Greenhouse Horticulture Automation with Crops Protection by using Arduino

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***Abstract*—Agriculture significantly contributes to economic growth, generating employment opportunity also simulating the small-scale agriculture experiences. However, unforeseeable weather patterns, natural disasters, and unwelcome intruders are significant threat which brings severe financial losses for the owner. To overcome these challenges, this study aims to develop IoT-based automation greenhouse integrated with intrusion detection and prevention system. Automation greenhouse provides optimal environmental conditions for crop growth and enhances agricultural productivity, additionally inclusion of intrusion detection and prevention practices could detect and give immediate responses towards intrudes approaches. The automation greenhouse with intrusion detection and prevention with IoT-based provides the real-time monitoring and control as instant intrusion notification will be send to user through mobile application remotely. Thus, IoT-based automation greenhouse invention provides the sustainable environment condition for crop growth and reducing crop losses from treats.**

***Keywords*—IoT-based; automation greenhouse intrusion detection and prevention; real-time monitoring**

I. INTRODUCTION

Greenhouse horticulture involves a completely enclosed structure that separates the indoor environment from the external environment, creating ideal conditions for plant growth [1]. Typically, a framed structure is covered entirely with transparent cladding that allows sunlight to penetrate into the greenhouse. Prefect environmental condition accelerates the speed of plant growth, increase the crops productivity, and shorten the harvest duration also minimize the effect from pests or diseases [2]. In contrast to the traditional farming practices of ancient times, where farmers relied primarily on their experience and visual observations, modern greenhouse horticulture leverages advanced technology for precision and efficiency. Historically, the reliance on visual observations often led to inaccuracies and occasional mistakes in managing crops, which could have significant negative consequences for yields. As the global population continues to grow, so does the demand for food production. With the emergence of Industry 4.0, technologies are occupying the agriculture sector, leading to the development of IoT-based greenhouse systems. IoT-based systems are equipped with an array of sensors and telecommunication technologies that gather data on the greenhouse's conditions. The data collected by these systems are transmitted to cloud platforms through network interconnections, where they are recorded and analyzed to improve crop productivity [3]. High-tech urban agriculture (HTUA) is an innovative solution applied in big cities like Amsterdam, where space is limited. It incorporates environment controlling systems and horticultural lighting to optimize crop growth and maximize the harvest quantity within a shorter duration. As a result, the Netherlands has become one of the world's most food-productive countries, relying heavily on exporting agricultural goods. This paper aims to explore the advantages of IoT-based greenhouse systems and HTUA in enhancing food production, sustainability, and efficiency in the agriculture sector [4], [5]. The agriculture industry has always been vulnerable to risks that can cause significant crop reduction, one of which is the intrusion of wild animals. Traditional methods of deterring such intrusions, including scarecrows and physical fences, have limitations in terms of effectiveness and cost-efficiency [6]. However, over time, birds become familiar with scarecrows and their effective-ness is reduced. The destruction caused by these animals can resulted up to a 50% loss in farmers' finances. In India, the elephant-human conflict has shown the intensity of the intrusion of wild animals, as elephants cross human habitats to raid crops, posing a menace to both lives and property [7], [8], [9]. Adding to the problem, there are also unpleasant thefts who steal valuable crops from owners and sell them for personal benefits. Some farmers resort to armed protection, but this is illegal and only limited to certain occupations such as policemen or bodyguards. In Malaysia, legally owned guns are only available to those who need to protect themselves from predators or to safeguard their property. However, it is crucial to remember that with power comes responsibility, and the intentional shooting of someone can result in strict penalties, including the death penalty. This paper aims to explore the challenges of crop protection against wild animals and theft in the agriculture industry and discuss possible solutions to mitigate these risks. Some farmers have employed a range of techniques to address these challenges. Some have turned to wire-netting fencing, which, while providing a physical barrier, remains vulnerable to larger animals. Electric fencing, on the other hand, is an effective deterrent but has drawbacks, including high electricity consumption and the need for government approval due to wildlife regulations [10]. Conventional greenhouse agriculture struggles to maintain optimal temperature and humidity levels for plant growth during hot weather, resulting in stunted growth and plant death. Manual operation of the greenhouse makes it difficult to obtain accurate environmental parameters to support plant growth and maximize crop production. Additionally, there is a lack of security to protect against pest attacks and theft of crops by intruders, both human and wild animals. An automated greenhouse can revolutionize the monitoring and controlling management with technology, allowing for optimal environmental conditions through sensors and automatic controls while providing high-level security against crop theft and harm to young seedlings. This work aims to develop an advanced and sustainable automation greenhouse system to increase crop production while implementing an intrusion detection and prevention system to protect against attacks by wild animals and theft. The system integrates with cloud analytics to enhance traditional greenhouse technology. The adoption of this automated greenhouse with IoT technology holds the potential to revolutionize crop productivity in the agriculture sector, allowing for remote monitoring and control through a dedicated mobile application. [11], [12], [13]. Motivated by the merits of greenhouse horticulture automation with crop protection this paper presents a laser fence mechanism, alarming system, and automation gate for intrusion detection and prevention. The installation of a laser fence intrusion detection system will enhance security by alerting researchers of any intrusion into the greenhouse. Additionally, an automated gate will respond accordingly to ensure the safety and security of the greenhouse. The Blynk application and ThingSpeak cloud database provide real-time monitoring and control of the greenhouse environment, while weather condition monitoring, internet speed, and accuracy of intrusion detection were analyzed and tested. The study successfully provided an efficient solution to maximize crop production and ensure crop safety against natural disasters and unauthorized access.

