Alinteri J. of Agr. Sci. (2021) 36(1): 525-533
e-ISSN: 2587-2249
info@alinteridergisi.com

http://dergipark.gov.tr/alinterizbd
http://www.alinteridergisi.com/
DOI:10.47059/alinteri/V36I1/AJAS21075

RESEARCH ARTICLE

Development of Smart Home System based on Mobile Apps Control Using IoT for Educational Purposes

Ahmad Asyraf Rosli[1] • Muhammad Rusydi Muhammad Razif[2*] • Omar Abu Hassan[3] • Nor Shahida Mohd Shah[4] • Ili Najaa Aimi Mohd Nordin[5] • Khairul Nizam Mustafa[6]

[1]*Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, Muar, Johor, Malaysia.*

[2*]*Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, Muar, Johor, Malaysia.*
Cybernetics and Power Technology Focus Group, Universiti Tun Hussein Onn Malaysia, Johor, Malaysia.

[3]*Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, Muar, Johor, Malaysia.*

[4]*Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, Muar, Johor, Malaysia.*

[5]*Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, Muar, Johor, Malaysia.*
Cybernetics and Power Technology Focus Group, Universiti Tun Hussein Onn Malaysia, Johor, Malaysia.

[6]*MYFlexitank (M) Sdn. Bhd., Kedah, Malaysia.*

ARTICLE INFO

Article History:
Received: 30.03.2021
Accepted: 02.05.2021
Available Online: 21.06.2021

Keywords:
IoT
Smart Home
Education
Wireless
Infrared Sensor

ABSTRACT

The Internet of Things (IoT) with its enormous growth widens its applications to the living environment of the people by changing a home to a smart home. The smart home is a system, which connect homes with various types of digital devices to communicate with each other through the internet. Based on our prior study, 59% of the respondent among Malaysians are unaware about the IoT or just heard about it without knowing its concept. Thus, this project will present a development of a smart home system based on mobile apps control using IoT to educate Malaysian. This project uses a combination of wireless technology and infrared sensor to detect the motion and a microcontroller to control the usage of appliances in the home. Blynk as a mobile app has been programmed and used to control and display the usage of LED, fan and camera. The output of the appliances will be displayed on the Blynk in kind of LED icon and stream video. The IoT system has been successfully developed and able to follow the instruction given. The LED, fan and camera will turn ON when the switch button in Blynk is pressed. The system has a limited range of operation because it depends on the Wi-Fi signal range, which is about 50 meters of the developed smart home using IoT control. The proposed smart home prototype is useful in the education sector to expose all Malaysian to the current technology especially students and staffs in the university.

Please cite this paper as follows:

Rosli, A.A., Razif, M.R.M., Hassan, O.A., Shah, N.S.M., Nordin, I.N.A.M. and Mustafa, K.N. (2021). Development of Smart Home System based on Mobile Apps Control Using IoT for Educational Purposes. *Alinteri Journal of Agriculture Sciences, 36*(1): 525-533. doi: 10.47059/alinteri/V36I1/AJAS21075

Introduction

A smart home requires incorporation of a computer, information, and communication science as well as customer electronic gadgets into the internal facilities of residences [1].

Usually, smart home system enables the residents to manipulate devices and appliances such as air-conditioning, electric fans, lights, televisions, and webcams by a computer to attain home care, energy management, smart entertainment, and domestic security. Smart home is described as a domestic residence that has programmable digital controls and sensors that could alter home temperature, ventilation, lighting, appliance and tools operation in a way that responds to interior conditions in

*Corresponding author: Muhammad Rusydi Muhammad Razif

order to preserve energy [2]. The central controller will send regular switching indicators via the everyday household wiring, efficiently treating it as a variety of computer network. Every signal incorporates a code figuring out the unit and relates to home appliances practice such as flip on, flip off, brighten, or dim. While all the manipulation units hear for and receive all signals, certain signal only affect the equipment (or appliances) with the correct code. Apart from home appliances that receive signals, a smart home can also be equipped with sensors such as movement detectors and thermostats for the system to automatically respond to any modifications during the day, temperature, intruders, or something deemed important. It's also possible to turn ON and OFF the home appliances controlled using remote controls.

