Faculty of Electronics & Computer Technology and Engineering

DEVELOPMENT OF AUTOMATED AQUAPONICS SYSTEM BASED ON IOT AND SOLAR

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

MUHAMMAD LUTFI IQMAL BIN MD ROSLAN

Bachelor of Electronics Engineering Technology (Telecommunications) with Honours

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DEVELOPMENT OF AUTOMATED AQUAPONICS SYSTEM BASED ON IOT AND SOLAR

MUHAMMAD LUTFI IQMAL BIN MD ROSLAN

A project report submitted
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	TIDAK TERHAD	

Disahkan oleh:

Lutfi

DR. ADAM WONG YOON KHANG
Pensyarah Kanan
Jabatan Teknologi Kejuruteraan Elektronik dan Komputer
Fakulti Teknologi Kejuruteraan Elektrik & Elektronik
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Student Name : Muhammad Lutfi Iqmal Bin Md Roslan

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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 Electronics Engineering Technology (Telecommunications) with Honours.

Signature :

Supervisor Name : Ts. Dr. Adam Wong Yoon Khang

Date : 19 Jan 2024

Signature :

Co-Supervisor Name (if any) :

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DEDICATION

I dedicate this final year project report to my family, whose unwavering support, love, and encouragement has been the cornerstone of my journey. Their belief in my abilities and the sacrifices they made was the driving force behind my determination to succeed. In addition, I express my heartfelt thanks to my project manager Ts. Dr. Adam Wong Yoon Khang for his invaluable guidance, patience, and expertise, which not only shaped this project but also contributed to my personal and academic growth. I also thank my friends and classmates for the camaraderie, cooperation and shared experiences that have been an integral part of overcoming challenges and celebrating shared achievements. Finally, this report is dedicated to all the people who have inspired me and reminds me of the importance of persistence and passion. Their collective support has helped us reach this milestone and I am truly grateful for their contributions.

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ABSTRACT

The increasing demand for sustainable agriculture and growing concerns about food security have sparked the development of an automated aquaponics system that merges IoT and solar technologies. Present-day agricultural practices grapple with challenges related to sustainability, resource management, and food security, characterized by excessive water usage, heavy reliance on chemicals, and susceptibility to environmental risks. This project seamlessly integrates hardware components, such as sensors, pumps, and valves, with software systems capable of real-time data collection, analysis, and prompt responses. The utilization of IoT technology enables remote monitoring and control, while the integration of solar power diminishes dependence on the grid, promoting sustainability. Employing ESP32 microcontrollers with Wi-Fi connectivity, the system gathers data from various sensors like pH, TDS, ultrasonic, soil moisture, and DHT11, transmitting it to a cloud- based platform for comprehensive analysis and decision-making. Continuous monitoring yields real-time insights, resulting in enhanced yields, healthier produce, and improved fish production. With its user-friendly design, adaptability to local conditions, and integration with the Blynk platform, the system becomes accessible to small-scale farmers, offering a promising solution to advance sustainable agriculture and strengthen food security.

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ABSTRAK

Permintaan yang semakin meningkat untuk pertanian mampan dan kebimbangan yang semakin meningkat tentang keselamatan makanan telah mencetuskan pembangunan sistem akuaponik automatik yang menggabungkan teknologi IoT dan solar. Amalan pertanian masa kini bergelut dengan cabaran yang berkaitan dengan kemampanan, pengurusan sumber dan keselamatan makanan, yang dicirikan oleh penggunaan air yang berlebihan, pergantungan berat pada bahan kimia dan terdedah kepada risiko alam sekitar. Projek ini menyepadukan dengan lancar komponen perkakasan, seperti penderia, pam dan injap, dengan sistem perisian yang mampu mengumpul data masa nyata, analisis dan respons segera. Penggunaan teknologi IoT membolehkan pemantauan dan kawalan jauh, manakala penyepaduan tenaga suria mengurangkan pergantungan pada grid, menggalakkan kemampanan. Menggunakan mikropengawal ESP32 dengan sambungan Wi-Fi, sistem mengumpul data daripada pelbagai penderia seperti pH, TDS, ultrasonik, kelembapan tanah dan DHT11, menghantarnya ke platform berasaskan awan untuk analisis komprehensif dan membuat keputusan. Pemantauan berterusan menghasilkan cerapan masa nyata, menghasilkan hasil yang dipertingkatkan, hasil yang lebih sihat dan pengeluaran ikan yang lebih baik. Dengan reka bentuk yang mesra pengguna, kebolehsuaian kepada keadaan tempatan, dan integrasi dengan platform Blynk, sistem ini boleh diakses oleh petani berskala kecil, menawarkan penyelesaian yang menjanjikan untuk memajukan pertanian lestari dan mengukuhkan keselamatan makanan.

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LIST OF SYMBOLS

°C	-	Degree Celsius
%	-	Percentage

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LIST OF ABBREVIATIONS

V	-	Voltage
IoT	-	Internet of Things
RAS	-	Recirculatory Aquaculture System
IAAS	-	Integrated Agri-aquaculture systems
NFT	-	Nutrient film technique
IVCS	-	Intelligent Voice Control Systems
GIFT	-	Genetically Improved Farmed Tilapia
DO	-	Dissolved oxygen
PV	-	Photovoltaic
LDR	-	Light-dependent resistor
TDS	-	Total Dissolved Solids
EC	-	Electrical Conductivity
USB	-	Universal Serial Bus
LED	-	Light Emitting Diode

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CHAPTER 1

INTRODUCTION

1.1 Background

Agriculture remains an important sector of Malaysia's economy, contributing 12 percent to the national income and was providing employment for 16 percent of the population [1]. This proves that this sector is very important and has been a major contributor to the country's opinion in the past. It not just can make money but at the same time it can also save our world from global warming. But today Malaysian more prefer live in modern life, they don't show interest in agriculture. They also don't know about the benefit of agriculture activity.

Aquaponics is a symbiotic agricultural system that combines the cultivation of fish and other aquatic creatures (aquaculture) with the cultivation of vegetables or plants (hydroponics) [2]. Plants are fed aquatic animal excrement, and in exchange, they help clean the water that is returned to the fish. Microbes play an important role in plant nutrition by converting fish waste and sediments into compounds that the plants may use to develop. This technique is developing as a major hope for long-term organic food production and a very efficient approach for addressing the issues of optimal water utilization and limited cropland. Aquaponics can be used to sustainably raise fresh fish and vegetables for a family, to feed a village or to generate profit in a commercial farming venture, year 'round, in any climate[3].

The Internet of Things (IoT) enables real-time monitoring and control of various parameters critical to aquaponics, such as water temperature, pH level, dissolved oxygen content, and nutrient levels [4]. IoT sensors collect data from these parameters and transmit it to a central control system, allowing users to remotely monitor and adjust the system as needed. Solar power serves as a sustainable energy source for the automated aquaponics system. Solar panels convert sunlight into electricity, which powers the pumps, sensors, and other electrical components. Excess solar energy can be stored in batteries for use during low light conditions or at night, ensuring continuous system operation.

Aquaponics research includes things like fish biology, plant physiology, water quality management, system design and engineering, nutrient cycling, and figuring out how to get the most out of production factors. Researchers and people who use aquaponic systems are always looking for ways to make them more efficient, productive, and profitable. They are also looking into how to use new technologies and different species. Aquaponics promise to grow food that is sustainable and good for the environment. It could help solve problems like a lack of space and water and the need for more resilient and resource-efficient farming methods. Aquaponic systems are becoming more popular and used all over the world because they can provide fresh, locally grown food all year long, regardless of temperature or location.

1.2 Aquaponics Systems for Sustainable Food Production and Climate Resilience

Addressing global warming through aquaponic systems involves implementing specific strategies and practices focused on reducing greenhouse gas emissions, conserving resources, and promoting sustainability. This can be achieved by prioritizing energy efficiency using energy efficient equipment, exploring renewable energy options, and optimizing energy consumption. In addition, efforts to reduce carbon emissions could include mitigating transportation emissions through local aquaponics systems, offsetting residual emissions through carbon offsetting initiatives. and apply water conservation techniques, such as rainwater harvesting and efficient irrigation methods. Proper nutrition management, selection of climate-resilient fish and plants, and outreach through education and awareness are also key to using aquaponics to mitigate heat. up globally. By combining these practices, aquaponic systems can contribute to sustainable food production while reducing environmental impact and promoting climate resilience.