The remainder of this paper shall be arranged in the following manner: Section II will introduce related research. Our mechanism is motivated and described in Section III, followed up by related results and discussion in Section IV. Finally, in Section V, we will conclude the paper and outline potential areas of future research.

II. RELATED WORK

According to [14], automated greenhouse systems are crucial for efficiently controlling the climate and other environmental conditions within greenhouses. With the world's increasing population, the need for sustainable food production has become a significant concern. These systems often rely on microcontrollers, such as the Atmega328, as their central control units. These automated greenhouse systems are equipped with various sensors, including temperature, soil moisture, humidity, and light sensors. These sensors work together to create and maintain optimal growing conditions for plants. The microcontroller collects data from these sensors and, based on predefined threshold values, generates digital commands to control temperature, humidity, water valves, and even trigger light-dependent resistors (LDRs) when necessary. In [15], an Automatic Watering System based on Arduino was developed to address the challenge of controlling the precise amount of water needed for plant growth. The system utilizes a soil moisture sensor to detect the moisture level in soil and automatically irrigate the plant according to its demand. The sprinkler system determines the watering progress based on the received moisture level with-out any human intervention. According to [16], an automation irrigation project has been developed based on the readings from a soil moisture sensor. The Arduino microcontroller is used to control all the devices connected to the system. A drip irrigation system is used to efficiently water plants through narrow tubes and valves, and a Liquid Crystal Display (LCD) displays the moisture level of the soil. The relay module is used to turn ON and OFF the water pump based on the voltage readings received by the microcontroller, which is in turn based on the moisture level of the soil. According to the book by [17], an Internet of Things (IoT)-based system for greenhouse farming using Arduino and an ESP8266 module. This project aims to control and monitor environmental parameters within a greenhouse where Aloe Vera crops are cultivated. The system is integrated with the Blynk application via cloud computing, enabling remote access to greenhouse conditions. This IoT-based approach demonstrates the potential for technology to enhance and modernize greenhouse farming. In this paper, the authors describe a monitoring and controlling system for a greenhouse. The system collects data from various sensors, such as water, humidity, light, and temperature sensors, and sends the information to a base station, which is essentially a microcontroller circuit. The base station then stabilizes the environmental parameters to maintain optimal growing conditions inside the greenhouse. Actuators such as pumps, light bulbs, and fans are used to control the various environmental parameters.

The use of Internet of Things (IoT) technology in greenhouse cultivation has led to significant improvements in microclimate control and data sharing, as well as long-term artificial light source utilization. According to [18], precision technology in advanced greenhouses provides optimal plant growth conditions and increased productivity. Wireless Sensor Networks (WSN) plays a crucial role in these systems, enabling real-time monitoring of climate conditions and remote control. Commercial greenhouses now integrate communication devices, mobile applications, and decision support systems, leading to improved crop condition optimization and predictive capabilities. The paper discusses the importance of microclimate control in greenhouse cultivation and the use of sensor nodes for data collection. To create the perfect environment for plant growth, the microcontroller system regulates temperature, humidity, and light intensity within the greenhouse. Precision irrigation and temperature-humidity control are common techniques utilized in greenhouse cultivation, and the sensor nodes are used to measure moisture levels in the soil for a consistent watering process. The dynamic monitoring system is used to measure the environment conditions and synchronize the approaches to maintain the greenhouse microclimate. The Internet of Things has significantly improved management systems in greenhouses, but challenges arise when network connections vary in strength, affecting the accuracy of information and system response time. However, according to a study by [19], the Internet of Things in Greenhouse Farming is a viable solution to the food crisis, as it enables the maintenance of optimal environment conditions for plant growth and protection from harsh outdoor conditions.

In a study by [20], a remote monitoring system for greenhouse environment parameters was developed using the NodeMCU ESP 8266 Microcontroller and Blynk Application. Components such as DHT11, light sensor, and TDS sensor were integrated with an Arduino board to collect data and transmit it to a web server for precise monitoring. The system aimed to replace manual monitoring and enable more efficient control of the greenhouse environment. Similarly, [21] presents a study on dynamic monitoring and remote control in a greenhouse using the ESP8266 NodeMCU as the central unit. The system allows for real-time monitoring and control of environmental parameters such as temperature, humidity, light intensity, and moisture level using IoT technology. The collected data is sent to the cloud for storage and analysis, and users can remotely control the system through an instruction controller. The Wi-Fi network connection is established using the HTTP protocol with private API keys for data security. Overall, this project demonstrates the potential of IoT technology in improving greenhouse monitoring and management. The paper presents a greenhouse monitoring system that utilizes an Organic-Light Emitting Diode (OLED) module to display real-time parameters. The Android application Blynk enables data visualization on mobile phones via Internet of Things technology. With the NodeMCU, the system continuously sends current measurements to the cloud for remote monitoring and control. The research highlights the importance of modern technology in regulating microclimates for optimal crop growth.

