important for the plant to grow, which uses a red wavelength for photosynthesis. The growth of the plant also depends on the temperature. High temperature may slow plant growth and will cause an increase in moisture loss. The optimum temperature is 28-31°C for the plant to grow.

In the test, commercial Plectranthus amboinicus seeds were planted in two different pots. Each of the pots was filled with soil. The results were recorded for four weeks at the end of the day. Plant A was placed in the greenhouse, and plant B was placed outside the greenhouse. Figure 4.5 shows the Plectranthus amboinicus plant.

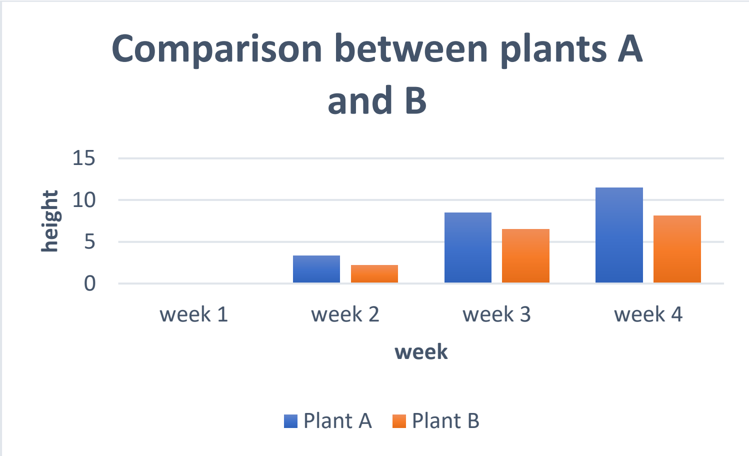
Figure 4.5

Plectranthus amboinicus plant

Based on the results recorded for four weeks, it is shown that environmental factors influence plant growth, as can be observed from Figure 4.6. Plant A had better growth than plant B; see Figure 4.7 for comparison at week 2 and Figure 4.8 for comparison at week 4. Plant B had a yellow patch on the leaves in week 2. The greenhouse provided an ideal growing environment for plant A.

Figure 4.6

Plant growth across 4 weeks



The data were graphed from week 1 to week 4. Parts of the data for temperature and humidity are depicted in Figure 4.8. The temperature was maintained at 29°C indoors through the week. The indoor humidity reached a maximum of 78% in the morning. The moisture level decreased to 76% later in the day.

The overall result of this system indicates that the greenhouse supervision system has significantly improved with the incorporation of IoT. Through this system, users can track and monitor their plant conditions regularly. Sensor data allows further analysis for future improvement.

Figure 4.7

Comparison between Plant A (left) and Plant B (right) in week 2

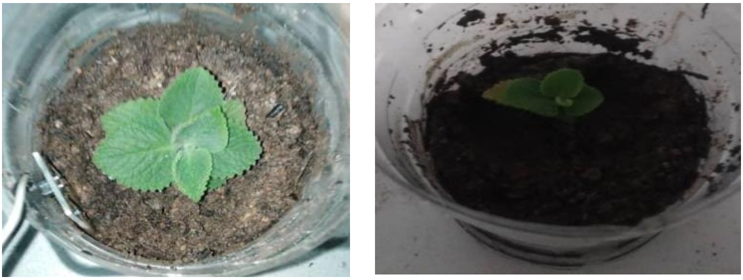
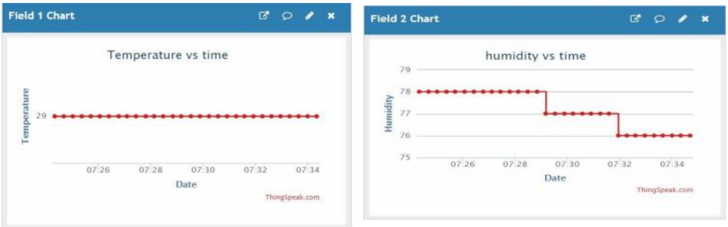


