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DEVELOPMENT OF AUTONOMOUS IOT HYDROPONIC SYSTEM

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A project report submitted in partial fulfillment of the requirements for the degree of Bachelor of Electronics Engineering Technology with Honours



UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DECLARATION

I declare that this project report entitled "Development of Autonomous IoT Hydroponic System" is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

I hereby declare that I have checked this project report and in my opinion, this project report is adequate in terms of scope and quality for the award of the degree of Bachelor of ElectronicsEngineering Technology with Honours.



DEDICATION

I am dedicating this thesis to my parents, Sabaruddin bin Yusof and Norzilawati Binti Yasir, who gave their full support through my ups and down and also to Anis Hazirah 'Izzati Binti Hasnu Al-Hadi that always there help builds my motivation up and cheer me up when i felt lost. Also, a big thanks to my project supervisor Ts. Nur Alisa binti Ali and Dr. Syukur for the guidance throughout completing this thesis and to all other UTeM lecturers. Without their dedication in teaching, I wouldn't reach until this far. Lastly, to my all-good friends, classmates, and teammates through bittersweet four years' journey. Thank you I appreciate all the support and good vibe through the process.



ABSTRACT

In an uncontrolled environment, the consequences of global warming make planting more difficult. In recent years, the digital divide between agricultural production and Internet of Things (IoT) technologies has narrowed. In the future, these technologies will allow for increased productivity through sustainable food cultivation, and environmental protection through effective water use and input and treatment optimization. Traditional agriculture often uses excessive amount of fertilizer and this increase amount of cost in producing food. Hence, this will contribute to higher inflation and will affect on food security chain. Therefore, fertilizer needed to be control on exact amount to reduce the cost of production. One of the techniques is by utilizing the internet-of-things (IoT) technology in hydroponics system. The goal of this project is developed IoT based system that can monitor and control the amount of liquid A&B fertilizer for hydroponics agriculture. Two nodeMCU ESP32 is used, at the endpoint will collect all data from sensors including PH, humidity, and temperature. These sensors data are transmitted to another nodeMCU (master node) wirelessly up to 70m range. The master node received all raw sensors data, display it on LCD, connected to indoor Wi-Fi, and send data to Cayenne IoT platform. All of sensors data from node 1 can be monitored on Cayenne dashboard. PH reading will be always monitor by nodeMCU and if needed, it will turn on the pump through connected relay and flow the A&B fertilizer into the hydroponics system. The automatic system is successfully developed where PH reading, temperature, and humidity can be accessed on Cayenne dashboard. Besides, this system greatly reduces the excessive amount of fertilizer usage and very effective in the area wherenoWiFicoverage.

ABSTRAK

Dalam persekitaran yang tidak terkawal, akibat pemanasan global menjadikan penanaman lebih sukar. Dalam beberapa tahun kebelakangan ini, jurang digital antara pengeluaran pertanian dan teknologi Internet of Things (IoT) telah mengecil. Pada masa hadapan, teknologi ini akan membolehkan peningkatan produktiviti melalui penanaman makanan yang mampan, dan perlindungan alam sekitar melalui penggunaan air yang berkesan dan pengoptimuman input dan rawatan. Pertanian tradisional sering menggunakan jumlah baja yang berlebihan dan ini meningkatkan jumlah kos dalam menghasilkan makanan. Jelasnya, ini akan menyumbang kepada inflasi yang lebih tinggi dan akan menjejaskan rantaian keselamatan makanan. Oleh itu, baja perlu dikawal pada jumlah yang tepat untuk mengurangkan kos pengeluaran. Salah satu tekniknya ialah dengan menggunakan teknologi internet-of-things (IoT) dalam sistem hidroponik. Matlamat projek ini dibangunkan sistem berasaskan IoT yang boleh memantau dan mengawal jumlah baja A&B cecair untuk pertanian hidroponik. Dua nodeMCU ESP32 digunakan dan akan mengumpul semua data daripada sensor termasuk PH, kelembapan dan suhu. Data sensor ini dihantar ke nodeMCU lain secara wayarles sehingga 70 meter. Nod induk menerima semua data sensor akan dipaparkannya pada LCD, disambungkan ke Wi-Fi dan terus dihantar data ke platform Cayenne IoT. Semua data penderia dari nod 1 boleh dipantau pada papan pemuka Cayenne. Bacaan PH akan sentiasa dipantau oleh nodeMCU dan jika perlu, ia akan menghidupkan pam melalui geganti bersambung dan mengalirkan baja A&B ke dalam sistem hidroponik. Sistem automatik berjaya dibangunkan di mana bacaan PH, suhu dan kelembapan boleh diakses pada papan pemuka Cayenne. Selain itu, sistem ini sangat mengurangkan jumlah penggunaan baja yang berlebihan dan sangat berkesan di kawasan yang tiada WiFi.

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CHAPTER 1

INTRODUCTION

1.1 Background

The 4th Industrial Revolution develops the agriculture sector with Artificial Intelligence (AI), the internet of things (IoT), and the capability of autonomous robots in planning, decision-making, and operations to remain competitive and sustainable. The objective is to accommodate population growth. Hence, the 4th Agricultural Revolution, with its innovative farming technology (smart farming), may handle food demands, depletion of natural resources, climate change, and food waste [1]. Access to nutritious and secure food is one of the biggest problems individuals face today. Farmers employed fertilizers, chemicals, and pesticides to increase food production, resulting in soil contamination. Due to that, researchers are trying to find a better solution to produce a portion of safe and healthy food. The problem can solve by using the hydroponics system.