1.3 Problem Statement

The inefficiency and environmental impact of traditional agricultural and aquaculture operations is one of the primary issues that an automated aquaponics system based on IoT, and solar technologies attempts to address. The problem statement here is that agriculture in many regions is facing two major challenges is water scarcity and limited access to electricity. These challenges can severely impact crop yields and productivity, leading to food insecurity and economic losses for farmers. Water scarcity can arise due to various reasons such as drought, overexploitation of groundwater, and inadequate storage and distribution infrastructure. Limited access to electricity can also be a significant challenge, particularly for farmers in remote or rural areas who may lack access to the power grid. This can limit the use of irrigation systems and other technologies that require electricity, leading to suboptimal growing conditions and reduced crop yields. Next, many small-scale farmers lack access to the technology and resources needed to implement advanced irrigation and aquaponics systems. The population is increasing day by day so it will be difficult for us to maintain the food balance if we follow the traditional agriculture system as time moves. Third, lack of time to cultivate. Nowadays , people always want to get rich and do many things to reach their target. Time constraints due to a tight work schedule have left many urban residents reluctant to undertake farming activities in their home areas.

1.4 Project Objective

The main aim of this project is to provide a sustainable and efficient solution for food production that optimizes resource usage, generates renewable energy, and can be remotely monitored and controlled.

Specifically, the objectives are as follows:

a) To design and build an energy-efficient and sustainable system that can be controlled and monitored remotely using the ESP32 microcontroller and powered by solar energy.
b) To program an automated aquaponics system which can be controlled and supervised by using the Internet of Things (IoT) devices connected with blynk applications.
c) To evaluate and improve the system's performance and efficiency based on data analysis.

1.5 Scope of Project

An aquaponics system works by creating a symbiotic environment where fish and plants grow together. The system comprises two main components: the fish tank and the grow bed. The fish tank houses the fish, and their waste produces ammonia, which is toxic to the fish if left untreated. However, in an aquaponics system, the wasted water is pumped into the grow bed, where beneficial bacteria convert the ammonia into nitrites and nitrates. These nitrates serve as a source of nutrients for the plants in the grow bed. The plants absorb the nutrients and use them for growth, cleaning the water as they do so. The water is then recirculated back into the fish tank, providing clean and oxygenated water for the fish. In addition, the plants help to filter the water, removing any solids or excess nutrients, preventing the build-up of harmful chemicals in the system.

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To make the system more efficient and sustainable, IoT-based sensors and controllers can be used to monitor and control environmental conditions, such as pH levels, temperature, nutrient levels, water levels and soil moisture levels. In addition, renewable energy sources such as solar power can be integrated into the system, reducing reliance on conventional energy sources. Generally, an aquaponics system provides a sustainable and efficient type of agriculture, delivering high crop and fish yields while reducing environmental effect and human needs.

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Aquaponics is a sustainable farming technique that combines aquaculture and hydroponics to produce food in a closed-loop system. However, the lack of automation in traditional aquaponic systems makes it difficult to maintain the ideal conditions required for optimal plant and fish growth. To address this problem, an automated aquaponics system based on IoT, and solar technology is proposed. This literature review explores the current state of research on automated aquaponics systems and the use of IoT and solar technology in aquaponics.

2.2 Agriculture and Aquaculture

Agriculture and aquaculture share common challenges and opportunities, and there are several areas of synergy between the two. Agricultural by-products and waste can be used as animal feed and fertilizer in aquaculture, promoting circular economy principles and waste reduction. Integrated systems, such as aquaponics, which combine aquaculture with hydroponics or soil-based agriculture, create a symbiotic relationship in which fish wastes fertilize the plants and the plants purify the water for fish [5].

The aquaculture industry has experienced significant growth and is now an important source of protein for human consumption. Demand for aquaculture products is expected to reach 62% of the world's total production by 2030 as the world's population continues to grow. In 2018, aquaculture already accounted for 46% of his total production, and current trends point to the potential for even greater increases in the coming years [6]. China remains a major player in global aquaculture production. However, the high demand for aquaculture products creates large amounts of wastewater and poses significant environmental risks. Composed of solid waste, nutrients and emerging pollutants, aquaculture wastewater poses problems such as eutrophication, chemical toxicity, and food security issues.

This paper examines supply and demand dynamics, best practices, characteristics of aquaculture wastewater, current challenges, and wastewater treatment technologies in the aquaculture industry. Figure 2.2.1 provides a simplified classification of culture systems in aquaculture. It categorizes these systems based on factors such as structure, water exchange, crop fortification, fish farming methods, and integration with other agricultural practices. The structural aspect refers to the physical environment where fish are raised, such as ponds, channels, or circulating aquaculture systems (RAS). The classification of water exchange systems is based on the amount of water used during cultivation and includes open, closed, and semi-closed systems [7].

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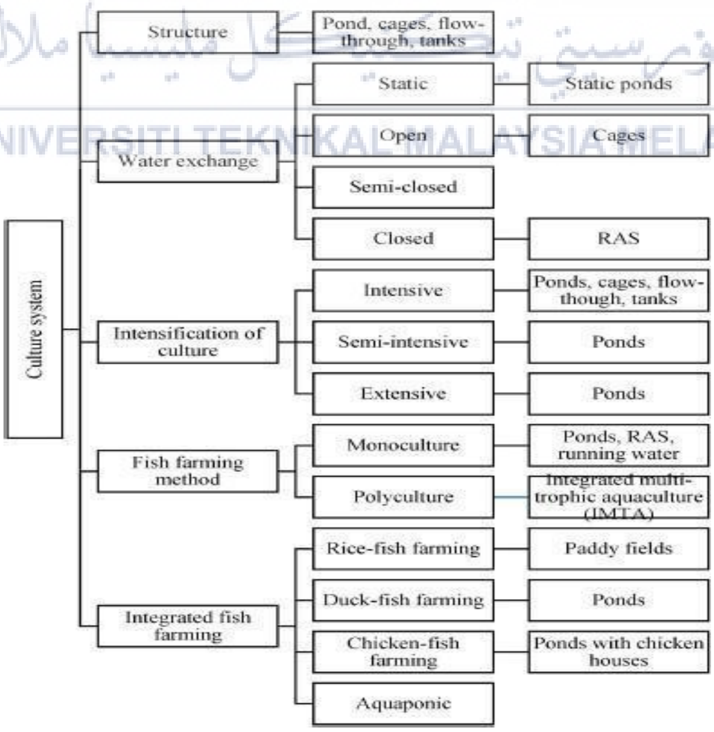

Figure 2.2.1: Types of aquacultures. Adapted from [7]

Aquaculture is widely recognized as an important agricultural activity that has the potential to address global food shortages and alleviate poverty. Proponents argue that aquaculture could provide affordable protein to millions of people in developing countries while restoring depleted fisheries. Egypt and Nigeria are two of Africa's leading aquaculture countries and employ similar production systems. In Egypt, tilapia is the dominant fish species, while in Nigeria, African catfish is preferred.

These countries have promising aquaculture industries due to the presence of freshwater bodies, institutional commitments, and high demand for fish. However, despite the progress and great potential of the aquaculture sector, both countries face various limitations, such as low penetration of the technology, insufficient supply of fry and high cost of fish feed. This paper provides insights on the aquaculture sector in Egypt and Nigeria, covering production systems, prospects, opportunities, and challenges that are hindering the growth of aquaculture in these countries[8].