Figure 4.8

Comparison between Plant A (left) and Plant B (right) in week 4

Figure 4.9

Temperature and humidity measurements



CONCLUSION

In this project, a greenhouse was successfully constructed. The greenhouse system parameters were tracked continuously using an intelligent system based on IoT. The system can measure the temperature, humidity, light intensity, and soil moisture and present the values on an LCD. Besides that, the data stored in the cloud account (ThingSpeak) can be downloaded and viewed. The water pump, cooling fan, and light help keep the greenhouse in the preferred environment. Environmental control is essential for maintaining and cultivating healthy plants and enhancing plant growth.

With the proposed greenhouse architecture, the plant productivity can be increased compared to existing methods. Improvement to the design can be tried as well. For example, the current design does not have a rain sensor with an open roof. If this can be implemented with a proper filter, much water can be saved. Another possible improvement is; if the current system's fan size is increased, it could improve the ventilation system to maintain the greenhouse temperatures and subsequently, improve the climate efficiency. These improvements in the greenhouse system would yield a better plant productivity. Implementation of different greenhouse systems with the same intentions would certainly increase the interest in these systems in the future.

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5
Design and Implementation of IoT Interactive Kiosk

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Abstract – Students at educational institutions such as schools or colleges often carry belongings when they head to their classes. Many universities and high schools sustain traditional lockers in the libraries for the students to keep their belongings in the absence of a strong security system, which may result in the loss of their belongings. In this work, an interactive kiosk with the technology of the Internet of Things (IoT) that serves as a smart locker system is proposed. In particular, a smart and efficient process flow for the system is developed, in order to enable the users to register for a locker with minimum required credentials and place their personal belongings securely. With the aid of Raspberry Pi and Arduino, the system allows the users to place their belongings for the duration they wish for. The duration is calculated after the user checkout from the kiosk. To enhance the security system, the kiosk requires the user for the fingerprint to grant the authorised user access to the locker. From this work, we have demonstrated a working prototype for the IoT-enabled interactive kiosk with a variety of smart features, which include: simple and efficient user registration process, enhanced locker security and protection, greater user flexibility for pick-up, and drop-off, and automated calculation of locker occupancy duration. Therefore, the proposed innovative solution is a feasible approach for allowing campuses to experience a transition from traditional to modern smart locker systems.

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INTRODUCTION

Nowadays, everything can be connected over the internet. The Internet of Things (IoT) is described as the things or objects that can be used or controlled via the internet (Burgess, 2020). The IoT technology has been integrated into kiosks among various fields such as tourist assistance kiosks, charging kiosks, or vending machines. All of these are internet-enabled projects. In the world of the modern age, where everything is turning smart, Self–Service Technology (SST) is dominantly implemented everywhere, for instance, malls, hospitals, university campuses, and many more (Lumsden, 2019). Different types of kiosks have been constructed to fulfil the growing demands among individuals (Holowicki, 2020).

Swamy et al. (2016) invented a smart trolley for automated billing purposes using Wireless Sensor Network (WSN) technology along with the technology of radio-frequency identification (RFID). The proposed system eases the checkout process after the shoppers are done with their shopping. The kiosk's main contribution is providing automated billing service on a cost-effective basis as it only needs a single passive sensor and utilises a camera as a barcode scanner device that is cheaper than any barcode scanner. Prerna et al. (2018) invented a system for smart billing by using the technology of RFID and LIFI. The project simplified the billing process and enhanced the security of the system by using the LIFI technique. The framework is easy to use and considered to be flexible. Besides, it does not require any training before using the system. In addition, the project helps to reduce the time wasted in waiting in long queues. Karjol et al. (2018) invented an IoT-based shopping trolley. The authors believe that such a framework is suitable to be used in markets. This smart trolley eases the billing process and reveals the product relevant information to the customer upon their request.