Hydroponics is a system in which plant growth does not rely on soil but on nutrientrich water that does not include the chemicals found in soil. Numerous techniques, such as nutrient film technique (NFT), deep flow technique (DFT), and dynamic root floating (DRF), are employed in hydroponics to improve nutrient-providing plant growth. Two types of soilless culture exist water culture and substrate culture. The development of plants in hydroponics is more rapid than in soil, which gives plants more nutrients and controls the output quality [2]. Various commercial and speciality crops can be grown with hydroponics, including green vegetables, tomatoes, strawberries, peppers, cucumbers, and many more [3]. Nutrient composition and pH levels are critical to keeping in check for improved plant growth conditions [4]. As a result, monitoring pH, humidity, and electrical conductivity (EC) for nutrient status evaluation are widespread in hydroponic solutions used in greenhouse plant cultivation. Hydroponic systems, on the other hand, offer a significant opportunity for water savings in the agricultural industry since they improve water efficiency by recycling excess irrigation water [5]. Hydroponic enables the use of previously inappropriate regions for traditional agriculture, such as sterile and damaged soil areas. However, installing hydroponic systems is costly and time-consuming [6].

The Internet of Things is a new issue with significant technical, social, and economic implications [7]. The fundamental concept of the IoT is the pervasive presence of many items with interaction and collaboration capabilities among them to achieve a shared goal [8]. It expects that the IoT will significantly impact many aspects of daily life and this concept will use in various applications such as domotics, assisted living, and e-health. It is also an ideal emerging technology for providing new evolving data and computational resources for developing revolutionary software applications [9]. IoT can see as an essential architecture for modern agricultural systems. In the literature [6, 7, 10-12], several IoT technology has been employed for environmental monitoring based on open-source and mobile computing technologies.

This project developed an autonomous IoT hydroponic system by monitoring various parameters such as pH level, temperature and relative humidity.

1.2 Problem Statement

Traditional farming presents difficulties, including physical ploughing, weeding, pests, and climate. Some soil-based crop diseases are introduced through soil-based agriculture. It also demands large land use. Hydroponic-based agriculture eliminates all of these difficulties. The hydroponic system grows plants quickly, healthily, with little water, in a space-saving method, and without pests, illnesses, or weeds. It is similar to traditional agriculture. Hence, the prerequisites for implementing this system would be the same in most respects, i.e. maintaining proper nutrient levels, employing proper irrigation techniques, and taking care of plants. In addition, with the fourth industrial revolution (IR 4.0), technology such as IoT can help to monitor the hydroponic system remotely as well as reduce human labour.

1.3 Project Objective

The main aim of this project is to propose a development of autonomous IoT hydroponic system. To attain this, the work will be divided into numerous components and will be carried out methodically in concerning to the following objectives:

- i. To design an autonomous IoT hydroponic system.
- ii. To develop and control hydroponic system using IoT for monitoring various parameters such as pH level, Temperature and Relative Humidity.

1.4 Scope of Project

The scope of this project are as follows:

- i. Two sensors which are pH water level and DHT 11 It will be connected through WiFi module ESP32.
- ii. Microcontroller that had been used is ESP32 and there is also another one called Receiver.
- iii. The ESP32 is connected and fully developed on Arduino IDE.
- iv. The IoT platform that been choosen is Cayenne.

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1.5 **Project Significant**

An autonomous IoT hydroponic system from the objective has been developed. Hydroponic system is useful and beneficial in this project for agriculture industry. This project presents one of the best autonomous IoT hydroponic system in ordered to monitored various parameters such as pH level, temperature, and relative humidity.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The world's population has increased tremendously from 1.65 billion in 1900 to 7.4 billion today. The rate of increase is not diminishing, and by the end of the century, the Earth's population predicts to reach 11.2 billion. Contrary to the increase, arable land is shrinking, from 0.5 ha per person in 1960 to 0.2 ha per person in 2020 [12]. Without a change in agricultural methods, the globe will not have enough food to meet the needs of all its inhabitant's need.

2.2 Traditional Agriculture

Traditional agriculture is a primitive kind of farming that relies heavily on indigenous knowledge, traditional tools, natural resources, organic fertilizer, and the cultural values of the farmers. Notably, about half of the world's population continues to employ it. Traditional agriculture is described by extensive farming employing indigenous knowledge and tools. Conventional tools like an axe, a hoe and a stick the use of practices such as slash-and-burn and shifting cultivation, the use of cattle grazing to produce fallow land, a lack of environmental accountability and responsibility and excessive production. In the traditional irrigation method, farmers would water their crops after a predetermined period of time (typically a few days) [13]. However, this technique is flawed because certain crops do not need water until later in the season, resulting in water waste. In contrasts, the other crops require water earlier in the growing season. In addition to wasting water, overwatering can lead to crop diseases. Controlling the pH level, temperature, relative humidity, and light irradiation around a plant are crucial factors.



Figure 2.1 Traditional Agriculture [13]

2.3 Hydroponic System

Hydroponics is a subset of hydroculture, which involves cultivating plants in a soilfree medium or an aquatic environment. Hydroponics derives from the Greek words hydro', which means water, and ponos', which means labour, translates as water labour. Professor William Gericke invented the term hydroponics in the early 1930s to describe the cultivation of plants with their roots suspended in water containing mineral nutrients [3]. Mineral nutrient solutions are used in hydroponic gardening to feed plants in water rather than soil [10].

