International Journal on Robotics, Automation and Sciences

Development of an IoT-based Wireless Controlled Power Adapter

Kar Chung Chin, Gin Chong Lee*, Hao Ren Yon and Hock Kheng Sim

***Abstract* – Energy waste issues in electrical appliances due to inefficient usage monitoring are commonly faced by almost every person. This project aims to develop a wireless controlled power adapter operates autonomously based on occupancy of a specific space. In this way, convenience is brought to the user, and energy waste could be prevented. This system provides two modes of operation: manual and automatic. Using the mobile phone user interface, the user can manually and wirelessly control the power adapter. When there are no occupants in the specific space, the system will automatically shut off the power adapter. In contrast, if a person is detected in a specific space, the power adapter will be automatically switched on. WIFI protocol is used for the entire communication system. Experimental demonstration has been conducted to show the functionality. This proposed system offers the user to control in a long-distance range as long as the system is connected to a random WIFI network.**

Keywords—Wireless, Power Adapter, Energy Waste Management, Internet Of Things.

I. INTRODUCTION

Developing autonomous power consumption management in premises involves monitoring, controlling, and managing various subsystems within a building. This includes HVAC, lighting, security, and access control. Generally, Building Automation Systems (BAS) [1] utilize sensors, controllers, and communication networks. BAS uses different protocols as compared to home automation. By using Internet of Things (IoT). technology, such as WIFI and Bluetooth protocols, wireless controlled power adapters enable remote control and efficient energy monitoring in a premise [2]. Through the IoT, real-time monitoring and informed decisions could be achieved. Wireless controlled power adapters are improved with the integration of cloud services and data technology, allowing users to control and monitor them remotely. This eliminates the need for manual switching and enhances convenience.

Energy waste occurs when energy is wasted without being productively used. In some cases, people leave rooms without turning off ceiling fans, resulting in the fans running even when nobody is present, wasting energy. This lack of contribution by the energy consumed leads to wastage. Energy waste is a significant issue faced by people today, as it unknowingly increases electricity costs [3].

In this work, it aims to solve the energy waste problem of electrical appliances that almost every person may face. The objective of the project is three-fold:

*Corresponding Author email: ginchong.lee@uow.edu.my ORCID: 0009-0006-7664-5851
Kar Chung Chin is with Department of Engineering, School of Engineering, Computing and Built Environment, UOW Malaysia KDU Penang University College, 32, Jalan Anson, 10400 Georgetown, Pulau Pinang. (e-mail: 0203003@student.uow.edu.my).
Gin Chong Lee*, is with Department of Engineering, School of Engineering, Computing and Built Environment, UOW Malaysia KDU Penang University College, 32, Jalan Anson, 10400 Georgetown, Pulau Pinang. (phone: +604-238-6368; fax: +604-238-6330; e-mail: ginchong.lee@uow.edu.my).
Hao Ren Yon is with Department of Engineering, School of Engineering, Computing and Built Environment, UOW Malaysia KDU Penang University College, 32, Jalan Anson, 10400 Georgetown, Pulau Pinang. (e-mail: haoren.yon@uow.edu.my).
Hock Kheng Sim is with Department of Engineering, School of Engineering, Computing and Built Environment, UOW Malaysia KDU Penang University College, 32, Jalan Anson, 10400 Georgetown, Pulau Pinang. (e-mail: hockkheng.sim@uow.edu.my).

International Journal on Robotics, Automation and Sciences (2025) 7, 1:7-18
https://doi.org/10.33093/ijoras.2025.7.1.2
Manuscript received: 27 Dec 2024 | Revised: 21 Jan 2025 | Accepted: 13 Feb 2025 | Published: 31 Mar 2025
Published by MMU PRESS. URL: http://journals.mmupress.com/ijoras

- Develop an android-based software application.
- Construct a hardware circuit of power adapter that links with the software application.
- Integrate power adapter and software for wireless control using a mobile phone.
- To implement an occupancy detection mechanism

This work also aims to analyze the functionality and features of existing wireless control power adapters in the market. The purpose is to determine the essential functions required for a wireless control power adapter. Based on the gathered information from review and study, it will be used to generate a new feature that addresses a specific problem identified in the problem statement. However, it should be noted that the performance level of the generated features may not be optimized, with limitations in ranges and latency that may constrain the system.

II. LITERATURE REVIEW

This sections centers around the investigation and evaluation of existing products that align with the objectives and scope of the project mentioned in the previous chapter. It consists of six sub-sections, with the first two sub-sections dedicated to reviewing the overall application and implementation of the existing wireless control power adapter.

A. Review on Low-cost Wi-Fi Wireless control power adapter with On-off and Energy Metering

The wireless control power adapter utilizes a reliable WIFI communication protocol for its implementation. It incorporates a WebApp that enables users to measure and monitor power consumption from mobile phones, PCs, and tablets. The ESP-WROOM02 microcontroller with its WIFI module is responsible for managing system operations and connections. The adapter employs a latching relay [4] driver powered by a voltage quadruple circuit. It is important to note that for communication to function properly, all devices must operate within the same network.

The flow operation in Figure 1 begins with the connection of the WIFI microcontroller to the home access point, which is the router. The user accesses the WIFI router's SSID (Service Set Identifier) and password. The WIFI router or access point assigns an IP address to the WIFI microcontroller. A link is created between the design button on the WebApp and the HTML button after the WebApp has been designed. Web pages are created and structured using HTML [5]. A webpage displays energy consumption programming using HTML. Data from the WIFI microcontroller can be accessed through the webpage and linked to the data, allowing the website to display the obtained data.

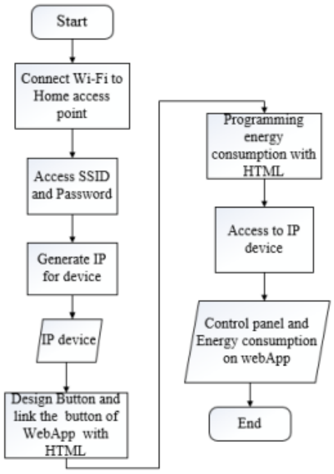

Figure 1. The flow operation of the WebApp process [6].

B. Review on Existing Graphic User Interface

In this review, the graphic user interface will be the main focus on the current wireless control power adapter device with Bluetooth Low Energy (BLE) communication protocol and it is controlled by the smartphone software application. An Android software platform is used to control the wireless control power adapter. This platform is built using API (Application Programming Interface) technology which supports Bluetooth Low Energy communication [34].

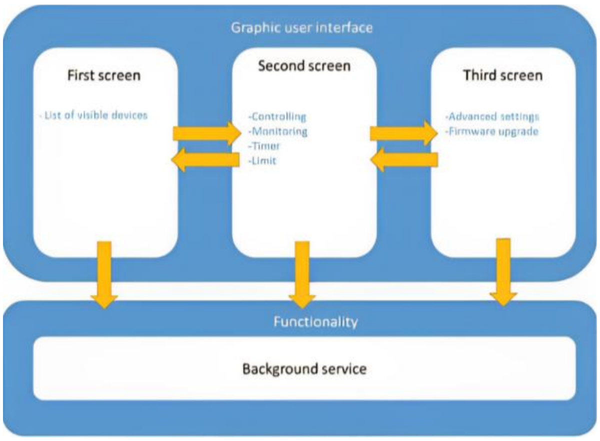

Figure 2. Software application modules [7].