An Environmental Monitoring System is proposed that utilizes the Arduino and Thing-Speak to monitor weather conditions inside a greenhouse. ThingSpeak, an open-source application and Internet of Things platform, stores and displays live data streams in the cloud, allowing for real-time analysis and interpretation. The system is designed to continuously update and transmit data from sensors to ThingSpeak for further analysis and display. In a related project, [22] developed an automatic sprinkler system for greenhouse using an Arduino microcontroller AVR Atmega328 and a soil moisture sensor. The system is connected to the ThingSpeak platform through the Internet of Things (IoT) network for real-time monitoring and control. Users can register for a new account, obtain the channel ID and Application Programming Interfaces (API) keys to access their data on ThingSpeak. Once data is collected, users can analyze it through charts and graphs presented on the platform. This automation technology is widely used for irrigation to simplify the watering process and increase crop yields. Similarly, [23] proposed a design that utilizes ThingSpeak and Arduino to automate the irrigation system in a greenhouse. The goal is to reduce water usage and prevent waste. ThingSpeak creates a channel in the cloud platform that enables data exchange. Users can access the environment parameters in the green-house by logging into their account using the same credentials they used during registration. ESP8266 is used to establish a Wi-Fi module and link the Graphic User Interface (GUI) to the ThingSpeak database. This allows users to retrieve all the measurement parameters in the greenhouse and visualize the soil moisture values through an Android application on their electronic device.

Agriculture automation using IoT is becoming increasingly popular and the ThingSpeak platform is often used for data aggregation and visualization. As described in [24], [25], Thing-Speak serve as a database for storing and analyzing data collected from greenhouse sensors. In [26], IoT system for greenhouse automation is presented, employing an Arduino Mega microcontroller and Wi-Fi module in conjunction with ThingSpeak. This system is divided into a monitoring and control system, with real-time sensor data display and remote-control capabilities via ThingSpeak. It effectively monitors and controls various greenhouse parameters, such as temperature, soil moisture, and light intensity, using sensors and relays to trigger actions based on sensor readings. On the wildlife protection front, the study in [27] introduces the Smart Laser Fence, a non-harmful method to deter animals from protected areas using laser beams. This innovation is considered safer and more practical compared to traditional methods like chili and electric fences.

The IOT Based Security System (IBSSS) discussed in [28] supports the implementation of a laser fence as a protective boundary. The laser fence is designed to detect the presence of wild animals by using laser beams and PIR sensors placed on the opposite side of the laser source. When the connection between the laser and PIR sensor is broken, an alarming system activates. Additionally, the system includes an automatically targeted laser gun that points in the direction of the intrusion present. The laser gun uses an ultrasonic sensor fixed on a servo motor to detect the position of the intruder and fires accordingly. According to [29], an intelligent surveillance security system has been developed using a laser fence with GSM communication. The system is energy efficient, utilizing a laser beam, LDR, and mirrors to save costs. Total internal reflection of light is employed by placing two parallel mirrors and receiving incident light from the laser, creating a sub-layer with a zigzag shape. The system also features an image monitoring camera and a GSM module for network communication, notifying the user when an intrusion occurs.

The implementation of a junction box as a protection measure against wild animal intrusion is discussed in [30], [31]. An intelligent agriculture system, using the XBee networking system, is proposed to prevent crop damage. The system utilizes four laser sources placed at different angles and paired with LDR sensors, with each junction box containing a laser gun and LDR sensor. Additionally, precision agriculture techniques are employed, utilizing a smart sensor system to monitor environmental conditions and a watering system, with data transmission facilitated by a GSM module. A junction box is developed for crop field protection, utilizing a virtual fence made of laser and LDR sensors. The system uses GSM communication to send alerts to users in case of intrusion. Each junction box contains an Arduino microcontroller, RTC, XBee communication system, laser transmitter, and LDR sensor. The RTC is used to record the time of intrusion and send it through the XBee. The virtual fence is constructed by aligning the laser and LDR sensors across different junction boxes. In [32], introduces a wireless sensor network for crop protection against animal intrusion, featuring laser emitters, PIR sensors, XBee, and an Arduino MEGA microcontroller. The system utilizes automatic intrusion detection and aims to maintain ecological balance while deterring animals from crop fields through non-harmful means.

III. PROPOSED METHOD

In this section, we present our innovative smart greenhouse system with integrated crop protection. The flowchart illustrates the transceiver module workflow. Our advanced microclimate control involves long-distance monitoring, system configuration, and crop condition prediction via Wi-Fi connectivity. The ESP8266 acts as both transmitter and receiver, enabling real-time monitoring and remote control via the Blynk Android app. Additionally, environmental and intrusion data are continuously transmitted to the cloud for future analysis and investigation. All the environmental parameters are adjustable with the help of electronics devices to perform the prefect environmental condition for maximize the crop production. Besides, the laser fence will detect and respond when the intrusion happens. Blynk end users enable to constantly tracking the live stream parameters, receiving the intrusion notification also perform the decision making on system. The block diagram of automation greenhouse is shown in Fig. 1.

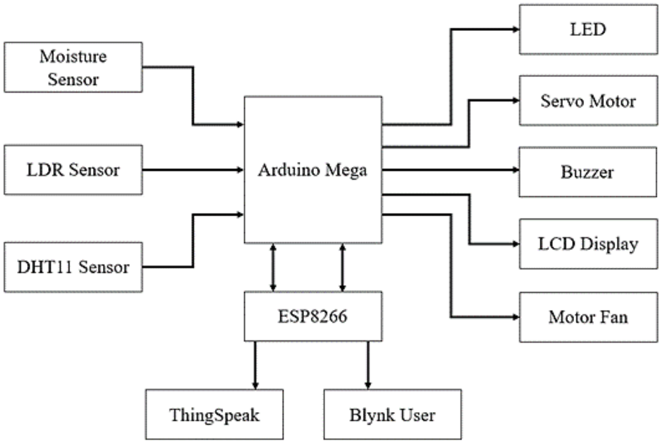


Fig. 1. Block diagram of remote monitoring greenhouse system.