Smart home is known as a dwelling incorporating a communication network of homes in 2003 for electrical appliances and services. Through smartphone or internet, the electrical or electronic appliances can be connected and controlled remotely from any location in the world. A previous project of smart home automation developed by W. A. Jabbar *et al*. [3], used Android-based smartphone as a remote controller to control home appliances and monitor the home conditions in real-time. The updated data from several actuators and sensors that connected to a NodeMCU will transfer to an IoT server. The researchers used Adafruit IO Web and MQTT Dash mobile application to monitor the obtained data from the several sensors. The developed system is also equipped with IFTTT server to send notifications to the user through their mobile phones if anything occurs at their home. By using Google Assistant' voice commands or MQTT/Adafruit IO GUI, the home appliances can be controlled easily and efficiently [3].

In 2019, R. Sarmah *et al*. [4] had proposed an autonomous smart home system based on SURE-H prototype model. In this system, users can control the home automation via internet connection to access the cloud service. By using web-based applications over the internet, the remote users can access the server when connected to the internet. The security system has been enhanced where the user required to sending a request to assess the server and waiting for approval.

Internet of Things (IoT) is a technology that can connect various appliances or devices via internet access. Electrical and electronic appliances such as a heater, washing machines, webcam, fans and air conditioners could be connected and programmed to communicate with each other through internet [5]. The example of applications using IoT is a smart home, smart city, intelligent transportation system, earthquake detection, a smart grid system, agriculture, health center and supply chain system [6]. One of the significant advantage of IoT is that it can turn a non-smart system into a smart device, which allows users to access their devices through internet. For example, a home that is been converted into smart home can be accessed through internet and improve its security with the help of camera. A person can also monitor their electricity appliances usage and switch ON or OFF their appliances from anywhere, as long as they got an internet connection. A smart home can also be programmed to switch ON or OFF the fan and light of the room when the presence of a person is detected and this makes the system to be intelligent. A group of researchers did develop more advanced smart home by integrating voice recognition system and web-based service by setting a user-define command controlled for the home safety purpose [7].

An advanced IoT system with extra capability to detect and apprehend intruder has been proposed by Surantha et al. by using HOG and SVM methods [8]. The project was implement the IoT security monitoring system that indicates the connection between Arduino with Raspberry Pi 3. For communication, the board is equipped with a wireless LAN. Arduino was connected to PIR sensor to get signal and the Raspberry Pi 3 is connected to a USB web cam using a USB cable to take pictures. A buzzer is introduced in the system to release alerts via the GPIO port. The infrared sensor will read every movement of about 5 to 7 meters passing through the detection varies from it. In this motion detection process, the device will always read until the motion is detected.

In smart home ownership survey conducted by Rasyidah *et al*. [9], a group of respondents from the age of early 20s has been asked with some questions regarding their intention to buy a home and their considerations for buying a smart home. Based on the results, majority of the respondents do not own a house (94%) and have the intention to buy a house (93%). This indicated that at the early age of 20s, people have a high desire to buy and own a home even though the purchasing power is still low. For smart home purchasing question, the results show 61% of respondents will consider to purchase smart home, whereas 39% did not make decision yet to buy a smart home.

Today, the IoT technology awareness has widely discussed. Based on the study conducted by G. Bodur *et al*. [10] for nursing and medical school, some students are lack of knowledge in IoT because of the new and complicated nature of these applications towards them. Y. Gamil *et al*. [11] also made a survey among construction industry in Malaysia. Based on the survey, 63% of individuals have prior knowledge of IoT technology and concepts, and 57% know the benefits of IoT. Farooq *et al*. [12] has made a survey of awareness of IoT in Pakistan to know either this technology is known among Pakistanis as compare to other countries. The first hypothesis result showed that the foreign users are more aware and know about the term of IoT compared to the local citizen. The second hypothesis had proved that the local and foreign both know the IoT's impact in their lives.