Figure 2 demonstrates the division of the entire software application into modules for improved clarity. The software application consists of two separate modules: the Graphic User Interface (GUI) and the background functionality. The GUI module, shown in Figure 2, comprises three screens. The first screen displays a list of visible devices, while the second screen allows control, monitoring, and setting timer and threshold values for power consumption. The third screen provides advanced settings and firmware upgrades. The graphical user interface is implemented independently of the application's functionality, providing a user-friendly interface for interacting with the software.

C. *Smart Home Space Using Interoperable Building Automation Technologies for Occupancy detection purposes.*

Figure 3 shows the proposed architectural approach for monitoring the occupancy of individual rooms in a smart home environment using existing decentralized KNX technology. According to the figure shown, part 1 basically monitors occupancy in the individual room or specific space. It describes an interoperable implementation of KNX technology in LabVIEW and VLC technology, as well as an experiment to measure the parameters of the VLC communication system for detecting room occupancy using an interoperable LabVIEW/KNX communication solution for a VLC testing platform. A VLC (visible light communication) is a wireless communication technology that allows devices to transmit data from each other via visible light [8] [9] [10]. One of the advantages of VLC wireless connection is that VLC does not overlap radio channels, especially in a denser residential area. One potential application of VLC is its ability to establish the position of an individual in a specific area. With Cell-ID identification, it is possible to approximate the coordinates of a monitored object. A unique Cell-ID can be assigned to each VLC access point, and as soon as the monitored individual enters the illuminated region, it can be identified with an accuracy that corresponds to the size of the illuminated area. However, there are a few limitations of this technology which are Limited to the line-of-sight as it operates with visible light, Eye safety concerns, cost, and complexity.

Part 2 mentions the implementation of KNX technology and IoT platform [11] which uses IBM cloud with WIFI communication. An MQTT protocol [12] [13] is applied to the novel KNX software application gateway to detect occupants in an office room. The advantage of sending data to the Cloud system platform [14] is that it provides flexibility as it does not have a limited range to communicate within devices. Besides, it provides an ideal platform for managing, collecting, and analysing data in terms of reliability from devices using cloud-based communication. The limitation of using cloud-based communications is that it requires stable network connectivity to avoid any data loss and delays in communication.

Part 3 shows the implementation of KNX technology and BACnet [15] building automation technology via a KNX/BACnet hardware gateway. This uses an artificial neural network to predict occupancy depending on the relative humidity, temperature and level of CO2. The advantages of the BACnet protocols are flexibility and interoperability. BACnet protocols enable the seamless integration of devices from different manufacturers. This basically enhances interoperability and easier to integrate different devices in a building automation system as well as home automation. The BACnet protocol is highly flexible and can be used to monitor and control a wide range of building systems, including lighting, HVAC, access control, etc. As a result, a comprehensive building automation system can be designed according to the specific needs of the facility. However, the limitations of BACnet protocols are mainly due to limited security and lack of standardization. Security features are not provided by default in BACnet protocols, so additional security measures need to be taken in order to protect against cyber threats. It can increase the cost and complexity of implementing BACnet systems as a result.

III. METHODOLOGY

The system is classified into two sub-systems. Each of the sub-systems consists of a NodeMCU microcontroller and both of the sub-systems do not physically connect to each other. However, they communicate with each other by exchanging data via the Blynk cloud platform database. This provides several benefits that bring a huge contribution to the system. Since both sub-systems are communicated by sending data and receiving data from the Blynk cloud database, the distance between both sub-systems can be reached until unlimited. Thus, the system can be implemented in a wide range of spaces without the need for physical wires as long as both sub-systems are connected to a WIFI network. The system consists of software components and hardware components.

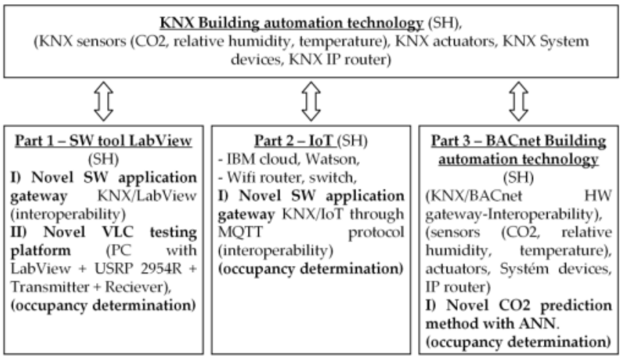

Figure 3. The schematic of the general system [3].

A. *The Network of the System*

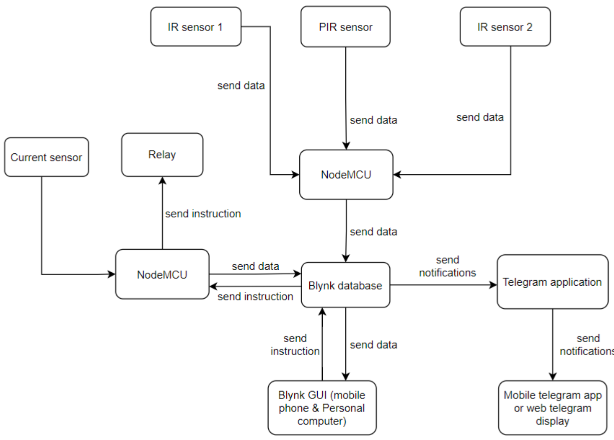

Figure 4. The sensor-actuator interfacing of the proposed system.

Figure 4 shows the system interactions with each component in the wireless control power adapter system. From the figure, the interaction between each component consists of data transmission, providing instructions, and sending notifications to notify users. There are three subsystems in the whole system. In the first subsystem, IR sensor 1 and IR sensor 2 [16] are the sensors located on both sides and the PIR sensor [17][18][19] is located in between both IR sensors of the occupancy detection system. Three of the sensors provide data information to determine the occupants in a particular space. NodeMCU contributes to gathering all the data sent by the sensors and transmitting the collected information to the database cloud. The second NodeMCU microcontroller will be installed at the second subsystem which is to control the switching of the relay. The instructions will be given by the Blynk database, and the current sensor [20] [21] contributes to provide the signal data to the Blynk database via the NodeMCU microcontroller. The Graphic User Interface will display the information received in the database which allows the user to monitor it whenever necessary. Besides, the User can send instructions by changing the values in the database displayed on the mobile phone or personal computer. The third sub-system is to provide the notification to the user via the Telegram software application and notify the user. Thus, the relationship between the Blynk database and the telegram software application is to send notifications.

B. Hardware implementation

The hardware components involve:

- Two NodeMCU microcontroller
- One PIR sensor
- One Current sensor (20A)
- Two IR sensors
- One 5V dc Relay module (AC load can handle is 10 A at 250VAC)
- NodeMCU Expansion Baseboard

From Figure 5, Sub-system 1 shows the physical construction and placement of the sub-system. From sub-system 1, the components involved are a 12V Lipo battery, a Connector, NodeMCU, 2 IR sensors, a NodeMCU expansion baseboard, and a PIR sensor. The 12 V Lipo battery act as the power source of the system which is connected to the NodeMCU expansion baseboard through a connector. The expansion baseboard will contribute to regulating the voltage and supply to the NodeMCU accordingly. Since NodeMCU has acted as the main brain of sub-system 1, the sensors will be connected to the NodeMCU to provide information as well as power supplied. Due to the delay in response of the IR sensor, some distance is required between the two IR sensors, in order to increase the accuracy of the occupants being detected. When the occupancies pass by, the IR sensors will have more time to react as the person is required to walk a certain distance in between. Thus, the placement of the PIR sensor is held in between two IR sensors which are to reduce the space occupied and makes the system much more compact.”