Agri-aquaculture systems, also known as integrated Agri-aquaculture systems (IAAS), have been promoted to increase food production, protect the environment, and ensure food security. This paper reviews the positive interactions found in Agri-aquaculture systems, such as using animal manure as pond fertilizer, utilizing crop by-products as fish feed, using pond sediments as fertilizers for terrestrial crops, and employing aquaculture wastewater for crop irrigation [9]. However, the current experimental evidence often lacks a comprehensive understanding of the system's behavior and trade-offs among farming components. Therefore, analyzing Agri-aquaculture systems requires broader scales and can benefit from resilience theory for further studies.

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2.3 Overview of Aquaponics System

Aquaponic systems have emerged as an increasingly popular and sustainable alternative to traditional agriculture due to their efficiency in resource utilization and environmentally friendly nature. These systems integrate aquaculture, the farming of aquatic organisms, with hydroponics, a method of growing plants without soil. The key concept behind aquaponics is the symbiotic relationship between fish or other aquatic organisms and plants that is shown in figure 2.3.1.

In aquaponic systems, the wastewater generated by the aquatic organisms is rich in nutrients, which serves as a natural fertilizer for plant growth. The plants, in turn, act as a natural filter, purifying the water that is then recirculated back to the aquatic environment. This cycle creates an optimal environment for both fish and plants, leading to efficient and productive growth within a controlled setting.

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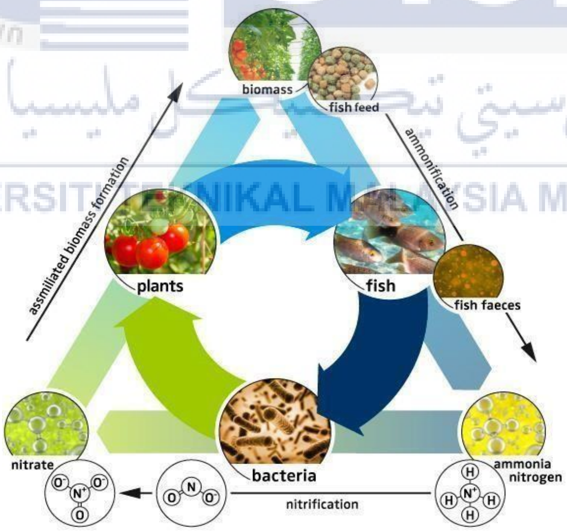

Figure 2.3.1: Symbiotic aquaponic cycle. Adapted from [10]

Aquaponics is highly regarded as one of the most effective farming methods available, as it harnesses the synergies between these two interconnected ecosystems [10].

This combination of aquaculture and hydroponics offers a holistic and self-sustaining farming system that maximizes resource utilization and minimizes environmental impact.

Aquaponics systems are designed by integrating a Recirculating Aquaculture System (RAS) with hydroponic components. The key principle is the circulation of water from the fish tank, passing through filtration units, and then being pumped into hydroponic beds for reprocessing that show in figure 2.3.2. Filtration plays a vital role in aquaponics systems and involves two main processes: mechanical filtration and biofiltration. Mechanical filtration is responsible for removing solid particles and debris from the water. This helps maintain water clarity and prevents clogging of the hydroponic components. Biofiltration, on the other hand, focuses on the conversion of harmful ammonia, produced by fish waste, into less toxic nitrates through a process called nitrification. This is achieved by utilizing beneficial bacteria that colonize the biofilter media. The biofilter serves as a habitat for these bacteria, allowing them to break down the ammonia and convert it into nitrites and then further into nitrates.

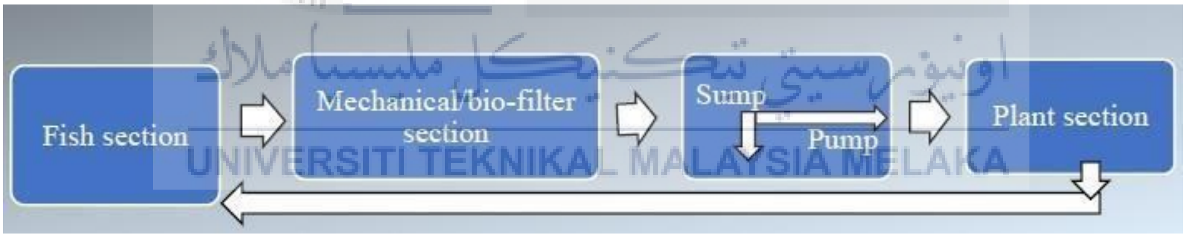

Figure 2.3.2 : Basic aquaponics system layout. Adapted from [11]

The configuration and complexity of filtration and other components in aquaponics systems can vary depending on the specific system design and scale [11]. Some systems may incorporate additional filtration steps, such as solids separators or additional biofilter units, to enhance water quality and nutrient cycling. The choice of filtration components and their arrangement is determined by factors such as the number and type of fish species, plant selection, system size, and desired production goals.

2.4 Types of Aquaponics System

Aquaponics systems typically consist of aquaculture tanks, hydroponic growth beds or troughs, and filtration components for biological and mechanical filtration. Choosing a hydroponic system model often depends on the type of hydroponic unit you are using.

The three main types are media-based beds, floating rafts, and nutrient film technique (NFT). Among these, medium-based systems are known for their efficient utilization of nitrogen due to the higher volume-to-surface area ratio of beneficial microorganisms compared to the other two types [12]. The hydroponic film technology system is characterized by the ability to increase the yield of vegetables by supplying plenty of oxygen to plant roots. Table 2.4.1 shows the explanation and benefit types of Aquaponics system.

Table 2.4.1 : Explanation and benefit types of Aquaponics system

Aquaponics System	Explanation	Benefit
Media-Based Aquaponics [12]	Plants are cultivated in grow beds or pots that are filled with a growth media, such as perlite, expanded clay pellets, or gravel.	1. Offers surface space and support for advantageous microorganisms. 2. A steady habitat for plants and fish 3. Water filtering using mechanical and biological methods
Nutrient Film Technique (NFT) [1]	Water is pumped via a trough or channel that slopes, creating a thin layer that runs over the roots of the plants.	1. Effective water resource management 2. Encourages oxygen exchange for healthy roots. 3. Appropriate for a range of plants

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Floating rafts [14]	A floating raft constructed of polystyrene, or a similar substance suspends plant roots directly in nutrient-rich water.	1. Plants are easily accessible for keeps. 2. Better nutrient absorption because of direct root-water interaction 3. Water must be constantly agitated and aerated to maintain dissolved oxygen levels and prevent stagnation.

Nutrient film technology (NFT) is known to provide high oxygen levels to plant roots but has limited suitability for macrophytes with extensive root systems. Floating raft systems overcome this challenge by providing effective removal of solid waste. Both NFT and floating raft aquaponics systems require biofilters and sedimentation tanks for nitrification and solid waste removal, respectively. Medium-filled systems use substrates such as pumice stones and clay beads as a growth bed and medium but can encounter problems such as clogging of the growth bed and insufficient oxygen levels during long-term operation.

Aquaponics structures have evolved to accommodate a wide range of scales, from small bench-top setups to village-scale systems and large commercial operations, as opposed to limited and impractical traditional models. This reflects the adaptability and versatility of aquaponics as a system. The size of an aquaponics structure is often determined by the number of fish being farmed [15]. Larger aquaponics structures tend to have higher resource costs but can also generate higher income. Food supplies are sufficient to ensure food security but may not be sufficient to generate significant income.

2.5 Advantages and Disadvantages of Aquaponics Systems

Aquaponics systems have many advantages when compared to conventional agriculture, however there are also some disadvantages to consider. The aquaponics system does not have to deal with the problems that traditional agriculture has, such as the necessity for cultivating soil, fallow land, and crop rotation. In comparison to traditional agriculture, it will save labor and remove barriers to crop rotation. Traditional soil cultivation and crop rotation need soil disinfection, which always results in crop pesticide harm.

Aquaponics systems offer environmental protection and water-saving benefits. According to a recent paper , aquaponics consumes 90% less water than traditional farming [16]. Figure 2.5.1 determines the water conservation per acre for both traditional and aquaponic systems. The traditional method of water conservation is high but for Aquaponics system water conservation is low. Overall, aquaponics contributes to environmental sustainability by conserving water resources and reducing waste, making it an eco-friendly solution for food production.