Methodology

The project start by conducting a survey to know the level of understanding among Malaysian people about IoT. From the frequency analysis of 100 respondents, the age range is from 16 to 40 years old. The required education background is from secondary school to postgraduate level. It also includes the education discipline such as science, technology and engineering field and other field such as economy and accounting, information technology, medical

and health, and others. For engineering and technology field, we conducted the survey on four major engineering field such as electrical, mechanical, civil and chemical. All the respondents have been asked the question either they have heard about the IoT or not. Then, we asked the respondent who answered 'Yes' or 'No' to more specific question, about their understanding on IoT, either they really understand about IoT and can programmed the IoT; understand a little about IoT and know about their concept; have heard about the IoT only; and never know about the IoT before. We also asked the respondents either they are interested to try the IoT tunnel to gain their understanding.

After the survey has been completed and data have been collected, a smart home system has been construct. Figure 1 shows the flow diagram of the smart home system. The system start when an infrared sensor detects any movement of the object. Once the sensor detect any movement, a servo motor will turn ON and the gate will open for 5 seconds and then will automatically close. The process will continuously repeat until no other movement has been detected. At the same time, the NodeMCU microcontroller which is connected to Blynk will display the Wi-Fi connection status either the network already been connected or not. A set of LEDs, camera and fan also have been introduced in Blynk application. They will turn ON when a user touches the switch on button on screen display in Blynk application. At the same time, the phone screen will display the output condition of the LED, camera and fan either they were ON or OFF. Figure 2 shows the flowchart of Blynk application.