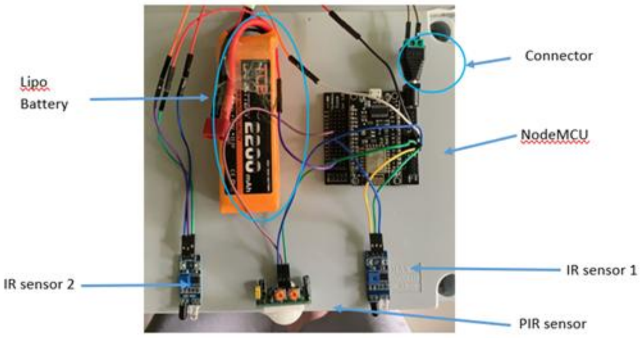

Figure 5. The first subsystem of the proposed system

Figure 6 shows the physical construction and placement of Sub-system 2 which cooperates with the conventional plug. The components consist of NodeMCU, 20 A current sensor, 5V relay module, and conventional plug. The placement of the component has been fixed with a purpose. The placement of the relay module must be faced near the current sensor which contributes to having closer connectivity and making the connection occupy lesser space with shorter multicore wire. The NodeMCU is required to place near the edge of the junction box [22] for the connection to supply DC power to the NodeMCU. Thus, a hole is required to be drilled and allow the wire to connect the NodeMCU via the hole. The remaining space will fit with the conventional plug.

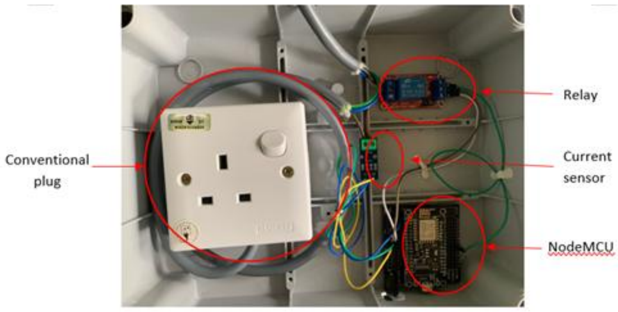

Figure 6. The second subsystem of the proposed system.

C. Software Components

The Arduino IDE (Integrated Development Environment) [23] [24] is a software application that is used for programming and developing code for Arduino boards [25] [26]. The applications of the Arduino IDE software are to provide a platform for the programmer to write code for any project [27] [28]. Besides, it is able to cooperate with hardware components such as sensors and actuators to perform the expected outcomes. In Arduino IDE software applications, it can compile code as well as upload code to the physical Arduino microcontroller board and execute every statement coded in the software platform. In the Arduino IDE, there is a library manager that facilitates the installation and management of libraries of pre-written code. Some of the sensor and actuators such as the servo motor and DHT11 sensor consists of their own library in order to operate with Arduino IDE software application.

The Blynk platform is designed to develop Internet of Things (IoT) applications. The software platform provides a drag-and-drop interface for creating graphical user interfaces (GUIs) for controlling and monitoring IoT devices, along with a cloud-based infrastructure for storing and processing data. There are three major components in the Blynk software platforms which are Blynk App, Blynk Server, and Blynk Libraries. Blynk App allows users to generate creative interfaces for projects with the use of various widgets provided [29]. Blynk server is responsible for all communications between smartphone and hardware [29]. It is considered open source which is able to easily handle more than a hundred devices and is usable in many types of devices and microcontrollers. Thirdly, the Blynk libraries are to enable all the popular hardware platforms to communicate with the server, and all incoming and outgoing commands can be processed [29]. Telegram is an application that is widely used among cross-platform users due to its powerful privacy and encryption features, as well as its support for large group chats [30]. The Telegram software application provides instant messaging and voice-over IP services via the cloud. accuracy of the occupants being detected [33]. When the occupancies pass by, the IR sensors will have more time to react as the person is required to walk a certain distance in between. Thus, the placement of the PIR sensor is held in between two IR sensors which are to reduce the space occupied and makes the system much more compact."

D. Software Implementation

The NodeMCU microcontroller is considered a third-party device that requires some installment to be done, in order to upload the sketch using Arduino IDE. First of all, Figure 7 shows the libraries that have been used for the program. The library "ESP8266WIFI.h" is installed to run and upload to NodeMCU from the Arduino IDE software platform.

```
#define BLYNK_PRINT Serial
#include <ESP8266WiFi.h>
#include <BlynkSimpleEsp8266.h>
#include <WiFiClientSecure.h>
#include <UniversalTelegramBot.h>
#include <ArduinoJson.h>
```

Figure 7. The libraries of the system required

The following step is to install the COM/Serial port driver. The ESP8266 IOT board can be connected to a computer's USB port and any data-capable micro-USB cable can be used to upload code to the board. There are two versions of NodeMCU which is NodeMCUv1.0 and NodeMCUv0.9 and both versions require a different port driver to drive the board. The NodeMCU used in the project is the latest version, which is V3 NodeMCU, the driver required to download and install CP2102 serial chip from the website. In addition, a Universal USB serial port is required to be downloaded and installed as well for the USB port of the laptop.

The following steps is to include the additional Board manager for the NodeMCU ESP8266 via an URL show below:

http://arduino.esp8266.com/stable/package_esp8266com_index.json

The URL is required to be inserted into the settings of the Preference under the "Additional Boards Manager URLs" section as shown in Figure 8 and Figure 9. Thus, the selection of ESP8266 board is available under the board manger section.

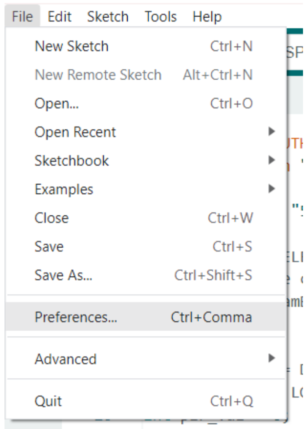

Figure 8. Open the file preference

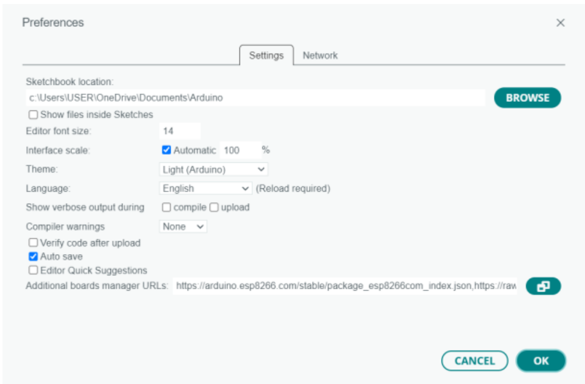

Figure 9. The preference setting.