The proposed system follows a structured workflow, as depicted in Fig. 1 and Fig. 2. Fig. 1 outlines the workflow for the transceiver module, which serves as a central component of the system designed for greenhouse monitoring and control. To achieve this, a network of sensors is strategically positioned within the greenhouse. These sensors include moisture sensors for soil moisture measurement, DHT11 sensors for temperature and humidity monitoring, and LDR sensors for assessing light intensity. The data gathered by these sensors is transmitted to an Arduino Mega microcontroller, which assumes the role of data processing and decision-making. Based on the collected data, the Arduino Mega implements various solutions. For security purposes, the LDR module detects intrusions at two levels, with the red LED and buzzer activated for the first level, and the yellow LED and buzzer for the second level. The NodeMCU transceiver module enables Wi-Fi connectivity, allowing the Arduino Mega to transmit real-time data and notifications to end-users via the Blynk platform. Simultaneously, all greenhouse parameters are sent to the ThingSpeak cloud platform for aggregation over time, enabling graphical visualization and comprehensive data analysis.

The flowchart shows in Fig. 2 states the developed smart greenhouse with crop protection mechanism. In greenhouse, ventilation system functions as balancing the temperature and humidity while the moisture sensor will acts as measure also estimate the water amount in soil. Laser fence will classify the intrusion level then the intrusion prevention system will activate once the intrusion event approaches. All the environmental parameters and intrusion notification enable to view from end user by Blynk application. The details for this architecture will explained on section below.

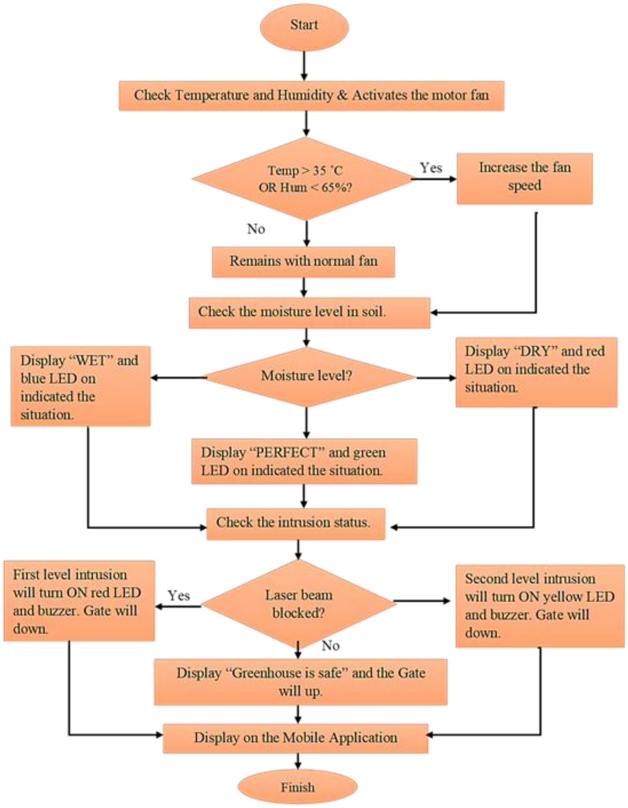


Fig. 2. Flowchart for greenhouse horticulture automation with crops protection.

Upon conducting repeated tests, the initial circuit for the greenhouse has been assembled and is presented in Fig. 3, depicting the connections between the Arduino Mega, NodeMCU ESP8266, sensor devices, and actuators. The TX pin of NodeMCU is connected to the RX pin for Arduino Mega and TX pin of Arduino Mega is connected to the RX pin of NodeMCU so it will establish the serial communication which allows data exchange between these two devices.

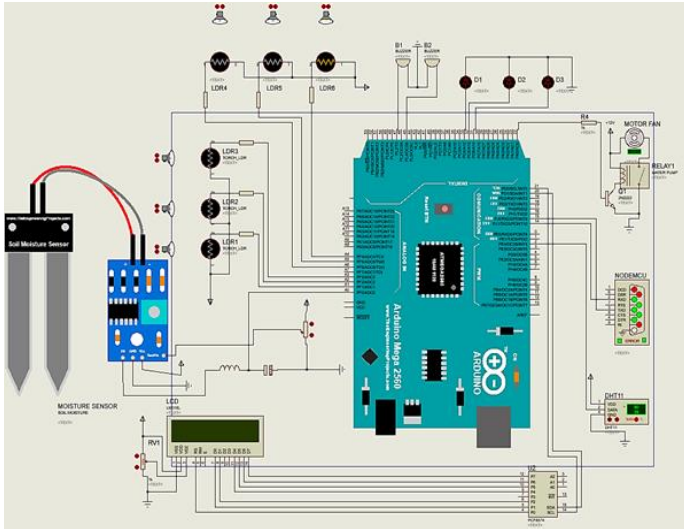


Fig. 3. Circuit design for greenhouse horticulture automation with crops protection.

IV. Result and Discussion

An effective automated greenhouse must meet several essential criteria, such as providing an optimal environment for crop growth, accommodating every stage of plant development, increasing yield quantity, reducing costs, and ensuring crop safety at all times. This section will describe the development of an automated greenhouse that incorporates a laser fence mechanism. The integration of sensors and actuators will also be discussed in the following section.