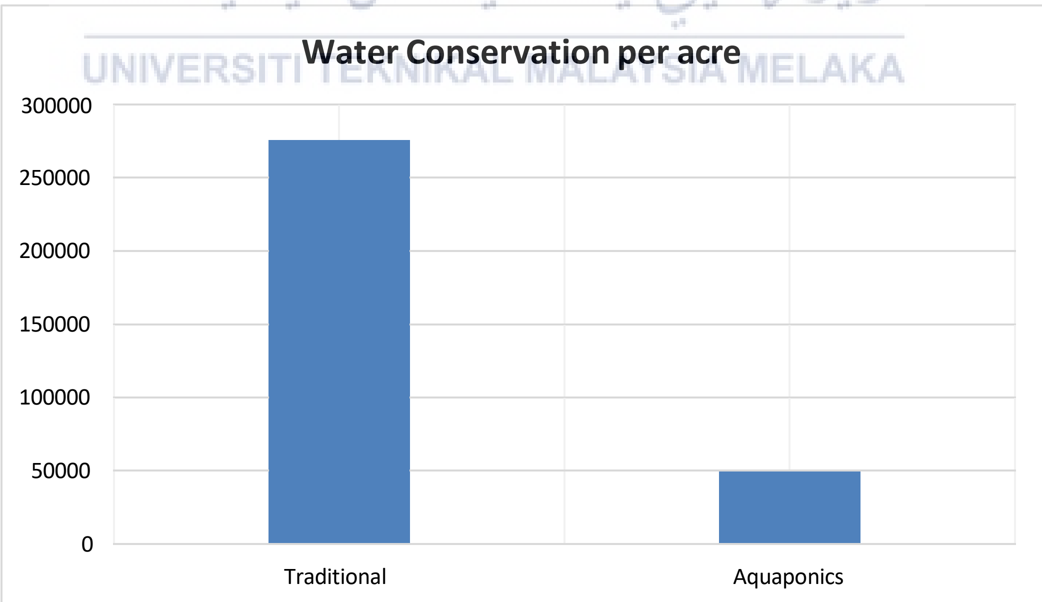

Figure 2.5.1 : Water conservation per acre. Adapted from [16]

Aquaponics systems have some disadvantages that should be considered. One significant drawback is the initial investment required to set up the system. The cost of acquiring equipment such as fish tanks, grow beds, pumps, and plumbing, as well as the necessary infrastructure like greenhouse structures or climate control systems, can be substantial. This upfront expense may deter individuals or businesses from pursuing aquaponics. However, it's important to note that the long-term savings on water and fertilizers can help offset these initial costs.

Another challenge is the technical knowledge and maintenance required to operate an aquaponics system effectively [17]. Achieving a successful balance between fish and plant health necessitates a good understanding of their biology and the symbiotic relationship between them. Monitoring water quality parameters, maintaining optimal pH levels, and managing the overall system can be complex. Additionally, regular maintenance tasks such as cleaning filters, managing fish populations, and ensuring suitable conditions for both fish and plants are crucial. Inexperienced or poorly managed systems may encounter difficulties in maintaining the health of the fish and achieving optimal plant growth.

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Despite these challenges, aquaponics systems offer numerous advantages and can be a highly efficient and sustainable method of food production. With proper planning, acquiring the necessary knowledge, and committing to regular system maintenance, the benefits of aquaponics can outweigh the disadvantages, resulting in a productive and eco-friendly agricultural system.

2.6 Analysis of Hydroponics and Aquaponics Systems

Hydroponics and aquaponics have emerged as prominent soilless cultivation techniques, garnering considerable interest in recent times. Hydroponics entails the cultivation of plants in a nutrient-rich water solution devoid of soil, while aquaponics combines hydroponics with aquaculture to establish a mutually beneficial environment for plants and fish. In hydroponics, essential nutrients are supplied through a water-soluble nutrient solution, affording growers precise control over nutrient composition. Conversely, aquaponics utilizes fish waste as a natural nutrient source for plants, with the waste being metabolized by beneficial bacteria.

Aquaponics and hydroponics were compared in terms of nutrient balance, pH levels, management challenges, and sustainability [18]. Hydroponics struggles with maintaining nutrient balance and pH, while aquaponics requires careful fish and water management. Hydroponics is efficient in water and nutrient usage but raises sustainability concerns due to synthetic inputs and energy-intensive infrastructure.

Aquaponics is considered more sustainable, integrating fish production and crop cultivation, reducing external inputs, and conserving water. Hydroponics is easy to set up and maintain, focusing on nutrient solutions and environmental control, while aquaponics is more complex, involving both plant and fish care. Hydroponics accommodates various crops, while aquaponics is better suited for leafy greens and herbs but may have limitations with specific nutrient requirements. Table 2.6.1 shows the comparison of hydroponics and aquaponics systems in several aspects.

Table 2.6.1 : Comparison of hydroponics and aquaponics systems [18]

Types	Hydroponics	Aquaponics
Source of Nutrients	Nutrient solution synthesized	Fish waste
Management of Nutrients	Control of nutrition levels is precise.	Fish health and waste conversion must be balanced.
Sustainability	Water and nutrient efficiency	It makes use of fish waste, lowers. external inputs and saves water.
Complexity of the System	Much easier to set up and handle.	Managing both plant and fish components are more difficult.
Crop Varieties	Versatile and adaptable to a wide range of crops	Mostly herbs and leafy greens

A comparative study was conducted to assess the effectiveness of aquaponics and hydroponics in lettuce cultivation. Aquaponics utilized GIFT (Genetically Improved Farmed Tilapia) fish as a nutrient source and income generator, while hydroponics relied on artificially prepared nutrient solutions [19]. Both systems employed the deep-water culture technique and were appropriately designed and maintained. Performance evaluation involved measuring and comparing various parameters between the two systems. The results indicate that aquaponics is highly efficient in terms of water, nutrients, and energy usage. This technique is particularly advantageous when micro-climatic conditions are controlled.

Figure 2.6.1 : Comparison of aquaponics and hydroponics plants [19]

2.7 Review on Existing project of Aquaponics System based IoT and Solar

IoT systems have been proposed to streamline agriculture and aquaculture, but they have limitations in communication. Some systems require farmers to be present at output devices, which can be time-consuming and inconvenient. Integrating IoT-based Aquaponics Systems and IVCS is expected to improve production efficiency, reduce manual labor, and attract investment in aquaculture. IoT models often use expensive microcontrollers, such as Raspberry Pi, despite lower-end alternatives. Lack of flexibility in sensor and actuator switching leads to power consumption [20]. Aquaponics is in its early stages, with limited available technologies, but new ones may be needed to meet evolving requirements.

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Aquaponic systems require heat, sun radiation, electricity, and other energy sources for economic and environmental sustainability. Hybrid energy systems can improve energy management. Aquaponics allows farmers to grow fish and plants simultaneously, making it a sustainable and environmentally friendly technology. However, pumps may be a challenge. Malaysia, with 12 hours of sunshine per day, offers a practical solution, with the production and growth rate of plants and fish remaining constant even with full power [21]. Aquaponics systems are particularly beneficial for rural agricultural activities without electricity. In this subtopic will discuss the prototype and equipment that will be used. The equipment must be appropriate so that the project to be developed achieves the objectives. The most important equipment in this project is NodeMCU and solar. Refer to table 2.7.6 show the aquaponics system project comparison.

IoT Based Solar Panel Monitoring and Control is an example of a project that uses NodeMCU and solar in IoT based. The proposed solar photovoltaic monitor system consists of two main sections: data acquisition and data processing [22]. In the data acquisition stage, sensors gather important information like voltage, current, temperature, humidity, and irradiance. This data is then transmitted via wired or wireless communication to the next step. Before further analysis, the data is temporarily stored in auxiliary devices like data loggers. In the data processing stage, the collected data is analyzed and prepared for presentation. At the data display and storage level, the processed data is received by a workstation, enabling the system to configure itself accordingly. The collected data can be accessed remotely via the internet from any location and at any time.

