Faculty of Electrical and Electronic Engineering Technology

DEVELOPMENT OF AUTONOMOUS IOT HYDROPONIC SYSTEM

DZAKI DZIAUDDIN BIN SABARUDDIN

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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 nutrient-rich 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.

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 soil-free 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]

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 floating-raft 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, large-diameter 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].