A. *Hardware Implementation*

The purposed automation greenhouse system functions as constantly environmental parameters up-to-do, climate control system together with crop protection mechanism. Automatic greenhouse always monitoring parameters then activates the actuators device to respond towards the sudden change in the greenhouse. Virtual laser fence mechanism can prevent the hazards from intruder also carried out the high pitch alarming system to chase away the intruder without any physical damaged towards it.

1) Automation greenhouse with climate control capability: The researcher employed several hardware components to construct the greenhouse system, such as Arduino Mega, NodeMCU Lua V3 ESP8266 WIFI with CH340C, LDR, LED, Buzzer, DHT11, Soil Moisture sensor, and laser diode, each with their unique function and specifications. The hardware device Arduino Mega is configured to continuously read all the real-time environmental parameters from attached sensor device includes DHT11, LDR sensor also the moisture sensor then converting all inputs into human visual. LCD display will constantly present the current reading like temperature, humidity, light intensity in greenhouse and moisture value of soil in greenhouse. NodeMCU is a powerful IoT development board based on the ESP8266 WiFi module with 128KB RAM and 4MB flash program memory. It features in-built Wi-Fi/Bluetooth, Deep Sleep mode, and CH340 USB converter for easy installation. With 9 GPIO pins and 1 Analog input pin, NodeMCU is perfect for IoT projects. The DHT11 sensor is a reliable and accurate digital output sensor that uses a digital signal acquisition technique. It has a small size, low power consumption, and easy-to-use four-pin package. It operates on 3.5V to 5.5V with an operation current of 0.3mA. The temperature range is 0°C to 50°C, and the humidity range is 20% to 90%, with 16-bit resolution. The temperature and humidity accuracy are ±1˚C and ±1%, respectively, with anti-interference ability and long-distance signal transmission. The moisture sensor measures soil moisture by passing current through the soil via two probes, with the module calculating the water content and providing results as moisture levels. The external probe serves as a variable resistor, modifying its resistance value based on the amount of water present. Both analog and digital outputs are produced. Analog Output (A0) creates the output voltage, while digital Output (D0) digitalizes the resistance value via the LM393 High Precision Comparator on board. Low analog voltage readings indicate higher water content, while high readings indicate lower water content. The laser diode has an electrically isolated case with lead electrical connection and a high reflective index glass lens that produces long-distance beams. It can be controlled by a GPIO pin from the Arduino board and requires power input from 3.3V to 5.0V.

The ventilation system is designed to run continuously to maintain the appropriate temperature and humidity levels for plant growth. The fan speed is controlled by the DC motor's duty cycle, which varies depending on the DHT11's readings. If the temperature exceeds 35˚C or the humidity falls below 65%, the fan speed will increase to raise the duty cycle from the normal 55% to 82%. Soil moisture is crucial for healthy plant growth and must be monitored to ensure proper irrigation.

In this moisture detection mechanism, the moisture sensor will detect analog measurement and classify into three status includes wet, dry and prefect. At first, the analog measurement received more than 800 will classify as dry condition where there are lack of water in plantation area. In greenhouse, LCD display will display “Plant is too DRY” and the red LED will be triggered to notified farmer. Then, analog measurement 500 will assigned to wet condition where the planation area had too much of water. LCD display will “Plant is too WET” then blue LED triggered. Lastly, analog measurement between 501 to 799 is the prefect range of moisture value. Prefect soil condition will show the statement “Soil is PREFECT” on LCD together with triggered green LED. After then, artificial light installed become the lighting supplement for entire greenhouse in Fig. 4 and Fig. 5. The installed hardware implemented can be control by user based on Blynk application. End user can interactive with artificial light by widget button on Blynk according to user’s decision. All the current greenhouse measurements and widget buttons will be displayed on Blynk Application in Fig. 6.

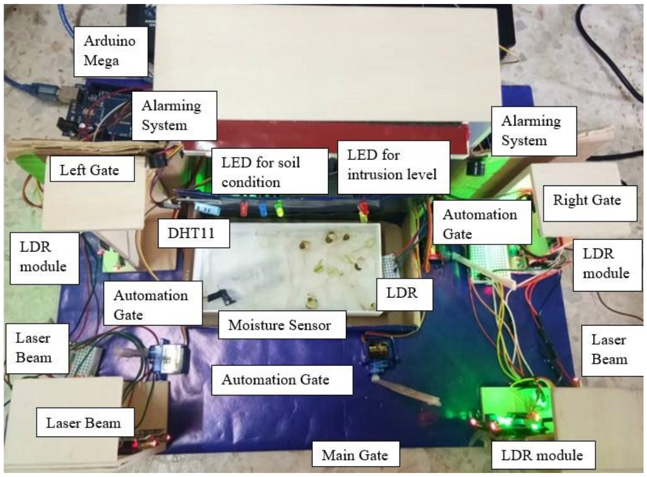


Fig. 4. The prototype of the greenhouse.