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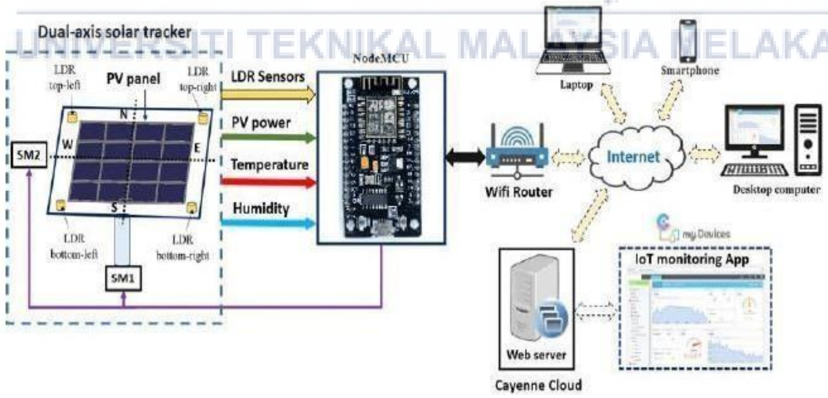

Figure 2.7.1 : Flow diagram of proposed system [22]

A review was conducted on data processing modules and transmission protocols for solar PV monitoring systems. These modules facilitate real-time data gathering, control, and management of connected devices. The collected data is transmitted using various protocols, including Wi-Fi, through the network layer. A comparison between large- and small-scale PV systems was performed, analyzing parameters, protocols, software, and monitoring platforms. Wireless protocols like ESP8266 Wi-Fi module (NodeMCU) were identified as suitable for solar PV system monitoring.

Design and construction of smart IoT-based aquaponics powered by PV cells is another example of a project that used NodeMCU and solar. The primary goal of the proposed system is to create an aquaponics monitoring system based on the Internet of Things (IoT). This system will continuously measure and present parameters such as pH level, oxygen level, and temperature to users [23]. The real-time monitoring of water quality in the aquarium tank is crucial for ensuring the optimal growth and survival of both fish and plants in the aquaponics system shows in figure 2.7.2.

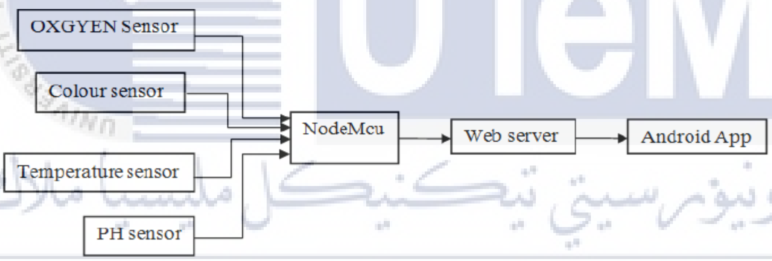

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Figure 2.7.2 : Block diagram of the proposing system.

The design includes a dissolved-oxygen (DO) sensor, which is used in aquaculture to verify that there is enough DO present. Otherwise, the fish might suffocate. A TCS2300 color sensor is used to detect the color of a test strip for Ammonia, therefore analyzing its level, which should ideally be less than 1(mg/L), a DS18B20 temperature sensor, and a pH sensor. The NodeMCU microcontroller is used to capture sensor measurements, and the data is subsequently uploaded to a database. Figure 2.7.3 depicts the NodeMCU microcontroller linked to the system sensors during design and prototype.

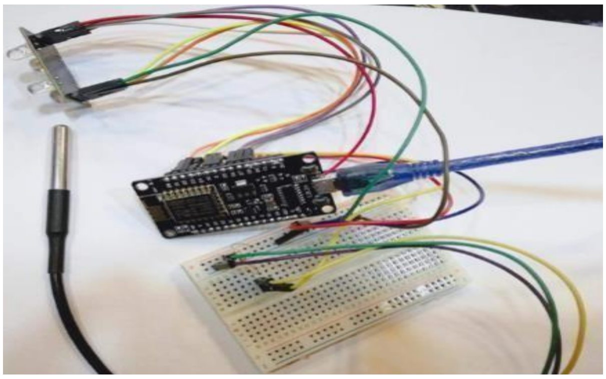

Figure 2.7.3 : The system's monitoring section [23]

A Study of IoT based Real-Time Solar Power Remote Monitoring System is another project used NodeMCU and solar panel where this project continuously monitors the status of various parameters associated with solar systems via sensors, saving time and ensuring efficient power output from PV panels while monitoring for faulty solar panels, weather conditions, and other such issues that affect solar effectiveness [24]. The proposed model of this system, shown in Figure 2.7.4, illustrates how these blocks are connected.

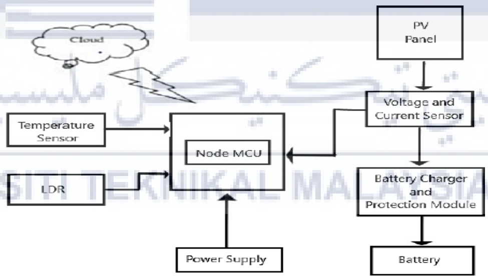

Figure 2.7.4. Proposed solar power monitoring system based on IoT [24]

The system utilizes a Node MCU microcontroller with an integrated ESP8266 Wi-Fi module to manage and handle all the data associated with the photovoltaic (PV) panel. To measure the voltage, current, and power generated by the PV panel, voltage and current sensors are used, and their readings are collected by the NodeMCU. Additionally, an environmental temperature sensor and a light-dependent resistor (LDR) are employed to measure the temperature and light intensity falling on the PV panel. These sensors are connected to the

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Node MCU and powered by a separate power supply. Acting as a central hub, the NodeMCU continuously streams real-time data, including current, voltage, power, light intensity, and temperature, while transmitting the collected sensor data to a server through the ESP8266 Wi-Fi module. Excess power from a PV panel is stored in a battery via a Battery Charger Module for future use. Sensor data is transmitted to the Thingspeak server's fields upon connection.

Intelligent Irrigation System Using IoT for Aquaponics Application one of the projects that use Node MCU esp8266 that act as a controller and send data to the Blynk application [25]. The system can be divided into three main components: input, controller, and output. The input section incorporates four sensors, namely the water flow sensor, temperature sensor, pH sensor, and TDS (Total Dissolved Solids) sensor. Figure 2.7.5 illustrates the block diagram of the system.

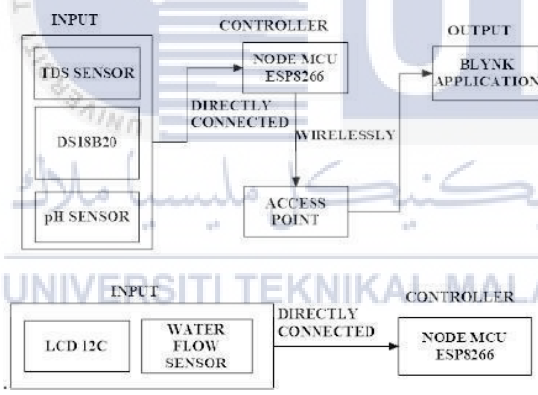

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Figure 2.7.5 : Block diagram of the system.[25]

This project intends to automate the creation of an Internet of Things (IoT)-based prototype for monitoring and gathering parameter data, such as temperature, humidity, and water level, in an aquaponics system. As a result, the system will operate more effectively and efficiently.

Architecture design of monitoring and controlling of IoT-based aquaponics system powered by solar energy is used NodeMCU serves as the microcontroller in the system, responsible for gathering sensor data from both the fish tank and the hydroponics grow bed [26]. It takes control of the pump by utilizing a relay, which facilitates the pumping of nutrient-rich water from the fish tank to the grow bed. Once in the grow bed, the water is filtered and cleansed. The filtered water is then drained back into the fish tank using a bell-siphon mechanism, completing the cycle. Figure 2.7.6 shows the IoT Aquaponics system overview. The proposed prototype contains several hardware components that fall into three main categories which are central control system, sensors, and actuators.