Shanthi and Selvaraj (2019) proposed an automated artificial intelligence (AI) enabled medical kiosk that is remotely controlled and equipped with sensors to enable users to access the doctors they need and send the relevant reports and monitor their conditions. The cloud system enables the users to communicate with the doctors they need from any region in the world. A patient could visit a provincial community where an automated AI-enabled medical kiosk is introduced; the clinical expert would distantly analyse the patient's clinical issue and give robotised medication conveyance at the doorstep. Gurubasavanna et al. (2018) implemented a charging kiosks project for public use, which gives a free open charging administration by utilising the most recent IoT innovation. Lai et al. (2019) deliberated about the means to alleviate the security issues and how they turn out in casting a ballot can be expanded by acquainting the elector to cast a ballot from any voting public regardless of whether he/she has a place with some other electorate from the assigned approved voting focuses. Sa-ngiampak et al. (2019) proposed an IoT-based smart locker system with an access sharing feature and named it a locker swarm. The authors developed a smart locker system that functions by scanning a quick response (QR) code by the user as an alternative to using keys. Awan et al. (2017) proposed a model that utilises the information security techniques to tackle the vulnerabilities available in the modern Android kiosk ATM, for instance, malware upload on ATM, network traffic monitoring, and source code theft.

Sawetsutipun et al. (2020) invented a model that serves as a facial image verification system that can be implemented in readily available kiosks. The model performs by comparing the picture available on the user ID and the image captured by the camera embedded in the kiosk. The model has scored an accuracy of 99.996% when tested on the Cross-Age Labelled Faces in the Wild dataset. Yang and Li (2013) proposed a framework that acts as an e-receptionist. This model can sense the approaching of guests using video-based motion detection and greet them orally. It will recognise their voice and analyse their questions or inquiries by utilising the technology of natural speech and replying to the guests accordingly using the text-to-speech feature. Phan et al. (2015) developed a smart kiosk that serves as an identity authentication device. The kiosk comprises two components: (i) gait-based embedded in the user mobile phone or smart wearable device to access online platforms such as Facebook, Flickr, Twitter, and Gmail, and (ii) interactive kiosk that enables the users to utilise services in correspondence with their identities.

Baskaran et al. (2016) invented a smart card that serves as a smart ticketing system by utilising RFID technology. The smart card bears all the information about the user, including his/her bank account information. The user can wave the card in front of the bus to open the door. The bus has a liquid crystal display (LCD) that shows the number of occupied places by the passengers and free spaces.

Wang et al. (2018) proposed a multi-functional delivery locker (MFPDL) that serves as a parcel delivery system that delivers parcels on time and automatically by using a password and the receiver's phone number. Besides, the uniform parcel delivery system monitors the delivery process automatically in a smart city. The parcel delivery system delivers a broad range of objects from small to large-sized objects such as furniture. The delivery system aims to enhance the delivery process and save the consumption of material and human resources. Amessafi et al. (2017) proposed a model that acts as a tourist guide to assist the tourist with any information he/she might need. The kiosk has a voice recognition feature. However, the authors of this work believe that the kiosk might face obstacles in recognising different accents. Khanna and Anand (2016) proposed a smart parking framework comprising of an on-location organisation of an IoT module that is utilised to screen and signalise the condition of accessibility of each single parking spot.

To ease the process of utilising the locker services for students visiting the library and increase its security system, a smart interactive locker kiosk for student assistance project was proposed. This type of kiosk assists the students in keeping their items and belongings in secured lockers using mobile numbers, fingerprints, and identity document (ID) numbers. The interactive kiosk offers two operations, namely the pick-up and drop-off. A user can step up, enter his/her student ID and mobile number. Eventually, the locker is unlocked for the student to place his/her belongings. Similarly, during the pickup operation, the system requests the user's particulars to unlock the locker for the user to take back his/her items. Based on our proposed methodology, we demonstrate the hardware implementation and software development to build a working prototype for the IoT-enabled interactive kiosk. Our design takes into account various smart features, which include: simple and efficient user registration process, enhanced locker security and protection, greater user flexibility for pick-up and drop-off, and automated calculation of locker occupancy duration.