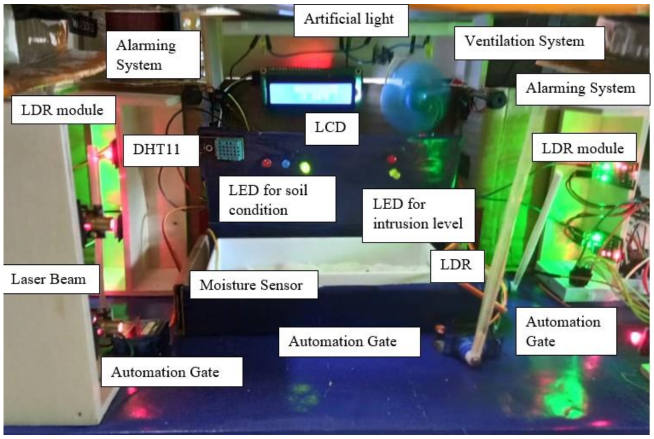


Fig. 5. The front view for greenhouse.

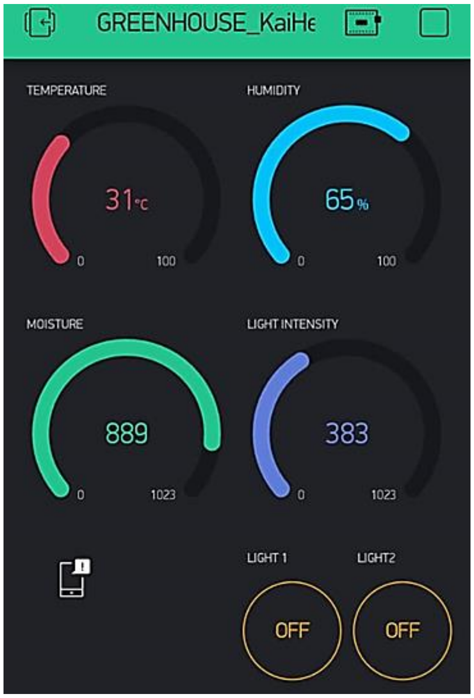


Fig. 6. Current measurement and widget button on blynk application.

B. *Software Implementation*

Blynk provides server that connecting managed deployed system also enables remotely take control the internet connected electronic devices with designed widget on interface builder. In the purposed system, end user will constantly view the actual environmental parameters, enables to control artificial light source remotely also receive the intrusion notification details. Then, ThingSpeak allows the instant line graph visualizations for the posted data received. All the parameters received will recorded and displayed into line graph. Line graphs construct the time-series relating between scale object that helps to analyze the trend of read parameters over the time line.

Fig. 7. Data visualization for environmental parameters and intrusion events happens.

1) *Data analysis in thingspeak*

To analyze the data, changes in the temperature, humidity, soil moisture level, and light intensity within the greenhouse are measured over time. In Fig. 7, the selected environmental parameters of the greenhouse are displayed on specific channels on the ThingSpeak cloud service over a certain time period. The intursion event can be interpreted where intrusion status “1” indicates intrusion happens, while “0” means no intrusion. Based on Table I, the average temperature inside the greenhouse is 31 degrees Celsius, while the average humidity level is approximately 73%. Additionally, the average analog measurement for soil moisture is 569, and the light intensity averages 547. Then, Table II express nterusion events happens on the left, main, right gate. On the figure explained there are two intrusion happen on right gate while no intrusion happen on left and main gate.

TABLE I. MEASURING AVERAGE PARAMETERS IN A GREENHOUSE ENVIRONMENT

SELECTED ENVIRONMENT PARAMETER	**AVERAGE MEASUREMENT**
HUMIDITY	73%
LIGHT INTENSITY	547
TEMPERATURE	31˚C
SOIL MOISTURE	569

TABLE II. INTRUSION EVENTS HAPPENS IN GREENHOUSE ALONG CERTAIN TIME PERIOD

LASER FENCE LOCATION	**INTRUSION EVENTS**
LEFT GATE	0
MAIN GATE	0
RIGHT GATE	2

2) Intrusion detection and prevention mechanism: Intrusion detection fence system built by surround the greenhouse from left, center and right. Each fence consists two pair of laser beam and LDR sensor align up and down that differentiate the intrusion level approaches based on body size of intruder in Fig. 8. At the same time, the alarming system and prevention will be activated also the end users will receive the intrusion notification from Blynk application. Blynk notification will states the information details about the actual location intrusion happens together with intrusion level involved immediately. When an intruder approaches, the system promptly detects their presence and analyses their size shown. Two intrusion levels are defined: the first for large-bodied intruders and the second for smaller ones. The detection is triggered when an intruder obstructs both the up and down laser beams and their respective LDR pairs in Fig. 10. For the first intrusion level is triggered when big body size of intruder step-into and blocked both up and down laser beam and LDR pair installed. Then, second intrusion level is triggered by smaller-bodies intruders as it only managed to block down laser beam LDR pair in greenhouse. Simultaneously, the system communicates with the Blynk application, sending out a detailed intrusion notification. This notification includes vital information about the intrusion event, such as the precise location within the greenhouse and the specific intrusion level involved. Yet, if there are no intrusion happens in greenhouse, LCD display will update the statement "GREENHOUSE IS SAFE!", intrusion prevention will not have activated also Blynk application user will not receive any notification shown in Fig. 9.

3) A comparison of results obtained on-site and via the blynk application: In this section, we will be comparing the results obtained on-site with those obtained via the Blynk Application at the same time. The LDR sensor is utilized to measure any intrusion events, and the NodeMCU is responsible for transmitting the intrusion event to the Blynk Application. The application displays the notification details regarding the level and location of the intrusion. Three scenarios were tested to determine whether they can trigger notifications on the Blynk mobile application simultaneously. Referring to Fig. 11, it is observed that no intrusion event occurred in the greenhouse, and consequently, no notification was displayed on the Blynk application. Fig. 12 and Fig. 13 illustrate that intrusions occurred in the greenhouse. However, in the second test, the first level of intrusion was detected, and in the third test, the second level of intrusion was detected. Table III describes the intrusion events that occurred and the corresponding Blynk application notifications. Then, Table IV shows the status of the automation gate along with the occurrence of intrusion events. Therefore, the comparison between the on-site intrusion events and the notification results on the Blynk Application display accurate and real-time information about the intrusion events that occur.