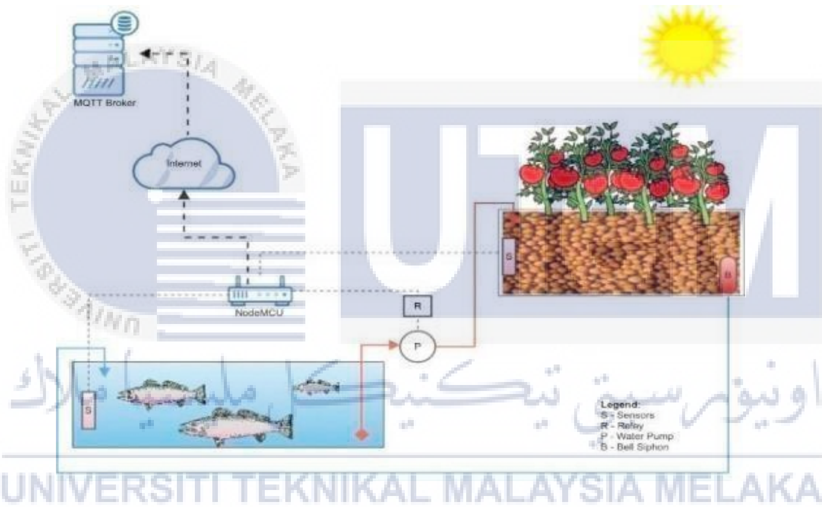

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Figure 2.7.6 : IoT Aquaponics system overview [26]

In the central control system NodeMCU acts as the main microcontroller powered by his 3V battery system. Integrate various interfaces such as GPIO, PWM, I2C, 1-Wire and ADC. The system is powered by solar panels that absorb sunlight and convert it into electrical energy. The Grove Base Shield Module is an interface board that allows connections between Grove sensors and microcontrollers. Various sensors are integrated into the system for data collection, including pH, solar, water level, water temperature, electrical conductivity (EC), soil moisture, TDS, total dissolved solids in water, temperature and humidity, and ion sensors for ammonia, nitrate, and nitrite. These sensors measure pH, solar, water level, water temperature, electrical conductivity (EC), soil moisture, TDS, total dissolved solids in water, CO2, temperature and humidity, and ion sensors for ammonia, nitrate, and nitrite. The proposed prototype enables comprehensive monitoring and control of environmental conditions within an aquaponics system by integrating a relay and water pump.

Table 2.7.6 : Project's comparison

Project's name	Hardware	Outcome
1. IoT Based Solar Panel Monitoring and Control [22]	- Solar panel - NodeMCU - Voltage and Current Sensor - Temperature Sensor - Servo motor	The system uses an Ethernet shield and NodeMCU to send data to the cloud, and an IoT monitoring app built in Blynk allows users to view solar tracking information in real-time and receive notifications when a threshold value is reached.
2. Design and construction of smart IoT-based aquaponics powered by PV cells [23]	- NodeMCU - PV panel - pH sensor - Temperature sensor - Oxygen sensor - Color sensor - Water pump	Crops were planted inside sponge-filled cups and carp fish were added to the tank after it was cycled for 24 hours. Observations were recorded every day for a week and the real-time values for each parameter were sent and displayed on a smartphone app. The results serve as a pilot plant for future system expansion and scaling.
3. A Study of IoT based Real-Time Solar Power Remote Monitoring System [24]	- PV panel - NodeMCU - Current sensor - Temperature sensor - Battery charge module	The system voltage was detected by the Current Sensor Module between the hours of 8.21 and 8.28 on a particular day, with a maximum voltage of 2.5 volts and a minimum value of 2.43 volts.

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4. Intelligent Irrigation System Using IoT for Aquaponics Application [25]	- Node MCU ESP8266 - Temperature sensor - TDS level sensor - Water pump - Analog pH sensor	TDS sensors detect not just dissolved solids such as ammonia and nitrates, but also EC values, which show how many nutrients are available for fish and plants to survive in a healthy ecosystem. The EC values are between 0.17 and 0.18, which are excellent. The solution's consistency is represented by the pH value of 6.59, which is in the range of 6.0-8.0.
5. Architecture design of monitoring and controlling of IoT-based aquaponics system powered by solar energy [26]	- Solar panel - NodeMCU - pH Sensor - Temperature Sensor - Water level sensor - Soil moisture sensor - EC sensor - Water pump	Grove sensors detect pH, light, temperature, water, water level, Ammonia, electrical conductivity, and other parameters in an aquaponics system. AI technologies will be used to optimize water quality, pH, air temperature, humidity, CO2, and predict the system's health to boost production.

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2.8 Summary

In conclusion, Chapter 2 of this research project focuses on conducting a literature review of previous studies relevant to the topic. The chapter discusses the findings and methodologies employed by other researchers in their respective studies. By examining these past research efforts, the researcher gains valuable insights and guidance for their own project. The review helps identify the distinguishing characteristics and features of prior research, providing a foundation to build upon and ensuring the project in this journal benefits from the existing knowledge in the field.

CHAPTER 3

METHODOLOGY

3.1 Introduction

The methods used to create this system by using ESP32 work as main component for this project are discussed in Chapter 3. The flow charts of the project, the software and hardware that are utilized, how the process functions, and how to build and implement the project will all be detailed. The parameters were chosen based on the findings of the literature review in Chapter 2.

3.2 Methodology

This thesis details the execution of a project utilizing the ESP32 microcontroller and solar panels to establish a sustainable aquaponics system. The core concept involves employing a closed-loop aquaponics design, recirculating water, and nutrients, and powering the system entirely through solar energy to mitigate water consumption and waste. Adopting a quantitative research approach, the study aims to quantify the system's efficiency and its impact on the environment compared to traditional agricultural and aquacultural practices. The design methodology integrates the ESP32 for control, monitoring, and data collection, emphasizing experimental validation to assess the project's success in achieving its objectives. Figures 3.2.1 and 3.2.2 depict the flow chart and block diagram, respectively, illustrating the operational sequence and component interconnections within the project.