METHODOLOGY

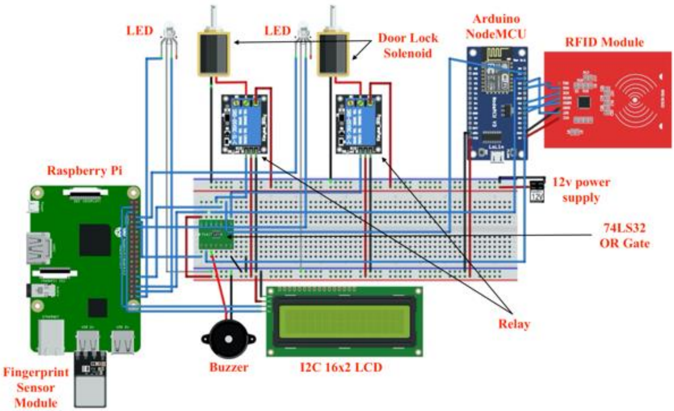
Figure 5.1 depicts the block diagram of the components that were utilised in the construction of the IoT interactive kiosk system. The system consists of an LCD, a Raspberry Pi, an RFID reader, a relay, a power supply, an Arduino NodeMCU, and a door lock. The LCD is used as a display device, where it shows a message that requests the user for the required credentials. The Raspberry Pi gives an output voltage of 5 V and controls all the components to work together. In this project, the components that are used need a high voltage to function properly. Hence, a 5 V relay is used. These components are connected to the 5 V relay. The relay is connected to the Raspberry Pi and is operated with 5 V. Moreover, a 12

V door lock is connected to the relay attached to the Raspberry Pi to control the door lock. The universal asynchronous receiver-transmitter (UART) module allows the fingerprint module to be compatible with the Raspberry Pi as the fingerprint module used is compatible with Arduino NodeMCU. The fingerprint module is used to scan the user's finger during the process of drop-off and pickup.

Three OR gates were deployed in building the project as the OR gate takes two inputs and gives one output. The two inputs are the Arduino and Raspberry Pi, while the output is connected to the buzzer, locker 1 and locker 2. When the user scans a fingerprint that is not compatible with any print that is stored in the database, the buzzer sets off an alarm. Similarly, if the user scans the wrong ID on the RFID reader connected to the Arduino, the buzzer initiates an alarm. Lastly, there is an RGB light-emitting diode (LED) attached to each door lock that indicates the availability of the locker. If the locker is empty, the LED will show green colour. If the locker is in use, the LED will show red colour.

Figure 5.1

Block diagram of the IoT interactive kiosk system



HARDWARE IMPLEMENTATION

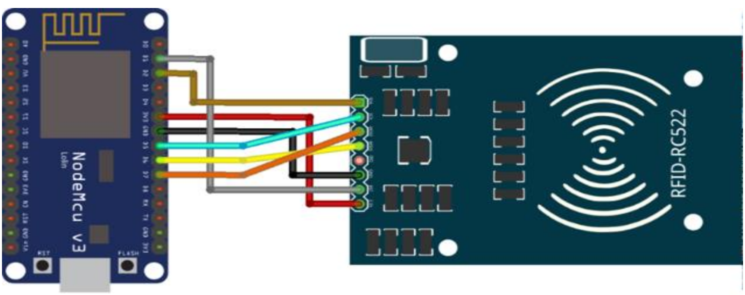
ESP8266 (NodeMCU)

NodeMCU is an open-source Lua based firmware and a board that is focused on IoT based applications. It incorporates firmware that causes sudden spikes in demand for the ESP8266 Wi-Fi system on a chip (SoC) from Espressif Systems and equipment that depends on the ESP-12 module (Last Minute Engineers, 2020).