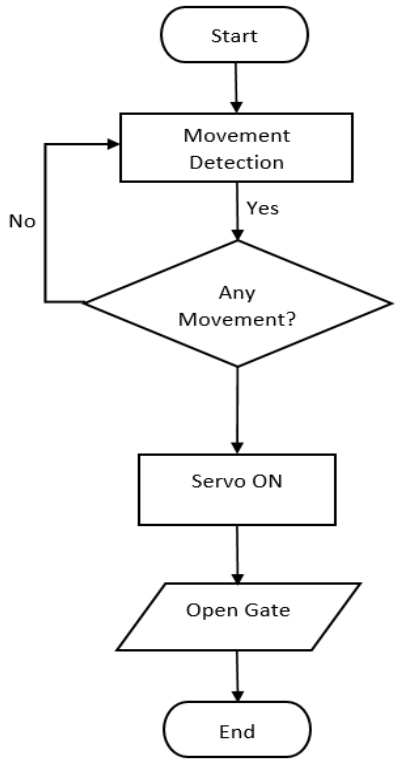

Figure 1. Flowchart of smart home system

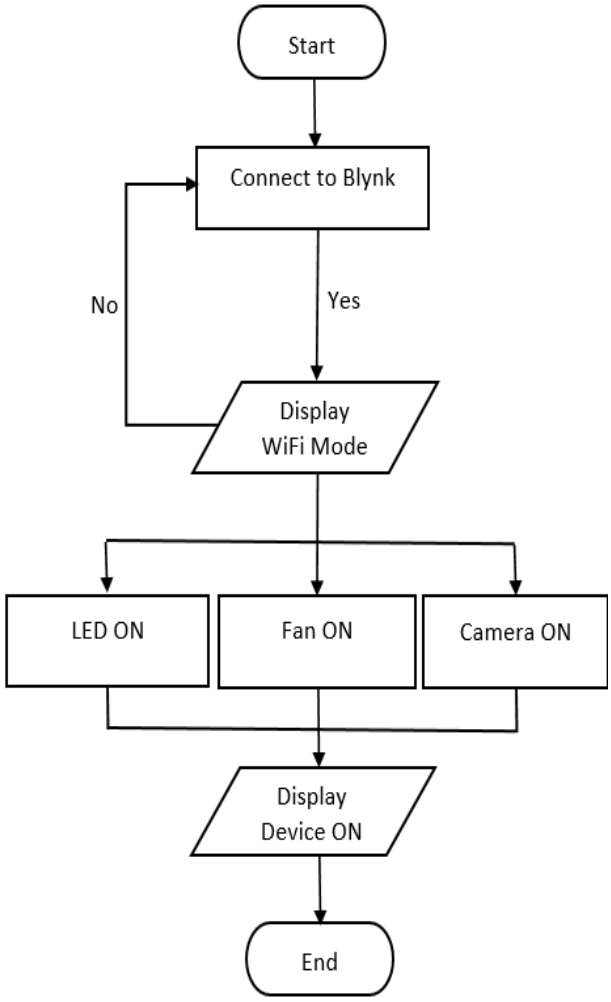

Figure 2. Flowchart of Blynk application

The experimental setup is shown in Figure 3. Based on this figure, the DC power supply is connecting to the Arduino Uno board, FTDI programmer and NodeMCU ESP8266. All the components need to be supplied with 5V DC voltage. The digital output port of the Arduino Uno board is connected to the input port of the servo, passive infrared (PIR) sensor, LED and the fan while the FTDI programmer connected to the camera. In situation where any human presence is detected in front of the door, a PIR sensor will capture the human movement and send the output to the Arduino Uno. Once Arduino receives the signal, the servo motor will turn ON. User can also control the LED, camera and the fan using the Blynk application via Wi-Fi connection in the mobile phone.

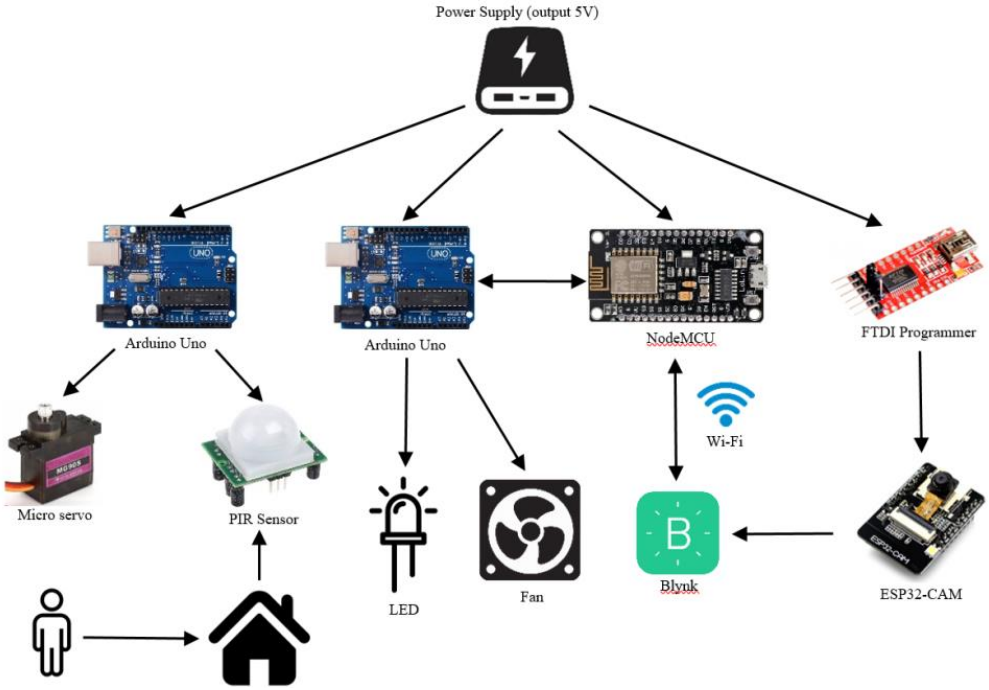

Figure 3. Experimental setup of the project

This system will activate the camera, fan and LED by using the Blynk and the servo will open the gate if any movement is detected. The devices will turn ON for certain time until there is no more motion. This system can also be controlled by mobile apps via internet. If there is no human presence, then the system will re-read its movement or return to the initial process. The hardware design includes the selection of electronics equipment and the integration of all components. The components correspond to the order of hardware specification in Table 1. The NodeMCU ESP8266 is used as a processing module and it is equipped with Wi-Fi module for communication with the mobile apps. A mobile apps called Blynk is used to monitor all the output devices. An Arduino Uno is connected to NodeMCU ESP8266 using USB cable.