Plants are grown in a nutrient solution instead of soil in hydroponic gardening. The benefit of hydroponics is that it may avoid many problems associated with soil-grown plants, such as cutworms and soil-borne diseases, which can destroy the crop. The user also has better control over the nutrients that their plants consume. To ensure optimum growth, it is easier Agriculture, like manufacturing, should use technological improvements to provide new answers to recurring difficulties. The evolution has been more visible, with the novel development of vertical agricultural structures attracting support from various global regions, all of which are moving forward with vertical farming projects [14]. Hydroponic technology produces crops efficiently in areas which cannot grow plants healthily. Hydroponics is extraordinarily productive and well-suited to automation. Hydroponics can be a domestic hobby. Simple hydroponic systems can assist people in growing herbs, flowers, or vegetables in their house area. In the future, hydroponics may be the only option

to cultivate food crops and medicinal plants to maintain the planet. As a result, hydroponics is the future of farming technology [15].

There are various hydroponic cultivation methods. The structure of each method determines the difference. Some of the systems utilization by hydroponic farms worldwide are Nutrient Film Technique (NFT) systems, Ebb and Drain systems, Drip systems, Deep Flow Technique (DFT) systems, and the Floating Raft systems.



Figure 2.2 Hydroponic System [3]
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2.3.1 Nutrient film technique (NFT) systems

Plants are cultivated in gullies in the NFT system, where nutrient solution is pumped throughout the reservoir. The thin film of fertiliser solution keeps the plant roots wet. The bottom of the roots should ideally be exposed to the nutritional solution. It functions similarly to a stream that provides dissolved nutrients to the line. This technique uses a pump to provide nutrients to the plants on a continuous basis, eliminating the need for a timer. Dr. Allan Cooper of the Glasshouse Crops Research Institute in Littlehampton, England, invented the nutrient film technique in the late 1960s. This strategy can be used to cultivate plants with huge root systems that can successfully reach down into the water. The majority of NFT channels are supplied at a rate of about 1 litre per minute. Because the roots are not in a growing medium, they must be always maintained moist. The fertiliser solution is combined in a primary reservoir before being cycled through the channels and returned to the reservoir. NFT is appropriate for lettuce, green crops, tomatoes, onions, herbs, and a variety of other short-term crops. Larger NFT channels are used in various regions across the world for lengthy crops such as cucumbers and tomatoes. Another benefit of this system is that because there is no growth medium or soil, the crop grows cleanly, and thus no washing is required, allowing farmers to just have yields [15].

2.3.2 Ebb and flow/flood and drain systems

The Ebb and Flow (also known as flood and drain) technique of hydroponics involves flooding a growing area with nutrients for 5 to 10 minutes before draining the solution. A reservoir holds the nutrition combination. Ebb and Flow is often utilised in hobby systems but is rarely used in commercial production. Plant roots are typically cultivated in a substrate comprising perlite, rockwool, or larger clay pebbles in this arrangement [15].

2.3.3 Drip systems

The drip system is commonly used in spot hydroponic facilities to grow long-term crops such as cucumbers, tomatoes, peppers, onions, and so on. Nutrient solutions are delivered to plants through drip emitters. These timed emitters are set to run for around 10 minutes every hour, depending on the plant's stage of development and the amount of light available. The drip cycle flushes the growing media, providing fresh nutrients, water, and oxygen to the plants. Plants do not require soil because the system provides all they require. A timer in a drip irrigation hydroponic system feeds the nutritional solution via the base of each plant via drippers. Continuous drip systems are either recovery or non-recovery, which means that the used nutrient solution can be returned to the reservoir or run off as waste. Nonrecovery systems require less maintenance because the pH balance and nutritional strength remain constant with fresh solution provided, but recovery systems are more cost effective because they use the nutrient solution more effectively [15].

2.3.4 Deep flow technique (DFT) systems

More than 2-3 cm deep nourishing solution flows through 10 cm diameter PVC pipes into which plastic net pots with plants are placed, as the name implies. The plastic pots hold planting materials, and their bottoms come into contact with the nutrient solution flowing via the pipes. Depending on the crops planted, the PVC pipes can be stacked in a single plane or in a zigzag pattern. The zigzag technique saves space but is only ideal for low-growing crops. The single plane system is appropriate for both tall and short crops. Plants are planted in plastic net pots and secured to the PVC pipe holes. The net pots been filled by using old coir dust, carbonised rice husk, or a combination of the two. The planting material from been keep falling into the nutrient solution, a thin piece of net is placed as a lining in the net pots. Instead of net pots, use small plastic cups with holes on the sides and bottom. When the recycled solution falls into the stock tank, it aerates the nutritional solution. The flow of nutritional solution, the PVC pipes must have a slope with a drop of 1 cm every 30-40 cm. As part of CEA, this system can be installed in the open area or in protected structures [15].

2.3.5 The floating raft systems

Jensen separately discovered a method for growing a number of heads of lettuce or other green plants on a floating raft of expanded plastic in Arizona in 1976. Large-scale manufacturing facilities are now widespread and popular in Japan. In the Caribbean, lettuce production has been made possible by combining this hydroponic system with cooling the nutrient solution, which prevents lettuce bolting. The floating systems employ the floatingraft or mat method, in which nutrient-rich water is floated on Styrofoam rafts with holes drilled in them. This technique is ideal for growing short-season, shallow-rooted crops like basil, lettuce, and watercress, which thrive in high moisture conditions in the root zone. This technique is also known as dynamic root floating techniques (DRFT). The major benefit of the DRFT is that it can keep the nutritional solution at a constant temperature. Because oxygen is less soluble in warm water, the DRFT is ideal for hydroponic farming in tropical and subtropical countries such as Thailand and Malaysia [15].

2.3.6 Aquaponics systems

Aquaponics is the combination of fish aquaculture and hydroponic production. Plant grow beds are fed nutrient-rich wastewater from the fish tanks. A healthy bacteria population is essential for aquaponics. Beneficial bacteria that naturally reside in soil, air, and water convert ammonia to nitrate, which plants quickly absorb. It is believed that by eating nitrate and other nutrients in an aquaponic system, plants contribute to water purification, demonstrating synergy [15].