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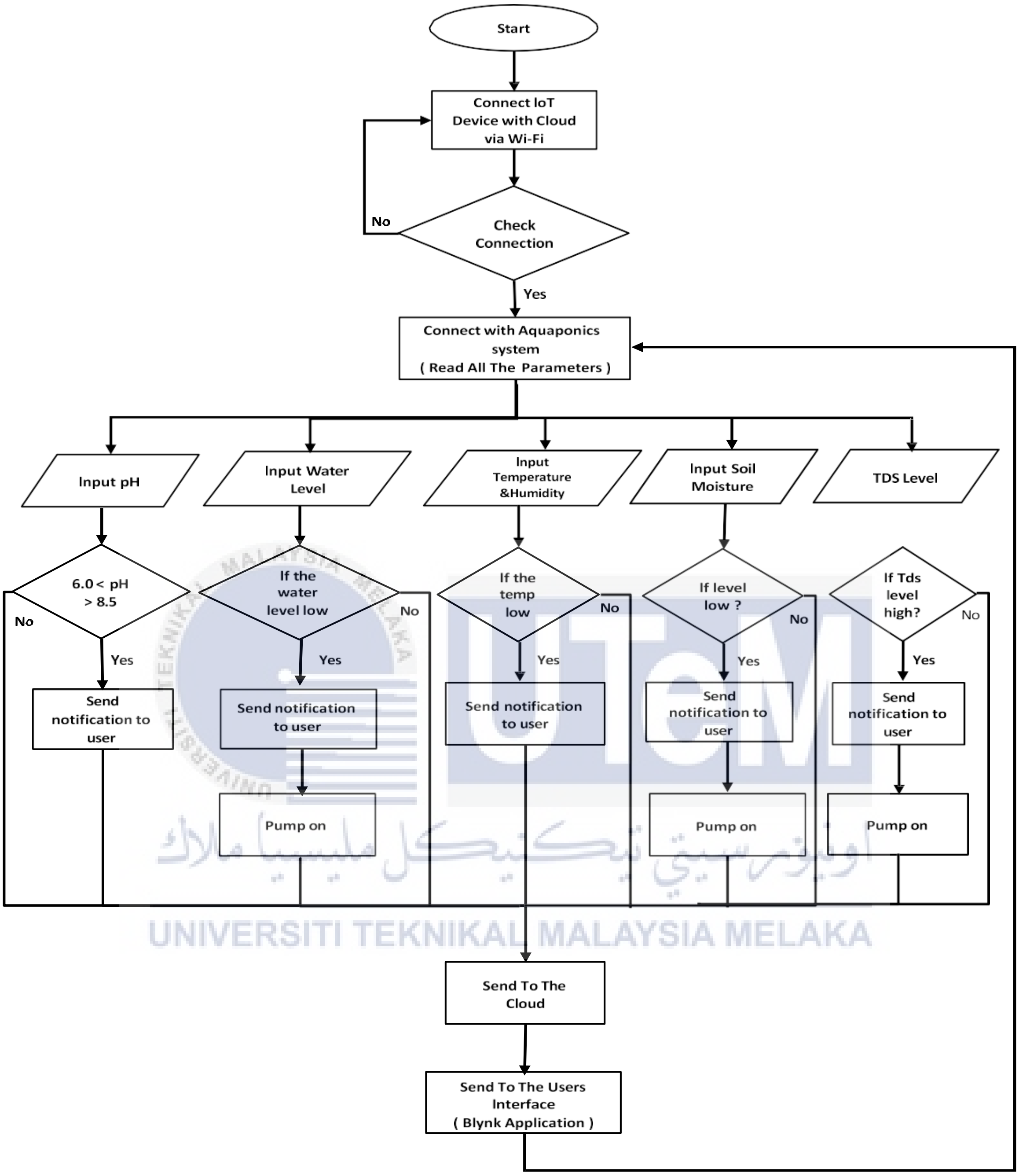

Figure 3.2.1: Flowchart

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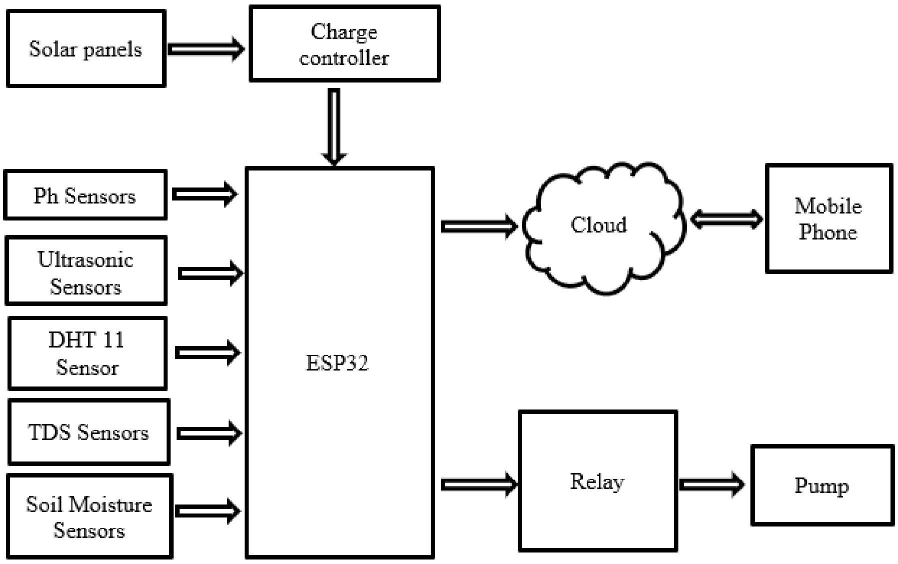

Figure 3.2.2: Block diagram

The flowchart, illustrated in Figure 3.2.1, outlines the sequential processes and interactions within the intricate system. It delineates the steps involved in collecting data from various sensors, now including the pH sensor, soil moisture sensor, ultrasonic sensor, DHT11 sensor, and the TDS sensor, all managed by the ESP32 microcontroller. The pH sensor measures the water's pH level, triggering adjustments to maintain the optimal range for the well-being of fish and plants. The soil moisture sensor monitors NFT grow bed moisture levels, regulating the water pump for precise watering. Simultaneously, the TDS sensor measures the total dissolved solids in the water, providing insights into nutrient levels critical for plant health. The ultrasonic sensor gauges water levels in the aquaculture tank, prompting adjustments or alerts for deviations from the optimal range. Additionally, the DHT11 sensor captures temperature and humidity data, facilitating environmental monitoring and necessary adjustments for plants and fish. The ESP32 processes and transmits the gathered sensor data, establishing communication within the wireless network. The data is then forwarded to a cloud and control device, presenting real-time information to users. Continuous monitoring of the aquaponics setup for alerts or notifications ensures prompt user notification in the event of any issues.

3.1 Experimental setup

Experimental setup for this project will be presented in this subtopic. Prior to project creation, a design phase is crucial for conceptual understanding and hardware selection. Key components for this project include solar panels, ESP32, ultrasonic sensor, pH sensor, DHT11 sensor, water pump, relay, and TDS sensor. To facilitate a smooth implementation, Circuit.io software is employed for circuit design before the actual construction. Once the project is designed using Circuit.io, experimental trials are conducted to validate system success and obtain desired outputs. The Arduino IDE software is utilized for programming the ESP32. However, it's important to note that there are some limitations in the design, which will be addressed in section 3.6. Figure 3.3.1 showcases the visual representation of the project design.