Figure 5.2 illustrates the connection between the RFID reader and the NodeMCU. This Arduino was chosen because the Wi-Fi module is implemented in the Arduino itself. Hence, it saves additional costs. If another type of Arduino was deployed, for instance, Arduino UNO or Nano, a separate Wi-Fi module is required to use the IoT feature. The NodeMCU was also used to utilise the feature of the Blynk application so that the administration can unlock the lockers in emergency cases from his/her smartphone. Using C and C++ programming language in Arduino Integrated Development Environment (IDE), the Wi-Fi username and Wi-Fi password need to be configured so that the Arduino can communicate with the Blynk application. The NodeMCU is faster than other types of Arduino. For instance, Arduino UNO, Nano, etc. On the contrary, the NodeMCU has a smaller number of pins relative to Arduino UNO or Nano. However, in this project, a large number of pins is unnecessary. The only required pins are the pins that need to be connected to the RFID module and three extra pins. One pin is connected to the buzzer. The other two pins are responsible for controlling door lock "1" and door lock "2".

Figure 5.2

NodeMCU and RFID connections



RFID

RFID uses radio waves to read data on the item from the stored label or tag attached to it (atlasRFIDstore, 2020). In this project, the RFID module was used by the administration to gain access to the locker. When the administration scans his/her ID, the authorised ID is stored in the database. Hence, when the authorised ID is scanned, the administration can unlock and lock both lockers within one minute without changing their availability. If the ID scanned is not authorised, the alarm will be enabled.

Raspberry Pi

The Raspberry Pi is a type of single computer board. It operates with Linux. The Raspberry Pi sustains a set of pins for general-purpose input/output (GPIO). The GPIO enables the user to control the components implemented in the circuit board and enables the features of the IoT (Opensource.com, 2020).

RGB LED

RGB stands for red, green, and blue, and the RGB LED can emit almost any colour (CircuitBread, 2020). However, some colours are difficult to be displayed by the RGB LED. In order to get the desired colour as an output from the LED, the intensity of each LED should be adjusted in the code. In this project, only two colours are needed; they are green and red. Green indicates the availability of a locker. On the other hand, red indicates that the locker is already in use.

Relay

The function of the relay enables the control of the circuits or the components that operate with high voltage with the help of a lower portion of voltage (OMRON Electronic Components, 2021). In this project, the relay is needed to control the 12V door lock with the 5V coming from the Raspberry Pi and the Arduino.

Liquid Crystal Display (LCD 16×2)

The LCD is a component that is essential in most embedded frameworks. It acts as an interface between the user and the system (WhatIs.com, 2021). The LCD is considered relatively cheap and readily available in markets. In this project, the LCD that was used is the 16×2 LCD. It consists of 16 columns and 2 rows.

Buzzer

A buzzer is an audio device that is used to give a beep sound to indicate an alarm (Farnell, 2020). In this project, the buzzer is used to alert the user if the door lock is not closed properly, if the information is wrongly entered or when the locker is opened and access is granted. In each operation, a different beep sound is given as output. This can be configured in the code.

OR gate

An OR gate is a logic gate that is used in electric circuits (ElectronicsTutorials, 2021). In this project, the OR gate was used as it takes two inputs and gives one output. The two inputs are from the Arduino and Raspberry Pi, and the output is connected to the buzzer. Thus, if a wrong ID is scanned by the RFID module that is connected to the Arduino, the buzzer will create a beep sound. On the other hand, if a wrong fingerprint is scanned by the fingerprint module that is connected to the Raspberry Pi, the buzzer will also create a beep sound.

SOFTWARE IMPLEMENTATION

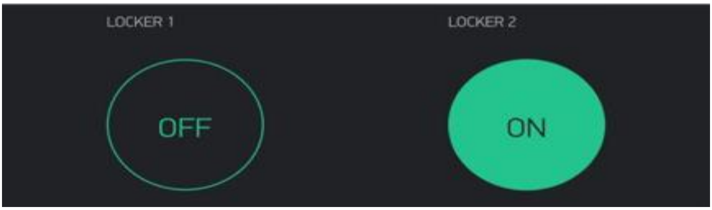
The project was carried by utilising the programming language of Python, C, and C++. Python is considered an easy language and can be self-taught (Python, 2021). Raspberry Pi is used in hardware implementation. Python is the most compatible language to program the Raspberry Pi. C and C++ are programming languages often used in Arduino-based projects (W3Schools, 2021). Since this project uses Arduino, C++ is the most suitable programming language for programming it.