Blynk is a convenient software platform that provides cloud service which enables the user to track data that has been sent wherever the user likes. By using such technology, the system can wirelessly communicate with each other without considering the distance range. After creating an account, the first thing required is to set up the DataStream as shown in Figure 10. First of all, is to select the name required to determine the DataStream and its color code. Follow by selecting the data type of the DataStream that is going to be received and stored in the Blynk cloud. Lastly, the minimum and the maximum need to be defined. If the DataStream receives a digital signal, the minimum will be set to 0 and the maximum is set to 1. However, if the data received is an analog signal from the sensors, the minimum and maximum is needed to be set in the range that depends on the possible range of the data that will be sent.

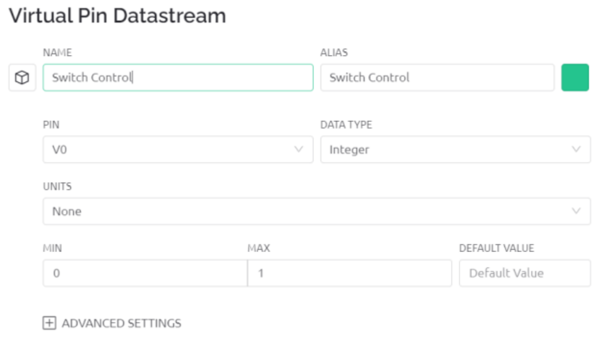

Figure 10. The DataStream for the Blynk cloud database

Figure 11 shows the interface of the web dashboard the interface button and display data are dragged from the widget box. There are only 2 controllable widgets provided to the user where the button labeled as switch control is to allow the user to manually switch the power adapter wirelessly. The second button is labeled as the automatic mode which is to activate the occupancy detection function that automatically switches off the power adapter.

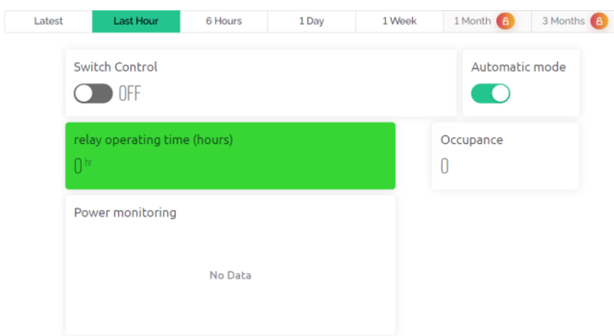

Figure 11. The web dashboard

The Arduino IDE software platform has been used to allow hardware devices such as sensors and actuators to cooperate with the Blynk cloud database. The program code Line1, Line 3, Line 4 and Line 6 shown in Figure 12 are the required libraries for the Arduino IDE to cooperate with the Blynk cloud server. In the first line of the program section, the statement "#define Blynk_PRINT Serial" defines the print function for the Blynk library to use. The "BlynkSimpleEsp8266" library enables the program coded to interact with the Blynk cloud by sending information to the NodeMCU ESP8266. The "WIFIClientSecure" presented in Line 4 is the library that provides secure communication over a WIFI connection. Last but not least is the "ArduinoJson" library which provides the functionalities to handle JSON data.

On the web page of the Blynk software platform, the Blynk AUTH token is found under the device info section after creating the device. Copy the Blynk AUTH token and paste the statement into Arduino IDE at the beginning of the program as shown in Figure 13. Line 8 shows the pasted Blynk AUTH token that allows the system to recognize the device created in the Blynk software platform.

```
1  #define BLYNK_PRINT Serial
2  #include <ESP8266WiFi.h>
3  #include <BlynkSimpleEsp8266.h>
4  #include <WiFiClientSecure.h>
5  #include <UniversalTelegramBot.h>
6  #include <ArduinoJson.h>
```

Figure 12. The libraries of the system required

```
8  #define BLYNK_AUTH_TOKEN "NOLQ75rNJX-KWGTjG-Somupnexef3fo1" //Enter
9  #define BOTtoken "6084632853:AAGHepnLvxWoCg0UJ0PdBqnXY2WHPPPKd-w"
10
11 #define CHAT_ID "5055816978"
12
13 X509List cert(TELEGRAM_CERTIFICATE_ROOT);
14 WiFiClientSecure client;
15 UniversalTelegramBot bot(BOTtoken, client);
16
```

Figure 13. The initiation of the Telegram bot and Blynk cloud

Figure 14. The Telegram bot setup

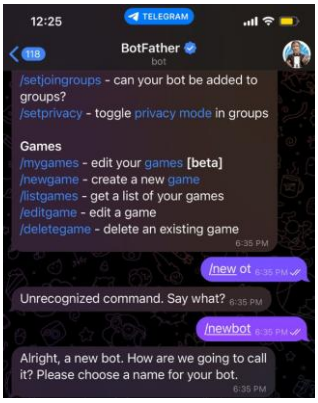

Figure 15. Generating a new bot

Telegram provides cloud service as well as an AI bot service for the user to cooperate with the Telegram software app. BotFather is the bot service provided by the Telegram software app as presented in Figure 14. First of all, it is to search BotFather and activate the bot service by typing "/start". After that, the BotFather will send an instruction on the selection of bot service. By inserting "/newbot" to generate the new bot and providing the name of the bot for identification as shown in Figure 15.

After creating a new bot via BotFather, information is given immediately which is the bot token by the BotFather itself. This identification information is important to link the Telegram software app with NodeMCU through Arduino IDE software. The second identification is the chat ID which requires searching the second bot called IDBot. Figure 16 provides the interaction with the IDBot after searching it. By following the statement shown in Figure 17, the ChatID will be provided. Both identifications will then inserted at the beginning section of the program code.

```
#define BOTtoken "6084632853:AAGHepnLvxWoCg0UJ0PdBqnXY2WHPPPKd-w"

#define CHAT_ID "5055816978"
```

Figure 16. The identification to be inserted in Arduino IDE

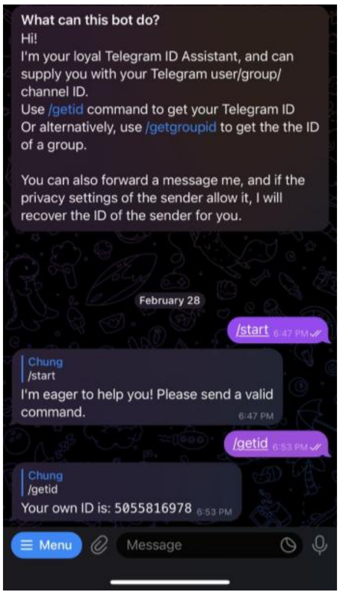

Figure 17. Get the chat ID of the bot created

Figure 18 is the overall operation flow chart of the system which at the beginning of the system is to search for WIFI for both sub-systems. When both NodeMCU is successfully connected, the system will immediately send a notification to the user via telegram to notify the user that the power adapter is ready to be controlled. The system will straight jump into sub-system 1 which is to read the data provided by the PIR sensor and IR sensors. Sub-system 1 mainly functions as a whole detection system that detect occupants from entering the confined space. The sensors will keep on sending data to the Blynk cloud database to update the latest information. Sub-system 2 is the subsystem that interacts with the Graphic user interface in the mobile phone and the hardware component wirelessly. The components include a relay, a current sensor, a modified power adapter, and a NodeMCU.