Table 1. Hardware specification

No	Name	Description
1	PIR sensor	PIR motion sensor for movement detection
2	NodeMCU	NodeMCU ESP8266
3	Arduino	Arduino Uno
4	Camera	Using ESP32-CAM for take picture
5	Fan	5V DC cooling fan
6	LED	5mm LED diode
7	Servo motor	Micro servo for open gate

To capture the picture, ESP32 camera is mounted to the FTDI programmer through jumper cable. The PIR sensor also receives the signal when it detects any motion and then it will turn ON the servo to open the gate for 5 seconds. The PIR sensor is located near to the front entrance to detect the presence of human and activate the devices when any motion of human is detected. The range of the PIR sensor detection is from 9 feet up to 20 feet (6 meters) to read the movement around it. The system will sense any movement continuously and it is ready to open the gate at anytime. If there is no human presence, the system will return to the initial process.

The software used to program the smart home is Arduino software whereas Arduino Uno has been used to control input and output of the smart home. It has 14 digital input/output pins, 6 analog input pins, a USB connection, reset button, power jack and an ICSP header. It could simply be connected to a computer by using a USB jack and programmed on Arduino Software known as integrated development environment (IDE). The Arduino Uno is recommended to operate at 5 V. The limitation of the input voltage is to protect the Arduino board from shorts or overcurrent due to the chip burnt [13].

Microcontroller Unit (MCU) is a computer on a single chip which includes more than one CPUs (processor cores) along with memory and programmable input/output peripherals. NodeMCU has been used in this project to control the LED and fan usage by connecting with Wi-Fi connection. The NodeMCU comes with the ESP-12E module consisting of ESP8266 chip Wi-Fi SoC from Espress if System. It is used to store data and programs in 4MB flash memory and 128 KB RAM. Furthermore, it has Wi-Fi / Bluetooth and Deep Sleep Operating features with high processing power and can be powered ON using VIN pin or Micro USB jack [14]. A passive infrared sensor (PIR sensor) is used to sense or detect a motion of human in surrounding of the sensor range. PIR sensors are essentially made of a pyroelectric sensor to detect levels of infrared radiation. The radiation is emitted more when it detects any hot stuff or anything that emits a low level radiation. The output of sensor will swing high or low to transmit the output data of one half sees more or less IR radiation than the other. The maximum

distance that PIR can detect is up to 6 meters with the coverage angle from 0 to 120 degrees [15].

Results and Discussion

The development of the smart home system with IoT technology for educational purposes focusses on the respondent of IoT awareness among Malaysian and hardware and software performance of the smart home prototype. From 100 respondents of our survey, 63% of the respondents have heard about the IoT. Then, the survey focused to the respondents who have different education background. From this category, 65% of respondents have degree level education background, followed by 22% diploma or equivalent level, 10% postgraduate and 3% SPM. Based on the responses, 33.33% of SPM background have heard about the IoT. Only half of diploma or equivalent level have heard about IoT, whereas 66.15% respondents with degree background level have heard about the IoT and most of the respondent in postgraduate level have heard about the IoT which is 80%. This results can be referred to Figure 4.