Blynk application is an IoT platform that enables the user to construct an interface between the hardware projects and the smartphone (Blynk, 2020). The Blynk app allows the user to create or construct a dashboard where the user can add buttons, sliders, switches, etc. In this project, the Blynk app was used to control the door lock over the internet. The reason Blynk was chosen over

Ubidots is that it is easier, and extra pins can be added or removed without modifying the code. Figure 5.3 shows a snapshot of the app controlling the door lock from the smartphone.

Figure 5.3

Controlling the door lock from the Blynk app



RESULTS AND DISCUSSIONS

This section presents and discusses the results that were obtained at the end of the project implementation in terms of hardware and software.

Figure 5.4 illustrates the final prototype of the kiosk that shows the locker with the LCD, fingerprint module, and LED.

Figure 5.4

System prototype of interactive kiosk

Figure 5.5 illustrates the messages displayed on the LCD by the kiosk. The system asks the user to press 1 on the keyboard for drop-off operation. Or else, 2 for pickup procedure. There is a third option as well, which is the temporarily unlock feature. The system provides an extra option for the user to open the locker temporarily, and the locker will remain reserved for the same user until the user picks up his parcel.

Figure 5.5

The system asks the user for the operation he/she wishes to perform

Figure 5.6 (left) shows the message displayed by the kiosk that prompts the user to key enter his/her ID. The ID should be 10 digits in length. Otherwise, the system will reject it. Figure 5.6 (middle) shows the error message displayed by the kiosk on the LCD screen when the user entered an ID that contains letters. This message was displayed as output as the system was programmed to only accept ID with 10 digits with no letters. Figure 5.6 (right) shows that an error message will appear when an incorrect ID is entered by the user.

Figure 5.6

A message prompting for a user ID (left); error message when the entered ID contains a letter (middle); error message for incorrect ID

Figure 5.7 shows the message displayed when the system asks the user to enter his/her phone; the phone number to be entered should be Malaysian. Otherwise, the system will reject the transaction

Figure 5.7

A message prompting the user to enter his/her phone (left); message prompting the user to enter a Malaysian number (right)

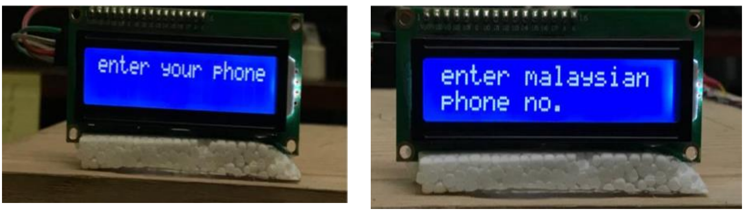


Figure 5.8 shows when the system asks the user to enter his/her name. Based on the criteria configured in the program, the user should enter his full name. Otherwise, the transaction will be rejected by the system.

Figure 5.8

A message prompting the user to enter his/her name (left); message prompting the user to enter his/her full name (right)

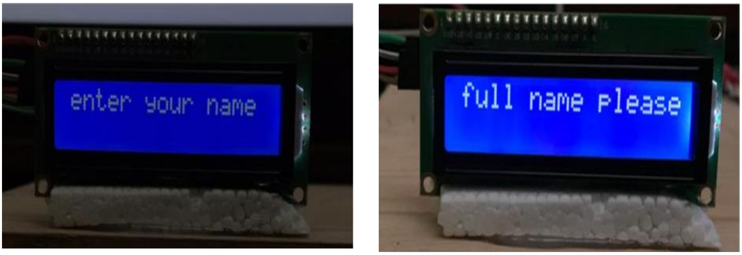


Figure 5.9 (left) illustrates the warning message displayed on the LCD screen by the system when the user enters a number when entering the name. Figure 5.9 (right) depicts the case when the user scans the wrong fingerprint that is not stored in the system database.