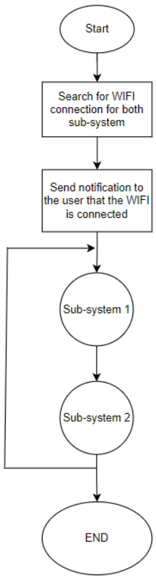

Figure 18. The Overall operation flow chart of the system

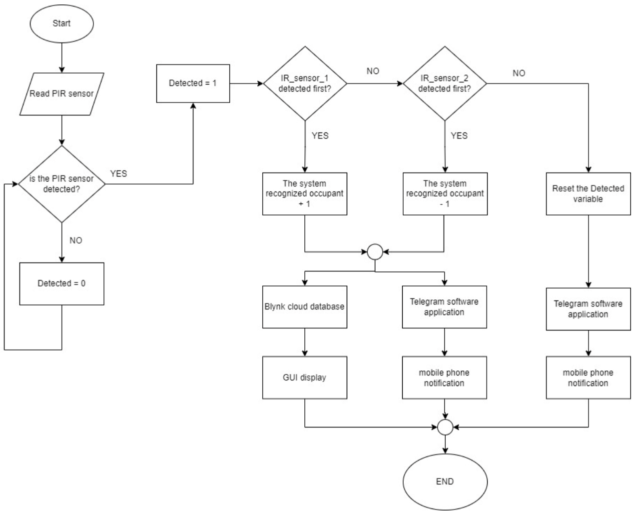

Figure 19. The flow chart of the sub-system 1

Figure 19 presents the operational flows of the sub-system with both IR sensors as well as PIR sensors cooperating with the NodeMCU microcontroller to send data to the Blynk database. From Figure 50, the beginning of the flow chart is to prioritize the PIR sensor readings to confirm whether a human passes through. If the PIR sensor is not detected, the system will recognize not detection by resetting the variable, Detected, and feedback to check again the reading of the PIR sensor. If there is a detection by the PIR sensor, the system will set the variable, Detected, and check the readings of IR_sensor_1 and IR_sensor_2. If the IR_sensor_1 is triggered first as compared to IR_sensor_2, the system will increase the number of occupants by one. This indicates that there is one person has entered the specific space. If the IR_sensor_2 is triggered first as compared to IR_sensor_1, the system will decrease the number of occupants by one which represents that one of the occupants is leaving the specific space. The information will immediately update to the Blynk cloud database as well as the Telegram software app. The

Blynk cloud database will send the display of the number of occupants that stayed in the specific space in the mobile phone or personal computer. Telegram is to notify the user that someone is leaving or entering a specific space by sending a fixed statement to the user. If only the PIR sensor is detected and the remaining IR sensors are not triggered, the system will reset the variable and notify the user through the Telegram software app.

Figure 20 shows the flowchart of subsystem 2 which cooperates with the second NodeMCU microcontroller. This sub-system is to deal with the relay and current sensor for physical hardware components. At the beginning of the operations, the input data is sent by the user input interface of the mobile phone or web platform in the personal computer. There are two modes that are classified as automatic mode and manual mode. The automatic mode is the mode where the data is abstracted from the number of occupants provided by sub-system 1. After abstracting the data of occupants, the system is required to determine whether the number of occupants is displayed to be 0. If there is nobody is identified in the specific space, the system will trigger the relay to be switched off. If there is at least one person detected in the monitored space, the system will be switched on the relay and notify the user via the Telegram software application. The notifications that are sent to the user provide the benefit of notifying them that the system is functioning well and that extra sensors and speakers are no longer required in the system. According to the theory, the number of sensors and actuators will increase the rate of the system getting faulty. Hence, the function brings a definite positive impact on the entire system as well.

If the manual mode has been switched on, the user is able to control the power adapter wirelessly through a mobile software application. The system will first read the input inserted by the user and check whether the button is switched on or switched off. If the user request to manually switch off the power adapter, the system will send a signal to the NodeMCU through a WIFI connection and triggers the relay to switch off. If the user provides the instruction to switch on the power adapter, the system will send a signal to the NodeMCU to switch on the relay. While the relay allows the current to pass through, the current will immediately sense the current passes through and calculate the power consumption for the user. Besides, the system provides a notification to the user as well to monitor the duration of the relay that has been switched on. This notifies the user to avoid some unnecessary drained power.

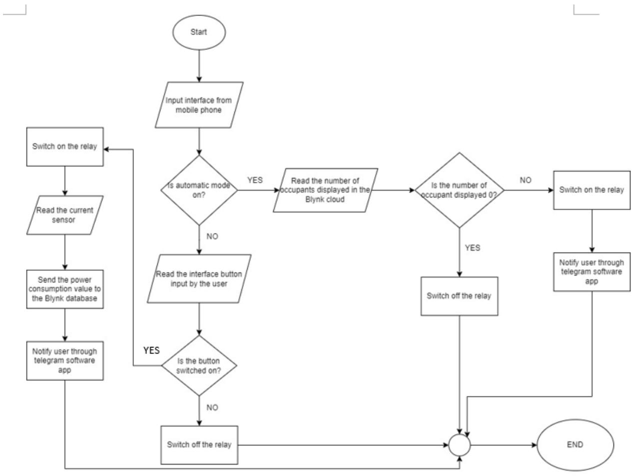

Figure 20. The flow chart of the sub-system 2

IV. EXPERIMENTAL SETUP

A. Range of the Occupancy Detection

The experiment is conducted to sense the distance range of sub-system 1 which is the occupancy detection system. The placement of system is normally placed beside the door internally or near the staircase. This experiment is conducted to find the borderline distance for the sensors to be detected and not detected.

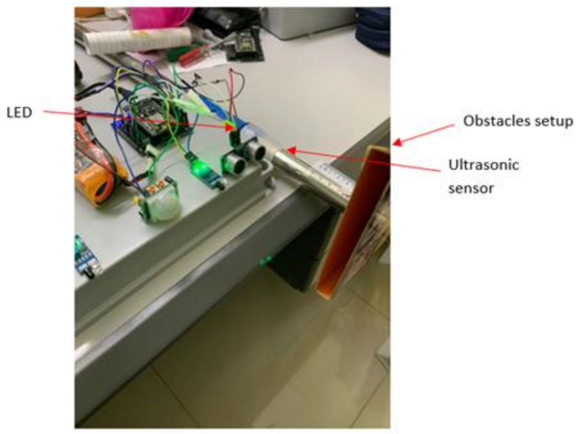

Figure 21. The setup of the experiment

Figure 21 shows the setup of the experiment which is to determine whether what is the distance required in order to accurately determine every occupant passing by. The setup in Figure 61 consists of an extra ultrasonic sensor [31][32], LED, and obstacles in sub-system 1. The ultrasonic sensor is placed to detect and provide the actual distance values and the LED act as the indicator to physically shows that the PIR sensor is detected. The obstacle is stuck and held by the extendable metal rod and for the ultrasonic sensor to measure the distance.