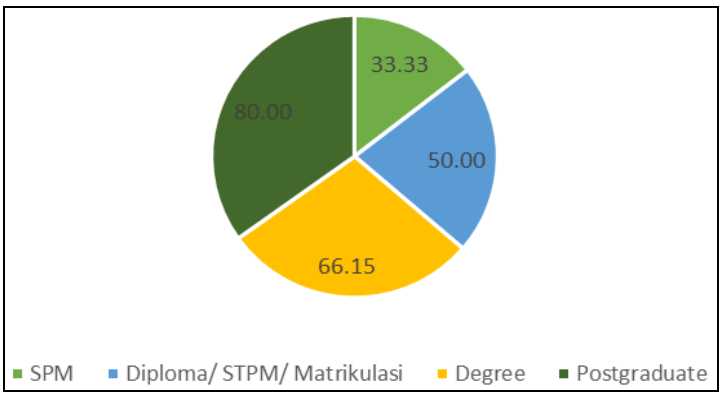

Figure 4. The percentage of respondents who have been heard about the IoT based on different level of education

Our survey also asks the respondents about their understanding on IoT. From a total of 100 respondents, 56% of them are from science, technology and engineering education discipline, followed by 27% others, 10% from economy and account, 4% from information technology and 3% from medical and health. Based on their responses, surprisingly there are no one from medical and health discipline who has heard about the IoT. Next, 33.33% of others have heard about the IoT before, more than half of science, technology and engineering have heard about the IoT which is 75% whereas the respondents from economy and account discipline, only 80% have heard about the IoT. For information and technology discipline respondent, all of them have heard about the IoT. The percentage of respondents who have heard about the IoT can be referred in Figure 5.

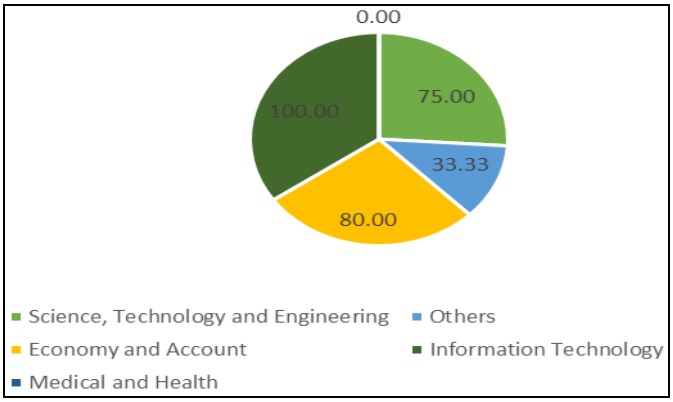

Figure 5. The percentage of respondents who have been heard about the IoT based on education discipline

The following results depict the percentage of respondents who understand about the IoT based on their engineering specialization. From 100 responses, 5% of them really understand about IoT and can programme the IoT, 36% of them understand a little about IoT and know about their concept, 24% have heard about the IoT only, and 35% never know about the IoT before. From the respondents who can programme the IoT and know its concept, majority comes from the electrical field which is 88.89%. Only half of the mechanical field can programme the IoT and know its concept which is 50%, and followed by 36.36% from the civil field. The chemical field is the lowest, only 28.57% of them can programme the IoT and know its concept. The results can be obtained in Figure 6.

Our last question regarding the respondent's interest in trying the IoT tunnel to gain their understanding in IoT, 88% of them give positive results, whereas the rest 12% show no interest in trying the IoT tunnel. Based on the finding in our survey, we conclude that many of Malaysian peoples are still lack of IoT knowledge depending on their education level

and education discipline, but majority of them still interested to learn and try something that related to IoT application, thus, this IoT tunnel project is very significant to educate them.

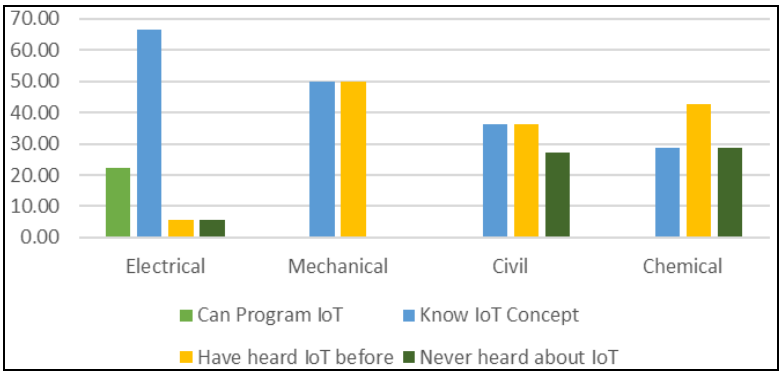

Figure 6. The percentage of respondent's understanding about the IoT based on their engineering specialization

In experimental testing, each component has been tested before it is assembled as an integrated system. A PIR sensor has been installed in front of the door and its function is to detect human moving around within approximately 10 meters. When the PIR detects any motion, the LED diode lights up for a five seconds when PIR sensor sensed a motion and gate opened. The PIR sensor and its control system can be seen as in Figure 7.