Figure 5.9

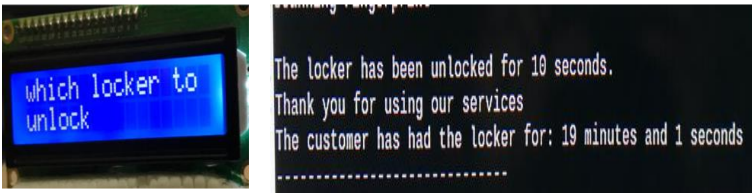
A warning message in which the entered name contained numbers (left); message when the wrong fingerprint is scanned (right)

Figure 5.10 (left) presents the situation when the administration password is entered. Only the

administration should know the password to unlock any reserved locker and make it available to users. Figure 5.10 (right) illustrates the feature provided by the kiosk. The system is programmed to calculate the duration of how long the user used the locker so that it can be used in the future for collecting money based on this duration.

Figure 5.10

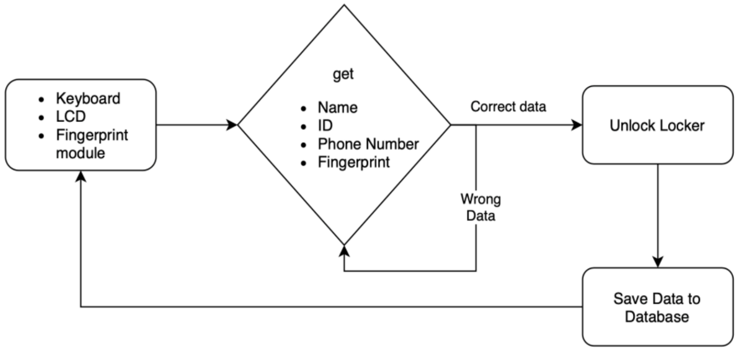
The system asks the administration which locker to unlock (left); message showing the duration of how long the lockers were in the reservation (right)



The overview of the entire framework is shown in Figure 5.11.

Figure 5.11

Overview of the framework



CONCLUSION

In conclusion, the main objective of this project to design and implement an IoT-enabled internet kiosk has been successfully achieved. The project is implemented to serve as a smart locker system that can be utilised in campuses, gymnasiums, or anywhere that requires space for individuals to store their belongings safely. The kiosk allows the user to key in specific details during the pickup or drop-off operations to ensure safety and security for the user's belongings. Hence it is a win-win situation for the user.

For future work, since the system can calculate how long the kiosk has been in use, the kiosk can be utilised commercially to get paid for its services per hour/minute. Additionally, the system can be improved so that it offers the user the feature to check the availability of the locker from his/her smartphone.

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Index

This book presents the state-of-the-art Internet of Things (IoT) applications by the undergraduates from the Faculty of Engineering, Multimedia University. The advances in sensor technology, computing, and cloud technology ensure that the IoT finds its use in various diverse applications. The first chapter discussed the design and construction of a prototype egg sorter that can be used in the egg industry for determining the size of an egg utilising image processing techniques. Chapter two introduced a wireless intelligent IoT for tele-healthcare heartbeat monitoring system while Chapter three talked about the assistive prayer monitoring system for elderly Muslims. By tracking the movements of the worshipper based on an infrared distance sensor and a pressure sensor, the system is able to display a *rakaah* (cycles of prayer) counter. A greenhouse monitoring system is described in Chapter four whereby, a user can continuously monitor the conditions in the greenhouse via a ThingSpeak cloud account. The last chapter explored the use of IoT for an interactive kiosk that serves as a smart locker allowing users to place their belongings securely and efficiently. Overall, the five applications discussed in this book serve as useful references for further exploration on projects related to the IoT.

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