2.3.7 Aeroponics systems

Aeroponics is a more modern and high-tech type of hydroponic cultivation. The roots of the plants are hung in the air, while nutrients and water are provided as a mist. A timer guarantees that the pump produces a new mist (water) spray every few minutes. Similarly to the nutrient film technique, it is crucial that the pump is continually operating properly, as even a momentary interruption might cause the roots to dry out. This method is often appropriate for low-leaf plants such as lettuce and spinach. Root Mist Technique (RMT) and Fog Feed Technique (FFT) are the two most often employed Aeroponic Hydroponic Techniques. NASA has paid special attention to aeroponic techniques since a mist is easier to manipulate than a liquid in a zero-gravity environment. In 1983, GTI created and commercialised the very first available on the market aeroponic apparatus. It was known as the "Genesis Machine" at the time. The Genesis device was advertised as the "Genesis rooting system."

This system's design incorporates an A-frame with boards on each side, plant plugs on each side, and a mister positioned between the boards. With plant plugs, a circular, largediameter poly vinyl chloride (PVC) pipe is installed vertically. Although it is an uncommon method of spot production, it is a unique method of cultivation [15].

2.4 Internet of Things (IoT)

The Internet of Things (IoT) believes to be one of the fundamental pillars of the fourth industrial revolution because of its innovative potential and generous benefits to society [9]. IoT is a new paradigm transforming traditional living into a high-tech lifestyle. Smart cities, smart homes, pollution management, energy savings, intelligent transportation, and innovative industries are examples of IoT transformations. We may see a significant transition with the increased participation of IoT devices and technology in our daily lives. One such IoT advancement is the concept of Smart Agriculture Systems and Appliances, which include internet-connected devices, agricultural automation systems, and dependable energy management systems [16].

Precision agriculture is a new phrase added to the agriculture field that refers to all procedures that are followed, addressed, and simulated in a tech-driven manner. This association supports agriculture by aiming to enhance and improve agricultural processes to provide optimum output with reliable, fast, and distributed dimensions, thereby providing growers with a clear picture of the ongoing scenarios in the cultivation stretches. The incorporation of the internet has begun to modernise this industry by connecting devices, now known as the Internet of Things. The Internet of Things, coined in 1999 by a British futurist named "Kevin Ashton," is a network of interconnected devices [17]. Wireless Sensor Networks (WSN), Radiofrequency Identification (RFD), Near Field Communication (NFC), Long Term Evolution (LTE), and other devices and communication technologies connect the devices to the internet. This association supports agriculture by aiming to enhance and improve agricultural processes to provide optimum output with reliable, fast, and distributed dimensions, thereby providing growers with a clear picture of the ongoing scenarios in the cultivation technologies connect the devices to the internet. This association supports agriculture by aiming to enhance and improve agricultural processes to provide optimum output with reliable, fast, and distributed dimensions, thereby providing growers with a clear picture of the ongoing scenarios in the cultivation stretches.

This approach uses to cut down on energy use. These are just a few examples of climate monitoring, data analytics, early disease diagnosis, crop counting, smart irrigation, and other significant sectors where IoT can make an indelible mark. A communication channel between farmers, fields, and professionals can build with the spread of a network of devices [18].



Figure 2.3 Summary of Internet of Things (IoT) [10]

2.5 pH Level

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Chemical properties, such as pH level, are crucial for the optimal growth of soilless plants. The pH plays a crucial role in nutritional availability and absorption. The pH of growing plants is affected by the chemical composition of plant particles, the ratio of plant components, and irrigation and fertilization procedures. The recommended pH level for soilless plants varies by crop type [19]. The acceptable pH range for the medium was between 5.5 and 6.5 [15].

2.6 Temperature

Although the light-dependent reactions of photosynthesis are unaffected by temperature fluctuations, the light-independent reactions are affected by temperature. They are enzyme-catalysed reactions [20], as enzyme temperatures approach their optimal range, the total rate increases. It roughly doubles for each ten $^{\circ}$ C increase in temperature. Temperature significantly impacts the vegetative and photosynthetic activities of plants, as enzymes are denatured above the optimum temperature, causing the pace to decline until it ceases. It influences plant growth by raising or reducing the rates of many plant processes, including photosynthesis, respiration, and transpiration. For most vegetables grown in greenhouses, maximum activity reaches between 21 and 27 $^{\circ}$ C [21].

Aside from light, air temperature is the most critical environmental factor impacting vegetative growth, cluster development, fruit set, fruit development, fruit ripening, and fruit quality in greenhouses. The average 24-hour temperature determines the crop's growth rate—the higher the average air temperature, the faster the growth. It believes that the more significant the difference in air temperature between day and night, the higher the plant and the smaller the leaf size. Although maximum growth is known to occur at roughly 25°C day and night temperatures, maximum fruit yield is generally obtained at 18° C night and 20° C day temperatures. Most plants respond to the day temperatures and night temperatures within 24 hours. Internode length, plant height, leaf orientation, shoot orientation, chlorophyll content, lateral branching, and petiole and flower stalk elongation are all influenced by the difference between day and night temperatures. [15].

2.7 Relative Humidity

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The control of relative humidity inside the greenhouse is crucial since it affects plant quality. The average relative humidity (RH) for most crops is 60-75%. The most dangerous high humidity in closed greenhouses arises a few hours after sunrise since solar radiation transferred into the interior accelerates crop evaporation. High humidity levels resulted in a higher photosynthetic rate, which increases growth and photosynthesis. High humidity increased total cucumber production but did not affect early yield (primary stem fruit), fresh and dry weight, stem length, or leaf area. Ultimately, total cucumber yield connects to daytime humidity. Average plant growth occurs at relative humidity levels ranging from 25 to 80%, and growth is proportional to relative humidity. However, excessive relative humidity can damage plants since most pathogenic spores grow at a high relative humidity [15].