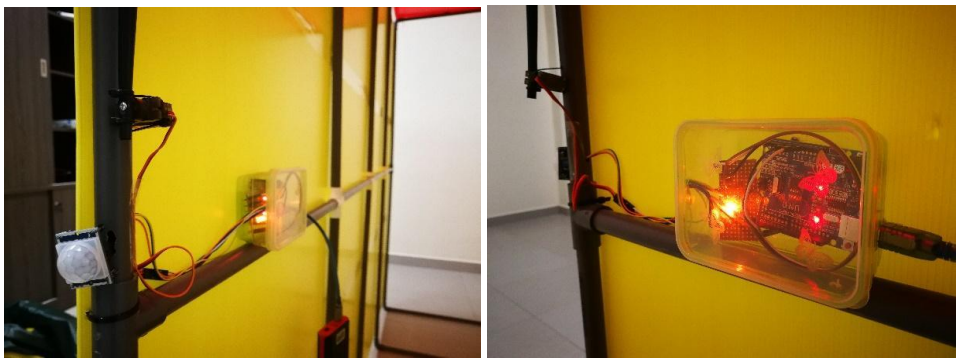

Figure 7. PIR sensor located in front of the door (left). The gate will open automatically when it senses any motion in front of the door (right)

The output of the PIR sensor can be seen through Arduino IDE software as in Figure 8. The serial monitor will display 'Motion Detected' when PIR sensor detects any motion and display 'Motion Ended' when it does not detect any motion. An ESP32-CAM module is used in this project to supply a stream video in Blynk display, so that user could monitor the condition of the smart home from their mobile through internet. During programming process, Future Technology Devices International (FTDI) programmer is needed to upload the programmed code through the U0R and U0T pins (serial pins). Figure 9 shows the interface of Blynk on a smartphone. Current view displays a live video streamed by the ESP32-CAM.