Fig. 8. The position of the laser fence at the left, main, and right gate.

Fig. 9. The display statement that no intrusion happen in greenhouse.

Fig. 10. The approach of a large intruder towards the left gate.

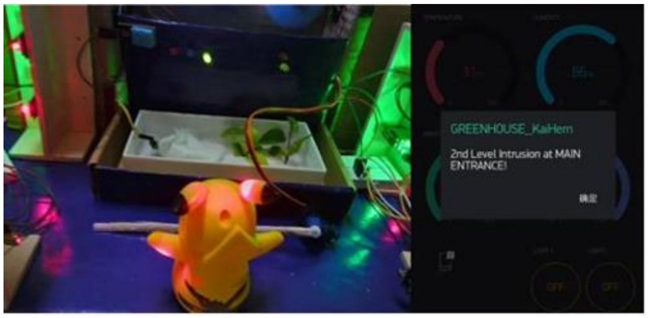
Fig. 11. First test in main gate.

GREENHOUSE_KaiHem

1st Level Intrusion at MAIN ENTRANCE!

确定

Fig. 12. Second test in main gate.



GREENHOUSE_KaiHem

2nd Level Intrusion at MAIN ENTRANCE!

确定

Fig. 13. Third test in main gate.

TABLE III. COMPARISON RESULT BASED ON INTRUSION EVENT AND BLYNK APPLICATION DISPLAYED

LASER FENCE AT MAIN GATE	SITUATION		NOTIFICATION DETAILS DISPLAYED ON BLYNK APPLICATION
	FIRST INTRUSION LEVEL	SECOND INTRUSION LEVEL	
FIRST TEST	NO	NO	NO
SECOND TEST	YES	NO	YES
THIRD TEST	NO	YES	YES

TABLE IV. COMPARISON RESULT BASED ON INTRUSION EVENT AND AUTOMATION GATE STATUS

LASER FENCE AT MAIN GATE	SITUATION		AUTOMATION GATE TURNING DOWN
	FIRST INTRUSION LEVEL	SECOND INTRUSION LEVEL	
FIRST TEST	NO	NO	NO
SECOND TEST	YES	NO	YES
THIRD TEST	NO	YES	YES

4) Comparison with internet speed and performance of automation greenhouse: In this section, the performance of the greenhouse system will be evaluated. The time taken for the system to respond was observed by comparing the internet speed and NodeMCU's time response to receive an instruction. Internet speeds of 10.1 Mbps, 20.0 Mbps, 45.7 Mbps, and 98.9 Mbps were selected for this testing section shown in Fig. 14.

Fig. 14. Results of internet speed testing.

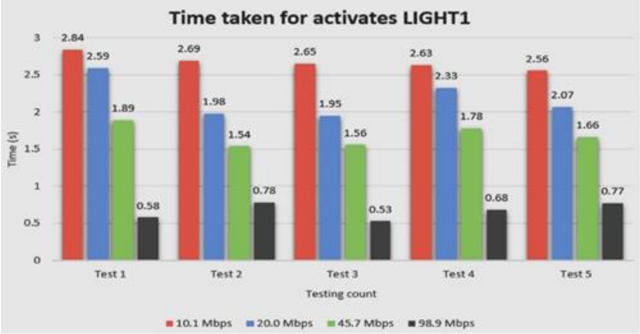


Fig. 15. The time taken for activates LIGHT1.

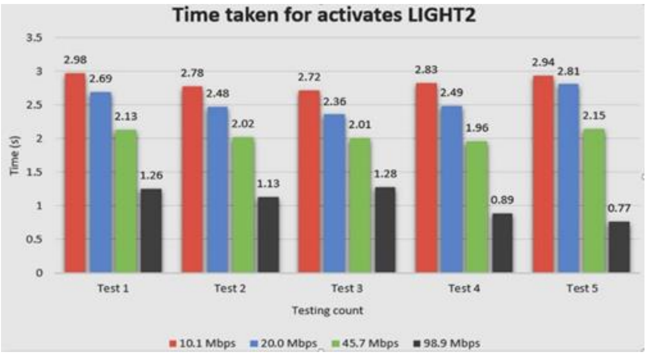


Fig. 16. The time taken for activates LIGHT2.

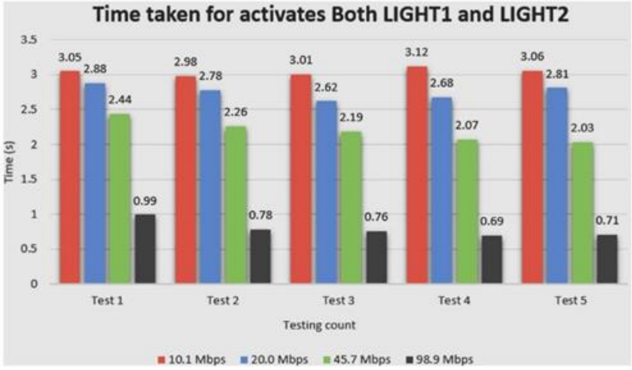


Fig. 17. The time taken for activates both LIGHT1 and LIGHT2.