CHAPTER 3 METHODOLOGY

3.1 Introduction

The Autonomous IoT Hydroponic System consists of two types of sensors. The sensors used are pH sensor (sensor 1) and Digital Humidity Temperature (DHT) 11 (sensor 2). Sensor 1 is an analog input, and it is connected to SPDT Relay with sensor 2. Sensor 1, sensor 2 and SPDT Relay are connected through WiFi module ESP32. This project consists of two WiFi module ESP32 which is the first acted as Master Node. The other ESP32 is a receiver module that receives data from the first module. After that, the data send to the IoT platform and LCD.

3.2 Methodology

3.2.1 Block diagram of the study

The first block diagram represents the first stage of the study as shown in Figure 3.1. The inputs are pH level sensor and Digital Humidity Temperature. The Wi-Fi module ESP32 is used as general-purpose microcontroller to receive and transmit data between input and output. The output is master node.



Figure 3.1 First Stage Block Diagram

The second block diagram represents the second stage of the study as shown in Figure 3.2. The input is from ESP32 (1). The WiFi module ESP32 (2) is used a microcontroller to receive and transmit data between input and output. The outputs are IoT platform (Cayenne) and LCD screen.



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3.2.2

This project has two stages. First stage is for Sensor 1 and 2 with SPDT relay. Second stage is for data input that get from stage 1 and go to IoT platform.

First stage as shown in Figure 3.3, the system will collect data of temperature and humidity. After that, it will check pH sensor. If the system receives pH value < 5, the system will turn on the relay. Hence, it will turn on the pump at the same time, fertilizer A&B will flow into the tank. Otherwise, the system will continue to check the desired pH sensor. After turning on the relay, the system will delay for 10 seconds. Then, the system will check again whether the pH value >5. If the pH value > 5, it will turn off the relay and send the pH, temperature, and humidity to the Master Node. If the pH value < 5, the system will continue running.



Figure 3.3 Reading of pH and SPDT Relay Process Flow

The second stage as shown in Figure 3.4, the system will connect to internet. Then, there is condition whether system receive the input data from ESP32 (1). If the conditions do not meet, the system will continue to reconnect to the internet until the conditions are met. After done, it will attempt into connect to Middleware platform. The system will go to next level, which will ask if the connection succeed, when succeed the display result will be on IoT dashboard.





Figure 3.4 Receiving Input and ESPNOW Process Flow

3.3 Experimental Setup

There are several hardware and software that consists in this project: Hardware:

- i. Analogue pH sensor
- ii. Digital Humidity Temperature (DHT) 11 sensor
- iii. WiFi module ESP32
- iv. LCD screen

Software:

- i. IoT platform: Cayenne
- ii. Add setting up library for each sensor on Arduino IDE



The sensor considerably enhances precision and user experience as an updated version of the prior version. The integrated voltage regulator chip can handle a wide voltage range of 3.3 to 5.5 volts. The hardware-filtered output signal has a low jitter. It may rapidly construct a pH meter using this pH sensor to test the pH value of various aqueous solutions.

Sensor	Analog Water pH sensor
Operating Voltage	5V
Module Size	43mm x 32mm
Measuring Range	0-14PH
Measuring Temperature	0-60C
Accuracy	± 0.1 pH
Response Time:	$\leq 1 \min$
Interface	PH2.0 (3-foot patch)
Cable Length	660mm
F	

Table 3.1 Specification Analogue pH sensor

Table 3.2 pH Electrodes Characteristics

FIGHADIN	Table 3.2 pH Electro	odes Characteristics	
VOLTAGE (mV)	pH value	VOLTAGE (mV)	pH value
414.12	- 0.00	-414.12	14.00
354.96	1.00	-354.96	13.00
295.80	2.00 NIKAL	-295.80	LAKA 12.00
236.64	3.00	-236.64	11.00
177.48	4.00	-177.48	10.00
118.32	5.00	-118.32	9.00
59.16	6.00	-59.16	8.00
0.00	7.00	0.00	7.00



3.3.1.2 Digital Humidity Temperature (DHT) 11

6

The DHT11 is an essential digital temperature and humidity sensor with a low-price tag. It measures the ambient air with a capacitive humidity sensor and a thermistor and outputs a digital signal on the data pin (no analogue input pins needed). It is simple to use, but data collection necessitates proper scheduling. The only major disadvantage of this sensor is that the user can only collect new data from it once every 2 seconds, so sensor values can be up to 2 seconds outdated when using our library. The disadvantage does not apply in this study since the system will have a delay every 10 seconds.

Item	Measurement Range	Humidity Accuracy	Temperature Accuracy	Resolution	Package
DHT11	20-90%RH 0-50 ℃	±5%RH	±2°C	1	4 Pin Single Row

Table 3.3 Technical Specification DHT11

Parameters	Conditions	Minimum	Typical	Maximum
		Humidity		
Decolution		1%RH	1%RH	1%RH
Kesolution			8 Bit	
Repeatability			$\pm 1\% RH$	
	25°C		±4%RH	
Accuracy	0-50°C			±5%RH
Interchangeability		Fully Inte	erchangeable	
	0°C	30%RH		90%RH
Measurement Range	25°C	20%RH		90%RH
Runge	ALAY 50°C	20%RH		80%RH
Response Time (Seconds)	1/e(63%)25°C , 1m/s Air	6 S	10 S	15 S
Hysteresis			±1%RH	
Long-Term Stability	Typical		±1%RH/year	
Temperature	ا مارسیا ہ	1:5:	Sur and	
	0	*1°C	9. 1°C	1°C
Kesolution	ERSITI TEK	NIKA 8 BitALA	YSIA 8 Bit LAK	A 8 Bit
Repeatability			±1°C	
Accuracy		±1°C		±2°C
Measurement Range		0°C		50°C
Response Time (Seconds)	1/e(63%)	6 S		30 S

Table 3.4 Detail Specification DHT11



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Wi-Fi module ESP32 is a development board. The ESP32 comes with several new capabilities. The most important feature is Wi-Fi and Bluetooth wireless capabilities and a dual-core processor.