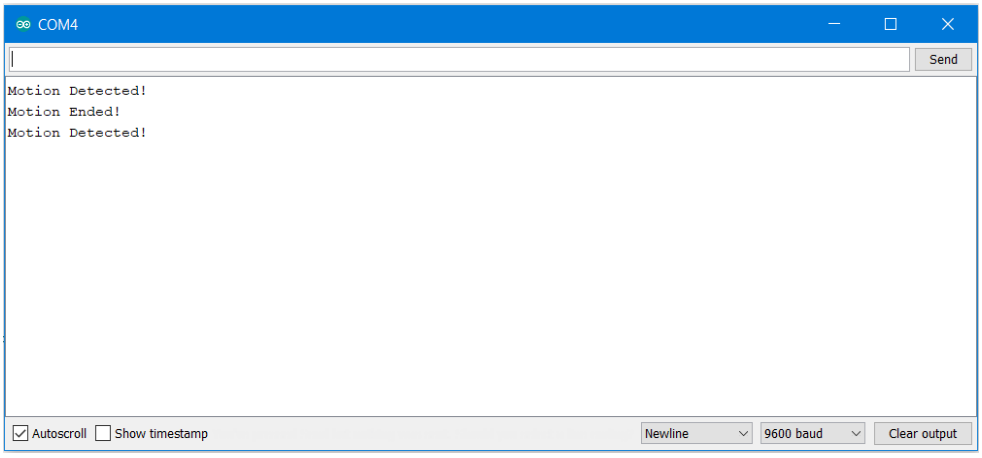

Figure 8. The output from the PIR sensor

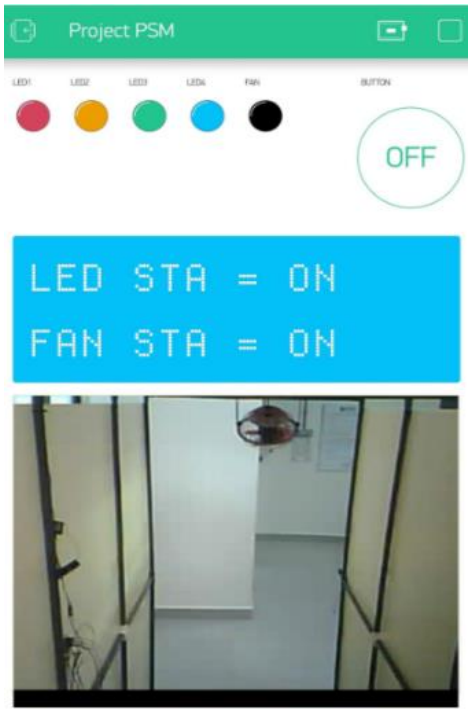

Figure 9. Blynk interface showing a live streamed video

In smart home design, the size of model is set to 8 feet long, 3 feet wide and 6 feet height. The body of the smart home model is constructed using PVC pipe and the wall is constructed using corrugated board as shown in Figure 10. The smart home model also equipped with Arduino UNO microcontroller, ESP32-CAM, fan and LED as shown in Figure 11. The Blynk apps has been used to control the fan, LED and display the live stream video on smart phone screen. This can be shown in Figure 12.

Figure 10. The smart home design (left). The door open when PIR sensor detects any motion in front of the door (right)

Figure 11. The components in smart home design

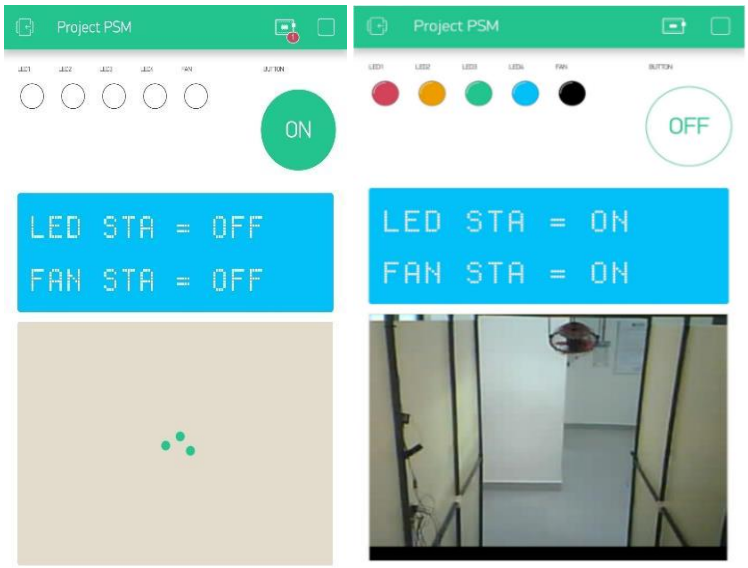

Figure 12. LEDs, fan and video stream turned off in Blynk interface before operated (left). LEDs, fan and video stream turned on in Blynk interface when operated (right)

Conclusion

In conclusion, the objectives of this project have successfully been achieved. We have gained a rough study of the awareness in IoT technology among Malaysians which is 63% of the respondents have heard about the IoT. For the smart home prototype, results showed that the electronic appliances and their monitoring system perform well based on IoT technology. The electronic components such as camera, lamp and fan can easily be controlled using smartphone and ready to be explored and operated by users with simple instruction such as installing the Blynk application, login the email and pushing several buttons.

Acknowledgement

The authors would like to give special thanks to Universiti Tun Hussein Onn Malaysia (UTHM) under UTHM-Matching Grant No. H865 and Ministry of Higher Education (MOHE) Malaysia.

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