Figure 22 provides the method that uses paper to act as the occupants where the obstacle prepared is black in color which will affect the performance of the IR sensor. After that, move the aligned hand toward the paper to detect the PIR sensor. The paper is placed only in front of the ultrasonic sensor and the IR sensor for the ultrasonic to read the distance as well as the voltage output of the IR sensor. When the hand that is aligned with the paper move towards the paper, the distance will get an approximate value as measured by the ultrasonic sensor. Hence, the indicator of the LED and the IR sensor will be observed on the serial monitor which will display the voltage output of the IR sensor and recorded accordingly. The distance will change by moving the metal rod away from the ultrasonic sensor. Repeat the step and switch the IR sensor 2 and replace the position of the measured IR sensor 1 due to the limited analog pin.

The recorded data can find out the equation of the relationship between the distance and voltage output provided by the IR sensor. By utilizing the equation formed, apply the minimum voltage output required for the IR sensor to detect the obstacle. The minimum voltage output required for the IR sensor to detect the obstacle.

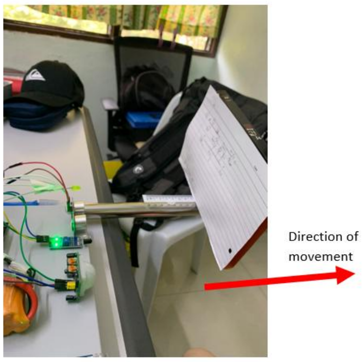

Figure 22. The detection of the sensor

B. Response Time for the Relay to React.

In this experiment, the response time for the relay to react is measured. The extra component used in this experiment is the software timer provided by the mobile phone and the load. There will be two sets of data, the first set of data is to trigger the relay to be switched on and the second set of data is to trigger the relay to be switched off. When the button provided in the Blynk platform has been switched on, the timer will immediately start, and the timer will stop as the relay has been triggered by the system. Repeat the step 30 times in each set of data to show the precision of the system.

Figure 23. The interface of the software timer

C. Measure the calibration factor of the Current sensor.

This experiment is to obtain the calibration factor that is required to apply the program code for the energy monitoring features. The purpose of the experiment is to make the measured AC power by the sensor is approached the actual AC power.

Figure 24 shows the setup of the experiment which consists of 250 ACV power supply, a power meter, the system, and the load. The load for this experiment uses a lamp. The power supply is adjustable by controlling the voltage supply to the system through a power meter that measures the actual power supplied to the system. Power meter not only measures power but the current and voltage has also been considered in displaying the values. Figure 69 shows the power meter where the value 13.97 represents the power in watts, the value 120.5 refers to the voltage in Si unit volts, and the value 115.9 is the current supplied in Si unit milliamperes. The power meter can be verified by applying a power formula that is related to voltage and current as presented below:

Power = Voltage * Current

Power = 120.5V * 115.9mA

Power = 13.978 W

According to the power calculation done above, it has been proven that the power meter is worked accordingly.

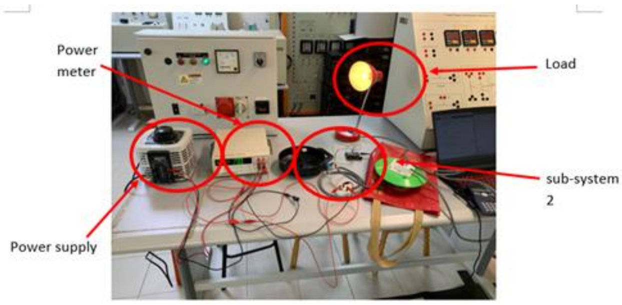

Figure 24. The setup of the experiment

V. Result and Discussion

A. Experiment 1: Maximum distance range of the occupancy detection

The Figure 25 and Figure 26 provide the relationship between the voltage output and the distance in graphical forms. The relationship presented in both graphs is in directly proportional within the distance of 15.12cm to 16.77cm for IR sensor 1. The best-fit line has been plotted in a red dotted line with the linear equation shown.

$$Y = 2.7756X - 40.906$$

Where the unknown, Y, represents the voltage and the unknown, X, refers to the distance between the obstacle and the IR sensor. By substituting the voltage of 0.31V into the linear equation, the distance can be calculated.

$$Y = 2.7756X - 40.906$$

$$0.31 = 2.7756X - 40.906$$

$$X = \frac{0.31+40.906}{2.7756}$$

$$X = 14.85\text{cm}$$

From the calculation above, the voltage output selected is 0.31V which is the voltage output where the IR sensor is still strongly detected. Since the linear equation shows changes state of IR sensor from low to high, the 0.31V in the linear equation represents the starting point of the IR sensor changes state. Thus, the distance 14.85cm calculated from the linear equation is the maximum distance range for IR sensor 1.

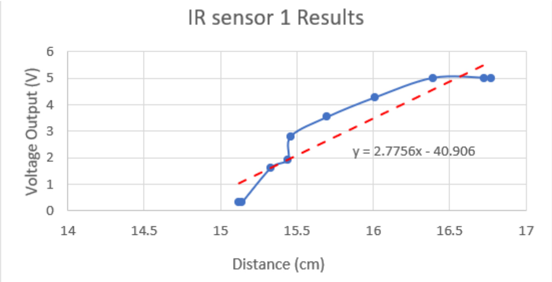

Figure 25. The voltage vs distance graph for IR sensor 1

Figure 26 shows the voltage output vs distance graph of IR sensor 2 with the linear equation of the best-fit line. By applying the same concept as done in IR sensor 1, the distance can be calculated with the equation given in the graphs is:

$Y = 2.6604X – 39.391$

$0.31V = 2.6604X – 39.391$

$X = \frac{0.31+39.391}{2.6604}$

$X = 14.922cm$

By comparing both calculated distances, the distance of IR sensor 1 is much shorter in contrast to IR sensor 2. Thus, the distance of 14.85cm will be considered to maximum distance for all the sensors to be detected.

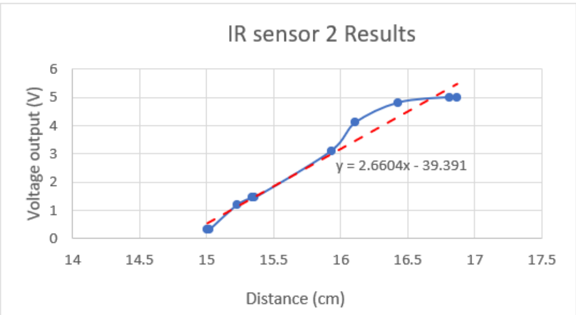

Figure 26. The voltage vs distance graph for IR sensor 2

B. Experiment 2: Response time for the relay to react.

There are 30 recorded data about the time duration for the relay to react after triggering the interface on the mobile phone. The average time for the relay to be triggered ON is:

Average time = Total time duration / total number of attempts

Average time = 17.34 / 30

Average time = 0.578s

By applying the same formula, the average time for the relay to be triggered OFF is:

Average time = Total time duration / total number of attempts

Average time = 62.49 / 30

Average time = 2.083s

By comparing both average times, the time duration for the relay to switch OFF is longer than the time duration for the relay to switch ON. The control latency of the relay to switched OFF is mainly due to the program code being long with many conditions which required time for the system to run through before switching the relay off.