As shown in Figure 3.8, The ESP32 can connect to different networks when configured as a Wi-Fi station (like your router). In this case, the router assigns the user's ESP board a unique IP address. By referring to the ESP's unique IP address, the user can communicate with the ESP using other devices (stations) that connect to the same network.

The user uses the ESP32 board to request information from the internet, such as data from APIs (for example, weather data), publish data to online platforms, use icons and images from the internet, or include JavaScript libraries to build web server pages because the router connects to the internet.



As shown in Figure 3.9, the user can connect to their ESP32 board using any device with Wi-Fi capability without having to connect to their network if the user sets it up as an access point. When the user configures the ESP32 as an access point, it creates its Wi-Fi network to which adjacent Wi-Fi devices (stations), such as the user's smartphone or computer, can connect. The user does not need to link to a router to control it. The ESP32 is a soft-AP since it does not connect to a wired network like the router (soft Access Point). This means that the user will not be able to load libraries or use firmware via the internet. It also does not work if the user makes HTTP calls to internet services to post sensor readings to the cloud or use internet services (like sending an email, for example). It is also useful if the user wants multiple ESP32 devices to communicate with each other without the usage of a router.



A flat-panel display or other electronically controlled optical device that makes use of polarizers, and the light-modulating capabilities of liquid crystals is known as a liquidcrystal display (LCD). Liquid crystals don't directly emit light, instead creating colour or monochromatic pictures with a backlight or reflector. There are LCDs that can show random images (like on a general-purpose computer display) or fixed displays with little information that can be seen or hidden. Examples of gadgets using these displays include preset words, digits, and seven-segment displays, such as those seen in digital clocks. They both make use of the same fundamental technology, although some displays have larger components, whereas others employ a grid of tiny pixels to create random images. Depending on the polarizer configuration, LCDs can be switched between being normally on (positive) and off (negative). A character negative LCD will have a black backdrop with letters that are the same colour as the backlight, while a character positive LCD will have black writing on a background that is the opposite of the colour of the illumination. To give white on blue LCDs their distinctive appearance, optical filters are incorporated.



Figure 3.10 I2C 16X2 LCD screen

IoT Implementation 3.3.2

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a) Cayenne platform

Cayenne has developed an IoT platform is ideal for any IoT project. The platform was created to help with the internet integration of data from sensors. Data collection and storage from IoT devices has become a lot easier. 🗧 🔶 C 🔒 accounts.mydevices.com/auth/realms/tayeme/protocol/openid-connect/auth?response_type=code8scope=email+profiles/dient_td=cayenne-web-app8states/NiouTeb... 🗣 🕑 🖈 🍺

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Log In	Cayenne myDevices
Email	Log In Email
dzakidziauddinsbdn@gmail.com Password	dzakidziauddinsbdn@gmail.com Password
Remember me Forgot Password?	Remember me Forgot Password?

Figure 3.11 Cayenne Platform

3.4 Schematic Circuit

The sender schematic diagram for all the components connection is shown in the Figure 4.1. ESP32 has both analog and digital inputs. The pH pin is connected to pin A35 on ESP32. The digital input of DHT11 is connected to pin D4 on ESP32. The SPDT relay is connected to pin D26 on the ESP32. All the input voltage (Vin) of DHT11, analog pH and SPDT relay are connected to the input voltage pin (Vin) on ESP32. All the ground pins for all components are connected to ground pins on ESP32.



Tuelle sie Tim Connection Sende	Table	3.5	Pin	Connection	Sender
---------------------------------	-------	-----	-----	------------	--------

ESP32 PIN	PH Sensor	DHT11
5V	VIN	VIN
GND	GND	GND
35	SIGNAL	-
4	-	SIGNAL

The receiver schematic diagram for all the components connection is shown in the Figure 4.2. The ground of LCD is connected to pin ground on ESP32. The input voltage connected to ESP32 (Vin). The input is connected to pin D22 on ESP32 and lastly connected to pin RX0 on ESP32.



3.5 Summary

The Autonomous Wireless Hydroponic System consists of two types of sensors. The sensors used are pH sensor (sensor 1) and Digital Humidity Temperature (sensor 2). This project has two output displays : Cayenne and LCD screen.

The first flowchart represents the beginning process of this project. This project used two sensors to read readings to turn ON the SPDT relay. The function of SPDT relay allows the motor to pump in the fertilizers A & B. The fertilizers will keep neutral pH level in order to prevent the plants from dying. If the pH level reach the desired pH level for the plants, the SPDT relay will turn OFF the motor and it will send all the reading such as pH level, Humidity and Temperature.

Next, all the readings that have been recieved will be collected. The other microcontroller will get all the readings from the master node. All the readings are collected using ESPNOW. The function of ESPNOW is connectionless communication between one ESP to another ESP.

Lastly, there will be a manual button for the SPD relay that will be displayed on IoT platform (cayenne). It will help user to turn ON or turn OFF the SPDT relay. Then, it will return to start to read back the pH level and continue looping the process.