TABLE V. AVERAGE ACTIVATION TIME FOR LIGHT1

INTERNET SPEED (MBPS)	AVERAGE TIME RESPONSE (S)
10.1	2.67
20.0	2.18
45.7	1.69
98.9	0.67

TABLE VI. AVERAGE ACTIVATION TIME FOR LIGHT2

INTERNET SPEED (MBPS)	AVERAGE TIME RESPONSE (S)
10.1	2.85
20.0	2.57
45.7	2.10
98.9	1.10

TABLE VII. AVERAGE ACTIVATION TIME FOR BOTH LIGHT1 AND LIGHT2

INTERNET SPEED (MBPS)	AVERAGE TIME RESPONSE (S)
10.1	3.04
20.0	2.75
45.7	2.20
98.9	0.79

Fig. 15, 16, and 17 depict the response time of the NodeMCU to receive a signal in relation to the internet speed. Five tests were conducted under three different scenarios, each with varying internet speeds. After analyzing the results, the average response time for different internet speeds, including 10.1 Mbps, 20.0 Mbps, 42.7 Mbps, and 98.9 Mbps, was calculated and recorded in Tables V, VI, and VII based on the respective event situations. Table V presents the average response time required to activate only LIGHT1, with the highest response time recorded at 10.1 Mbps internet speed, which took 2.67 seconds. The next highest response time was recorded at 20.0 Mbps, taking 2.18 seconds, followed by 45.7 Mbps at 1.69 seconds. The lowest response time was recorded at 98.9 Mbps, which took only 0.67 seconds. Then, Table VIdisplays the average time response, indicating that the shortest response time was observed for internet speed 98.9 Mbps, with 1.01 seconds, followed by internet speed 10.1 Mbps with 2.85 seconds, internet speed 20.0 Mbps with 2.57 seconds, and internet speed 45.7 Mbps with 2.10 seconds. Other than that, Table VII displays the average time required to activate both LIGHT1 and LIGHT2. The shortest time taken was observed with an internet speed of 98.9 Mbps, which was 0.79 seconds. This was followed by 10.1 Mbps, which took 3.04 seconds, internet speed 20.0 Mbps, which took 2.75 seconds, and internet speed 45.7 Mbps, which took 2.20 seconds. Thus, the finding in graphs and table provides evidence that the higher of internet speed the shorter time taken to response.

V. CONCLUSIONS

The greenhouse automation with crops protection prototype underwent both hardware and software testing to ensure its proper implementation. The hardware component was used to measure and provide information about environmental parameters and intrusion notifications to enhance plant growth and improve crop security. The Blynk mobile application served as an interface for users, while ThingSpeak acted as the cloud database that collected and displayed all the recorded data over time. The automated greenhouse is designed to mimic the real-time conditions of a greenhouse by maintaining suitable environmental conditions automatically. Users can remotely view, control, and receive intrusion alerts via the Blynk Application. The protection system for this automated greenhouse includes a laser fence, an alarming system, and an automated gate. The laser fence is used to detect any unauthorized encounters and estimate the body size and level of danger of approaching objects. Upon detection of intrusion events, the alarming system buzzer will be activated and the automation gate will be automatically closed. The triggered alarm serves to deter intruders and notify the relevant authorities of the threat of intrusion. The automation gate, when closed, protects the crops from damage or theft by unauthorized persons. Once intrusion event happens, the Blynk end user will immediately receive the intrusion notification with details like intrusion event location together with intrusion level involved.

Furthermore, the analysis of the weather condition in the automation greenhouse was conducted, and the average results were tabulated. Additionally, the performance of the greenhouse was tested by comparing the average time taken at different internet speeds. As fast internet speed, al-lows the actuators to perform quickly respond onto the unexpected change in greenhouse. However, there remains a research gap related to the long-term performance and reliability of the system. Future studies should explore the system's performance over multiple growing seasons to assess its durability, adaptability to changing environmental conditions, and overall reliability in real-world agricultural settings. The results indicate that higher internet speeds lead to shorter response times and increased accuracy. Additionally, the accuracy of the laser fence was investigated, and it was found that the notifications displayed on the Blynk application were exactly the same as the on-site situation. Blynk end user straight away received current intrusion event together with intrusion information details regardless of location or time periods. At the end, all objectives of this purposed system had achieved successfully. Researcher enable to prove previous discussed research paper which mention automation greenhouse enable to solve traditional farming issues, enhancing the quality and quantity of crops which simulate the sales practically. As well, laser fence mechanism is the best choice in term of cost-efficiency, generate incomes also humane.

The proposed automation system for greenhouses with crop protection holds immense potential for commercialization within the agricultural and floral industries. In an era where these sectors are under increasing pressure to deliver high yields and exceptional quality, this innovative solution offers a multitude of benefits. Firstly, it promises to significantly boost production by optimizing critical growth conditions, including temperature, humidity, and lighting. This enhanced control not only results in higher crop yields but also ensures the consistency and quality demanded by these industries. Additionally, the system contributes to cost savings, as it minimizes labor requirements and reduces resource wastage. Moreover, it mitigates the need for excessive pesticide and chemical treatments, not only saving on costs but also aligning with environmentally sustainable practices. Ultimately, the primary goal of this proposed work is to maximize crop productivity while increasing the income of the agriculture industry, making it an enticing prospect for commercialization.

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