Another set of data is recorded with the same 30 times records for both switch ON and switch OFF. However, the data recorded the time duration without any conditions in the program code. The average time can be calculated for both switching ON and switching OFF with the same formula as calculated above. Hence, the average time for the relay switching ON is:

Average time = Total time duration / total number of attempts

Average time = 6.5/ 30

Average time = 0.22s

By applying the same formula, the average time for the relay to be triggered OFF is:

Average time = Total time duration / total number of attempts

Average time = 6.64/ 30

Average time = 0.221s

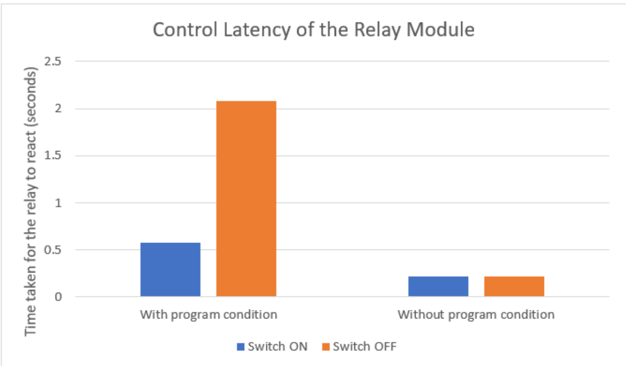

Figure 27. The Control Latency of the Relay

From the average time duration calculated, the time duration is significantly lesser with no conditions for both relays switching on and switching off. This can be concluded that the control latency of the system is affected by the program code conditions.

C. Experiment 3: Measuring the calibration factor of current sensor.

There are only 8 recorded data which is to prevent over-calibration. Over-calibration refers to the process of calibrating a system or device beyond the level that is necessary or optimal. An over-calibration can lead to inaccurate or unreliable measurements. Since the calibration values may not accurately reflect the actual conditions or behaviour of the system. It may result in errors in the output or control signals, which may lead to suboptimal performance or even system failure.

The experiment has recorded the current in RMS as the voltage supplied by the wall plug is constant at 240 Volts. In this experiment, the voltage supplied is not constant, hence, the program code is required to change manually from 240 volts to every volt supplied by the power supply. This is able to obtain the desired current RMS with a constant error with the actual current. The calibration factor is calculated with the formula as shown below:

Calibration factor = Arduino, Irms / power meter, Irms

The calibration factor is basically the ratio of sensor value displayed in the Arduino serial monitor and the actual current display on the power meter. By rearranging the formula,

$$Power\ meter, Irms\ = / \frac{Arduino,Irms}{Calibration\ factor} \quad (1)$$

The equation (1) is where the equation requires to be included in the program code to obtain the actual power. The average calibration factor is calculated with the general formula:

Average calibration factor = Total calibration factor / total number of attempts

Average calibration factor = 18.229 / 8

Average calibration factor = 2.28

The calculated calibration factor can substitute into equation (1) and include the substituted equation in the program code.

VI. Conclusion

Occupancy detection is one of the features that improve the convenience of the wireless control power adapter by automatically switching off the power adapter without the need for manual control or setup. The objectives of the project basically include developing a software application, constructing a hardware circuit that links with the software application, controlling the power adapter wirelessly with the GUI in the mobile phone, and implementing an occupancy detection mechanism.

There are some limitations and improvements that can be made in the project. The result of the first experiment conducted has proven that the distance range is one of the limitations of the system generated. The maximum distance range measured for the system to work accordingly is 14.82cm between the occupant and the system. A possible improvement is to replace the PIR sensor and IR sensor with a Lidar sensor which is capable to distinguish between the human and non-human objects as well as a longer distance range that improves the flexibility of the placement of the system.

Acknowledgment

The authors would like to express gratitude to the respected school academicians, for their valuable inputs, feedback, and suggestions that have significantly contributed to the overall quality and rigor of this research work.

Author Contributions

Kar Chung Chin: Conceptualization, Data Curation, Methodology, Validation, Writing – Original Draft Preparation;

Hao Ren Yon: Project Administration, Writing – Review & Editing;

Gin Chong Lee: Project Administration, Supervision, Writing – Review & Editing;

Hock Kheng Sim: Review & Editing.

Conflict of Interests

No conflict of interests were disclosed.

Ethics Statements

Our research work follows The Committee of Publication Ethics (COPE) guideline. https://publicationethics.org.

[1] Y.S. Choi, "A Study on security characteristics and vulnerabilities of BAS (Building Automation System)", *Journal of the Korea Academia-Industrial cooperation Society*, vol. 18, no. 4, pp. 669-676, 2017.
DOI: https://doi.org/10.5762/KAIS.2017.18.4.669

[2] H.L. Tsai, L.P. Truong, and W.H. Hsieh, "Design and Evaluation of Wireless Power Monitoring IoT System for AC Appliances", *Energies*, vol. 16, no. 1, pp. 163, 2022.
DOI: https://doi.org/10.3390/en16010163

[3] T. Moore, "Low-Energy Housing as a Means of Improved Social Housing: Benefits, Challenges and Opportunities", *Energy Performance in the Australian Built Environment*, pp. 91-109, 2019.
DOI: https://doi.org/10.1007/978-981-10-7880-4_7

[4] R. Morales-Caporal, A.S. Reyes-Galaviz, J.F. Casco-Vasquez and H.P. Martinez-Hernandez, "Development and Implementation of a Relay Switch Based on WiFi Technology," *2020 17th International Conference on Electrical Engineering, Computing Science and Automatic Control (CCE)*, pp. 1-6, 2020.
DOI: https://doi.org/10.1109/CCE50788.2020.9299142

[5] T. Michaud, "Foundations of Web Design: Introduction to HTML & CSS", *New Riders*, 2013,
URL: https://ptgmedia.pearsoncmg.com/images/9780321918932/samplepages/0321918932.pdf (accessed: 13 Feb, 2025).

[6] Y. Thongkhao and W. Pora, "A Low-Cost Wi-Fi Smart Plug with On-off and Energy Metering Functions", *13th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology*, pp. 1-5, 2016.
DOI: https://doi.org/10.1109/ECTICon.2016.7561264

[7] I. Horvat, N. Lukac, R. Pavlovic and D. Starcevic, "Smart plug solution based on bluetooth low energy," *2015 IEEE 5th International Conference on Consumer Electronics - Berlin (ICCE-Berlin)*, pp. 435-437, 2015.
DOI: https://doi.org/10.1109/icce-berlin.2015.7391301

[8] T. Komine and M. Nakagawa, "Fundamental analysis for visible-light communication system using LED lights", *IEEE transactions on Consumer Electronics*, vol. 50, no.1, pp. 100-107, 2004.
DOI: https://doi.org/10.1109/TCE.2004.1277847

[9] M. Cui, Q. Wang and J. Xiong, "Breaking the limitations of visible light communication through its side channel," *Proceedings of the 18th Conference on Embedded Networked Sensor Systems*, pp. 232-244, 2020.
DOI: https://doi.org/10.1145/3384419.3430728

[10] N. Litayem and A. Al-Sa'di, "Exploring the Programming Model, Security Vulnerabilities, and Usability of ESP8266 and

ESP32 Platforms for IoT Development", *2023 IEEE 3rd International Conference on Computer Systems (ICCS)*, pp. 150-157, 2023.
DOI: https://doi.org/10.1109/ICCS59700.2023.10335558

[11] M. Kashyap, V. Sharma and N. Gupta, "Taking MQTT and NodeMcu to IOT: communication in Internet of Things", *Procedia computer science*, vol. 132, pp. 1611-1618, 2018.
DOI: https://doi.org/10.1016/j.procs.2018.05.126