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CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents to preview the result and provide discussion from the data collection while undergoing the project process. This includes testing and analysis to measure the accuracy and preciseness of the data. This chapter is to ensure that all objectives of the project are fulfilled

4.2 Complete Circuit Setup

Complete circuit setup of the sender autonomous hydroponic system is shown in Figure 4.3. All the sensors which is pH level sensor, SPDT relay and DHT11 are connected to ESP32 in order to connected to reciever ESP32 and send the data by using ESPNOW. Then, it been ordered to interface with cayenne application.



Figure 4.1 Complete hardware circuit of Sender

Complete circuit setup of the receiver autonomous hydroponic system is shown in Figure 4.4. The 1602 LCD screen are using I2c to helps the connection more easily. The ESP32 reciever will produce both output either from LCD screen or Iot platfrom (cayenne).



Figure 4.2 Complete hardware circuit of Receiver

4.3 Cayenne Application Interface

Figure 4.3 until 4.8 show the process of producing cayenne's output. Cayenne will read all the readings that have been sent from sender code. As shown in COM 4 (Figure 4.3), is a sender that has successfully delivered. The delivery shows that the data has successfully sent to the receiver. Receiver is COM3 (Figure 4.4). COM3 will produce output as shown in the flowchart which it displays on the LCD screen and cayenne platform.

The other 3 figures show the other readings. The figures show that the cayenne can read actual readings. This process shows when pH changed its values, and all the other readings can be read with its actual values. There is no error in getting actual values.

All these results came out from the transmitter's readings, and it showed on the serial monitor COM 4 (Figure 4.6) as a sender and COM 3 (Figure 4.7) as a receiver that also display on the LCD screen



Figure 4.4 COM3 Receiver Serial Monitor



Figure 4.5 Cayenne platform showing the reading of all sensors

COM4 -	
and the second s	
Humidity: 52.00% Temperature: 27.10Sent with success	
Last Packet Send Status: Delivery Success	
[readPH] phValue 5.24	
pH:5.2357	
Humidity: 53.00% Temperature: 27.10Sent with success	
Last Packet Send Status: Delivery Success	
[readPH] phValue 5.28	
pH:5.2776	
Humidity: 53.00% Temperature: 27.10Sent with success	
Last Packet, Send Status; SITI TEKNIKAL MALAYSIA MELAKA	
[readPH] nhValue 5 29	
nH+5 2028	
ph.3.2520	
Autoscroll Show timestamp Newline v 115200 baud v	Ck

4.6 Comparison COM4 Sender Serial Monitor

💿 СОМЗ			_		\times
					Send
Humidity: 53.00					
Temperature: 27.10					
phValue: 5.28					
Humidity: 53.00					
Temperature: 27.10					
phValue: 5.26					
Humidity: 53.00					
Temperature: 27.10					
phValue: 5.30					
Humidity: 52.00					
Temperature: 27.10					
Autoscroll 🗌 Show timestamp	nandi Hilandi yan mbada mbara	Newline ~ 1	15200 baud $$	Clea	ir output
4.7 Comparison C	COM3 Receiver	Serial Monitor			
← → C i cayenne.mydevrces.com/cayenne/dashboard/devrce/3/b/2/00-/319-11ed-b193-	-d9789b2at62b		P 7	1 P /	* U 🕲
Cayenne + Create new project			Create Apr	Communit	ද්ද v Docs Us

Figure 4.8 Comparison of Cayenne platform showing the reading of all sensors.

Device 7f8a 🛛 👩

AKA

Commercialize your IoT solution using your own brand. Learn m

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Overview Date

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4.4 Collected Data

This is a collected data for 1 hour. As stated, pH value for a plant is between 5-7. From the Figure 4.9, it shows that the pH value readings are stable for the project to be developed. If the pH value keeps reducing, SPDT relay will be turned ON and motor will pump fertilizer A and B to neutralize the pH value. This can be seen in the graphs (Figure 4.14 until Figure 4.16).

In Figure 4.12, it can be seen the pH value has a sudden drop from suitable temperature which is 7.20 to 5.26. Hence, it is expected that SPDT relay is turned ON and fertilizers A and B neutralized the pH value, and it will stop when the pH value has been back to neutral. The system will keep on running until pH value is unnaturalized or the system is forced to stop.



Figure 4.9 pH level reading in 1 hour



Figure 4.10 Humidity level reading in 1 hour



Figure 4.11 Temperature level reading in 1 hour



Figure 4.12 Comparison pH level reading



Figure 4.13 Comparison Humidity level reading



Figure 4.14 Comparison Temperature level reading

4.6 Data Analysis

All the data have been analyzed throughout the finalized system. Then, there are a few analyses that have been made. This analysis data to analyze the best performance of the proposed system. Besides, the data and analysis are taken from using components that have been used, which compares the actual reading on theory and the measurement taken.

pH level	SPDT Relay
4.0	ON
4.5	ON
5.0.YS/4	OFF
5.5	OFF
6.0 Kp	OFF
6.5	OFF
7.0	OFF
7.5	OFF
ئىكل مايسى.8مالاك	او يوPF سيتي تيڪ

Table 4.1 Reading of pH level and SPDT relay

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4.7 Summary

From the result obtained, the pH level sensor can read from the water solution. In conclude, the best pH level for plant in hydroponic system is between 5.00 to 6.00. It is functioned to use this pH sensor so the relay will turn on the pump to flow the fertilization A and B.

This chapter provides a summary of the development of an autonomous hydroponic system. The data of pH value (sensor 1) and DHT11 (sensor 2) have been taken when the system is running. When sensor 1 met certain condition that has been decided —below pH 5.00 — hence, the SPDT relay will turn ON. Thus, the summaries of this project are as elaborated.

There are few problems while doing the project during FYP 1 and 2 as example, the understanding on connectionless communication using ESPNOW. After doing some reading on few journals on the project, EPSNOW is being used on ESP8266. ESP8266 and ESP32 that I'm using are the same thing which is Wi-Fi module. ESP32 is a new thing, and it has another function which is Bluetooth. The codes for ESP8266 and ESP32 are different, and the libraries are different too.

On the other side, for the hardware development. There is an error reading on pH level value during the early stage of hardware development. There is a minimum error value on pH level that can be ignored since the value is small.

After that, to combine between hardware and software to make it a whole system was hard. It took a plenty of time in order for it to function as a whole system. After doing a lot of reading and research on the hardware. The problem has been solved.



CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

In this chapter, it will explain about the conclusion and recommendation about the project. This chapter also concluded about what the project have been done and followed by a recommendation on how to improved the performance of the Hydroponic system based on the desired result.

5.2 Conclusion

MALAYS

At the end of project, the objective of the Autonomous IoT Hydroponic System was achieved. Both hardware and software were implemented succesfully to achieve the functionality that was expected. This project is combination between the Arduino IDE software, Fritzing for the Hardware Circuit design and prototype. The Autonomous Hydroponic System with Arduino Technology might bring more advantage to little farmer or some people that have limited spaces and places to plant some organic plant. With this project, it can manage the time consuming for monitoring and watering the plant and can improve the accuracy of pH level and will produce more healthier plant.

This project is developed for the functioning system of An Autonomous Hydroponic System.

5.3 Future Works

Some recommendations so the project can be upgraded in the future is to be able to save data in the data logger using Microsoft Excel in a (.xlsl) format. When users use the monitoring gadget, the data logger will allow the user to observe the system in their daily data. Aside from that, it may also be improved by incorporating an alarm system which notifies the user about when the level of water or pH below the minimum or the hydroponic system is not working as desired.

After that, adding more sensors such as electrical conductivity to monitor the available nutrients reading for the plant. The higher the electrical conductivity value, the more nutrients that available for a plant. Other than that, light sensor such as red, green and blue (RGB) light sensor can be added to measure the light intensity. The light intensity needs to be measured since the amount of light that receives by the crop could be affect the growth of a plant.

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APPENDICES

APPENDIX A

Coding for Sender

```
SENDER CODE
//ESPNOW
#include <esp now.h>
#include <WiFi.h>
uint8 t broadcastAddress[] = {0x40, 0x22, 0xD8, 0xF0, 0x93, 0xC4};
                         AALAYSIA
// Structure example to send data
// Must match the receiver structure
typedef struct struct message {
 float a;
 float b;
  float c;
} struct message;
// Create a struct message called myData TEKNIKAL MALAYSIA MELAKA
struct message myData;
esp now peer info t peerInfo;
// callback when data is sent
void OnDataSent(const uint8 t *mac addr, esp now send status t status) {
  Serial.print("\r\nLast Packet Send Status:\t");
 Serial.println(status == ESP NOW SEND SUCCESS ? "Delivery Success" : "Delivery Fail");
}
// PH Meter
#include "DFRobot ESP PH.h"
#include "EEPROM.h"
```

APPENDIX B

Coding for reciever

```
RECEIVE_CODE
#include <esp now.h>
#include <WiFi.h>
#include <Arduino JSON.h>
// Structure example to receive data
// Must match the sender structure
typedef struct struct message {
   float a;
   float b;
   float c;
} struct message;
JSONVar board;
// Create a struct message called myData
struct message myData;
                 UNIVERSITI TEKNIKAL MALAYSIA MELAKA
// callback function that will be executed when data is received
void OnDataRecv(const uint8 t * mac, const uint8 t *incomingData, int len) {
 memcpy(&myData, incomingData, sizeof(myData));
 board["a"] = myData.a;
 board["b"] = myData.b;
 board["c"] = myData.c;
  String jsonString = JSON.stringify(board);
  Serial.print("phValue: ");
  Serial.println(myData.a);
  Serial.print("Humidity: ");
  Serial.println(myData.b);
```

```
RECEIVE CODE
  Serial.println(myData.a);
  Serial.print("Humidity: ");
  Serial.println(myData.b);
  Serial.print("Temperature: ");
  Serial.println(myData.c);
  Serial.println();
}
//#define CAYENNE DEBUG
#define CAYENNE PRINT Serial
#include <CayenneMQTTESP32.h> _____
// WiFi network info.
char ssid[] = "CatDad";
char wifiPassword[] = "980726Widad";
// Cayenne authentication info. This should be obtained from the Cayenne Dashboard.
char username[] = "06b6bfd0-7319-11ed-b193-d9789b2af62b";
char password[] = "e473545ffce84c5348b4aeb8e05a390100500127";
char clientID[] = "37b72700-7319-11ed-b193-d9789b2af62b";
#include <LiquidCrystal I2C.h>
// set the LCD number of columns and rows
int lcdColumns = 16;
int lcdRows = 2;
// set LCD address, number of columns and rows
// if you don't know your display address, run an I2C scanner sketch
LiquidCrystal I2C lcd(0x27, lcdColumns, lcdRows);
```

PIN	PIN NAME	PIN TYPE	PIN DESCRIPTION
NUMBER			
1	PIN 1	Source	Ground pin of LCD
2	PIN 2	Source	Supply voltage of LCD
3	PIN 3	Control	Adjust Contrast Voltage
4	PIN 4	Control	Toggle between Command/Data
5	PIN 5	Control	Toggles LCD between read/write operation
6 _	NIVERSITI		Held High to perform read/write operation
7	PIN 7-14	Data/Command	Pins used to send command or data to LCD
8	PIN 15	Led	Normal LED like operation to illuminate the LCD
9	PIN 16	Led	Normal LED like operation to illuminate the LCD connected to ground