[12] D. Hanes, G. Salgueiro, P. Grossetete, R. Barton, J. Henry, "IoT fundamentals: Networking technologies, protocols, and use cases for the internet of things", *Cisco Press*, 2017.
URL: https://www.ciscopress.com/store/iot-fundamentals-networking-technologies-protocols-9781587144561 (accessed: 13 Feb, 2025)

[13] A. Apostu, F. Puican, G. Ularu, G. Suciu, and G. Todoran, "Study on advantages and disadvantages of Cloud Computing–the advantages of Telemetry Applications in the Cloud", *Recent advances in applied computer science and digital services*, pp. 118-123, 2013.
URL:http://www.wseas.us/e-library/conferences/2013/Morioka/DSAC/DSAC-16.pdf

[14] P. Sankar,R. Vallikannu, G. Justin, and S. Karg, "Ambient intelligence based LED lighting control system using BACnet protocol", *2023 IEEE International Conference on Artificial Intelligence and Applications (ICAIA) Alliance Technology Conference (ATCON-1)*, pp.1-5, 2023.
DOI: https://doi.org/10.1109/ICAIA57370.2023.10169530

[15] A. Kulkarni, P. Malaurie, V. Stenchly, H. J. Quenzer, N. Laske and R. Dudde "Silicon lens arrays for wafer level packaging of IR-sensors", *Informatics, Electronics and Microsystems: TechConnect Briefs 2018*, vol. 4, pp. 147-150, 2018.
URL:https://briefs.techconnect.org/wp-content/volumes/TCB2018v4/pdf/263.pdf

[16] R. Harikrishnan and P. Sivagami, "Intelligent power saving system using PIR sensors," *2017 International conference of Electronics, Communication and Aerospace Technology (ICECA)*, Coimbatore, India, 2017, pp. 573-577.
DOI: https://doi.org/10.1109/ICECA.2017.8212729

[17] G. Sasi, "Motion detection using passive infrared sensor using IoT", *Journal of Physics: Conference Series*, *IOP Publishing*, vol. 1717. No. 1., pp. 012067, 2021.
DOI: https://doi.org/10.1088/1742-6596/1717/1/012067

[18] A.E. Cetin, Y. Ozturk, O. Hanosh and R. Ansari, "Review of signal processing applications of Pyroelectric Infrared (PIR) sensors with a focus on respiration rate and heart rate detection," *Digital Signal Processing*, vol. 119, pp. 103247, 2021.
DOI: https://doi.org/10.1016/j.dsp.2021.103247

[19] H. Li, Z. Zhang, L. Zu, Y. Hao and H. Chang, "Micromechanical mode-localized electric current sensor," *Microsystems & Nanoengineering*, vol. 8, no. 1, 2022.
DOI: https://doi.org/10.1038/s41378-022-00375-1

[20] H. Yan, Y. Xu, J. Zou, Y. Fang and F. Cai, "A Novel Open-Circuit Fault Diagnosis Method for Voltage Source Inverters With a Single Current Sensor," *IEEE Transactions on Power Electronics*, vol. 33, no. 10, pp. 8775-8786, 2018.
DOI: https://doi.org/10.1109/TPEL.2017.2776939

[21] F. Rémouit, R. M. Pablo and J. Engström, "Review of electrical connectors for underwater applications", *IEEE Journal of Oceanic Engineering*, vol. 43, no. 4, pp. 1037-1047, 2017.
DOI: https://doi.org/10.1109/JOE.2017.2745598

[22] S. Chedup, D.N.K. Jayakody, B. Subba and H. Hydher, "Performance Comparison of Arduino IDE and Runlinc IDE for Promotion of IoT STEM AI in Education Process," *Lecture Notes in Electrical Engineering*, pp. 237-254, 2021.
DOI: https://doi.org/10.1007/978-981-16-0289-4_18

[23] U. Sarı, H.M. Pektaş, Ö.F. Şen and H. Çelik, "Algorithmic thinking development through physical computing activities with Arduino in STEM education," *Education and Information Technologies*, vol. 27, no. 5, pp. 6669-6689, 2022.
DOI: https://doi.org/10.1007/s10639-022-10893-0

[24] R. Rikwan and A. Ma'arif, "DC Motor Rotary Speed Control with Arduino UNO Based PID Control", *Control Systems and Optimization Letters*, vol. 1, no. 1, pp. 27-31, 2023.
DOI: https://doi.org/10.59247/csol.v1i1.6

[25] S. Z. Nasir, "Introduction to Arduino Uno - the Engineering Projects", *The Engineering Projects*, 2018.
URL:https://www.theengineeringprojects.com/2018/06/introduction-to-arduino-uno.html

[26] C. G. Ong, J. C. Fermano and A. C. P. Daniot II, "An Impact Study on the Arduino Programming Training for Beginners", *Science International*, vol. 34, no. 2, pp. 69-72, 2022.
URL: https://www.sci-int.com/pdf/637835425803920481.pdf

[27] B. Evans, "Beginning arduino programming", *Apress*, 2011.
URL: https://link.springer.com/book/10.1007/978-1-4302-3778-5 (accessed: 13 Feb, 2025)

[28] E. Media's, S. . and M. Rif'an, "Internet of Things (IoT): BLYNK Framework for Smart Home," *KnE Social Sciences*, vol. 3, no. 12, pp. 579, 2019.
DOI: https://doi.org/10.18502/kss.v3i12.4128

[29] G. F.Avisyah, I. J. Putra, and S. S. Hidayat, "Open Artificial Intelligence Analysis using ChatGPT Integrated with Telegram Bot", *Jurnal ELTIKOM*, vol. 7, no. 1, pp. 60-66, 2023.
DOI: https://doi.org/10.31961/eltikom.v7i1.724

[30] V.N. Sulistyawan, N. A. Salim, F. G. Abas and N. Aulia., "Parking tracking system using ultrasonic sensor HC-SR04 and NODEMCU ESP8266 based IoT", *IOP Conference Series: Earth and Environmental Science*, *IOP Publishing*, vol. 1203, no. 1, pp. 012028, 2023.
DOI: https://doi.org/10.1088/1755-1315/1203/1/012028

[31] M.M. Gabriel and K.P. Kuria, "Arduino uno, ultrasonic sensor HC-SR04 motion detector with display of distance in the LCD", *International Journal of Engineering Research & Technology*, vol. 9, no. 5, pp. 936-942, 2020.
DOI: https://doi.org/10.17577/IJERTV9IS050677

[32] T. Bhuvaneswari, V. Chitra and G.C. Cheng, "Voice Controlled Home Automation System Design," *International Journal on Robotics, Automation and Sciences*, vol. 5, no. 2, pp. 94-100, 2023.
DOI: https://doi.org/10.33093/ijoras.2023.5.2.12

[33] Thangavel, B. Thangavel, C. Venugopal, S. Immanuel, J.E. Raja and W.C. Chua, "Design and Development of Automated Solar Grass Trimmer with Charge Control Circuit," *International Journal on Robotics, Automation and Sciences*, vol. 6, no. 1, pp. 36-45, 2024.
DOI: https://doi.org/10.33093/ijoras.2024.6.1.6