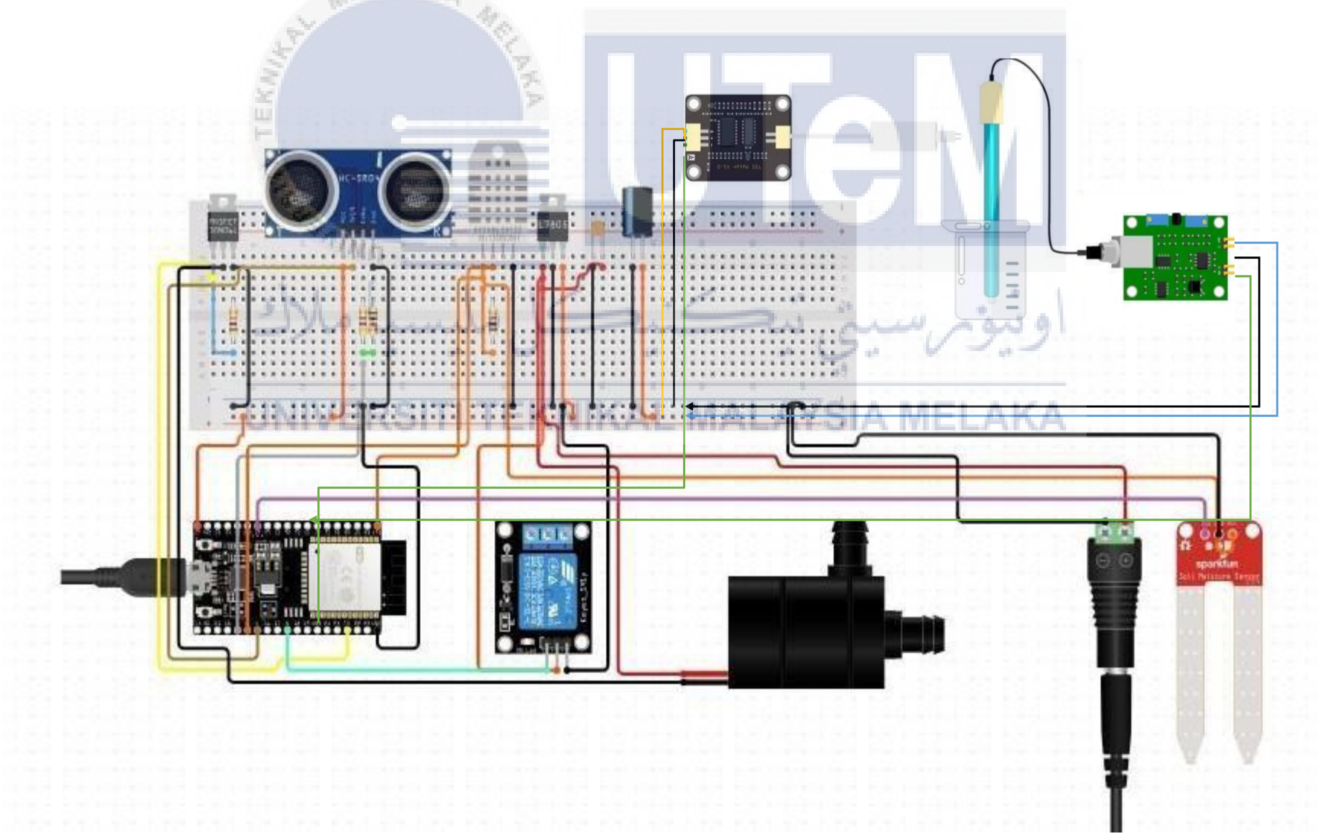

Figure 3.3.1: The circuit design of the project using circuit io.

3.2 Hardware and Software

Figure 3.4.1: Solar Panels

Solar panels are a vital component in an automated aquaponics system. They generate clean and sustainable power by converting sunlight into electrical energy. Solar panels enable off-grid operation, ensuring uninterrupted functionality even in remote areas or during power outages. They can also store excess energy in batteries for use during low sunlight periods. Solar power promotes energy efficiency, reduces reliance on conventional power sources, and minimizes the system's carbon footprint. Solar panels offer scalability and adaptability, allowing for expansion and optimization of energy production. Regular monitoring and maintenance ensure their optimal performance. Overall, integrating solar panels in an automated aquaponics system enhances sustainability, resilience, and self-sufficiency.

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Figure 3.4.2: ESP32

ESP32 can function as a full standalone system or as a slave device to a host MCU, which lessens the burden on the primary application CPU caused by communication stack overhead. Through its SPI/SDIO or I2C/UART interfaces, ESP32 may connect to other systems to provide. Wi-Fi and Bluetooth capability. The ESP32 family of system on a chip microcontroller features integrated Wi-Fi and dual-mode Bluetooth and are inexpensive and low power. The Tensilica Xtensa LX6 dual-core or single-core microprocessor, Tensilica Xtensa LX7 dual-core, or a single-core RISC-V microprocessor is used in the ESP32 series, which also has integrated antenna switches, RF baluns, power amplifiers, low-noise receive amplifiers, filters, and power-management modules.

Figure 3.4.3: Ultrasonic Sensor

Ultrasonic sensors can be used to measure the water level in fish tanks or grow beds. By emitting ultrasonic waves towards the water surface and measuring the time it takes for the waves to bounce back, the sensor can determine the distance to the water surface and thus the water level. This information is valuable for maintaining optimal water levels in the system. As an example, is placed in a water tank, when the water is full then the user will know that the water in the tank still has water and likewise when the water is low the user will also be able to know.

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Figure 3.4.4: pH Sensor

One of the most crucial pieces of equipment for evaluating water is a pH sensor. Alkalinity and acidity levels in water and other liquids may be determined with this type of sensor. When used properly, PH sensors may guarantee both the processes that occur inside wastewater as well as the safety and quality of a product. Typically, a number from 0 to 14 is used to represent the pH scale in its conventional form. A substance is said to be as neutral when its pH is seven. A material is more alkaline if its pH value is more than seven, whereas it is more acidic if its pH value is lower than seven.

Figure 3.4.5: TDS Sensor

Total Dissolved Solids (TDS) sensor measures the total concentration of dissolved materials, such as salts and minerals, and is an essential instrument for evaluating the quality of water. TDS measurements, which are often given in parts per million (ppm) or milligrams per liter (mg/L), offer information on the cleanliness of the water; lower numbers denote purer water, while larger values indicate a higher concentration of dissolved solids. This sensor is essential for applications including monitoring the water in aquaponic systems, determining the efficacy of water treatment methods, and analyzing the quality of drinking water. TDS levels ensure that water is safe to use for a variety of tasks, including drinking, farming, and industrial activities. They also act as an indication of possible toxins and impurities.

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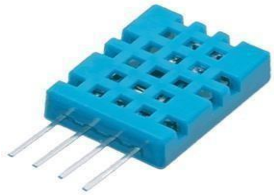

Figure 3.4.6: DHT 11 Sensor

Digital temperature and humidity sensor modules like the DHT11 are often utilized in electrical applications. It uses a 5V DC power source and has a capacitive humidity sensor and a thermistor to monitor temperature. It is capable of measuring humidity from 20% to 90% RH with an accuracy of 5% and temperatures from 0°C to 50°C with a precision of 2°C. The sensor transmits data in a serial stream of bits using a single-wire protocol for communication. It has four pins: VCC, GND, DATA, and NC, and it is small. When compared to more complex choices like the DHT22 or SHT series, it does have significant drawbacks.

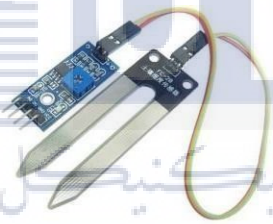

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Figure 3.4.7: Soil Moisture Sensor

A soil moisture sensor is a valuable tool used to measure the moisture content in soil. Its primary purpose is to assist in agricultural, gardening, and environmental monitoring applications by providing information about the soil's water levels and indicating when irrigation or watering is needed. Analog sensors generate voltage or current signals that are proportional to the moisture content, while digital sensors directly output moisture readings in digital format. Proper installation is essential for accurate measurements, and calibration may be necessary to establish a correlation between the sensor readings and actual soil moisture levels.

Regular maintenance is essential to ensure accurate readings and prolong the sensor's lifespan. By utilizing soil moisture sensors, users can obtain valuable information about soil moisture content, enabling efficient water management and promoting optimal plant growth.

Figure 3.4.8: Water Pump

A water pump is a mechanism that pumps, compresses, or transfers water. Gear pumps, peristaltic pumps, gravity pumps, and impulse pumps are among the many types of pumps. They are all relevant to a wide range of sectors. The water pump is the most often used type of pump in daily life. Water pumps are used for a variety of tasks in the home, light commercial, and agricultural sectors. It can be extremely beneficial, particularly in rural areas. A water pump can drain and fill a swimming pool or dam, as well as drain and fill a basement or shallow flooded area. It can also be used in agriculture to provide irrigation.

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Figure 3.4.9: Solar Charge Controller

A solar charge controller is a key component of a photovoltaic system that uses solar panels to control battery charging. Its main function is to prevent over-charging or over-discharging, protect the battery and guarantee its life. The charge controller works in different modes to efficiently charge the battery based on the voltage level. Provides protection against overcharge, deep discharge, and reverse current. There are two main types of charge controllers. PWM and MPPT each have their own advantages. Charge controllers often have displays for monitoring and may offer remote access and data logging capabilities. Choosing the right charge controller is critical for proper battery management and optimal charging in your solar system.

Figure 3.4.10: Arduino IDE Software

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The Arduino programming language is widely used to construct websites and apps, automate tasks, and do data analysis. The Arduino software is a general-purpose programming language, which means it may be used to create a broad variety of applications and is not specific to any problem. It has become one of the most extensively used programming languages today due to its flexibility and beginner-friendliness.

Figure 3.4.11: Blynk Application

This framework makes it easy for Arduino programmers to develop GUI elements using the Blynk toolkit's widgets. In a Arduino application, Blynk widgets can be used to create buttons, menus, data fields, and many more. These graphical elements can be linked to or interact with features, functionality, methods, data, and even other widgets once they've been developed. A solenoid valve, for example, can be turned on or off to control the flow of water and can also be programmed to perform a specific activity, such as departing the application.

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3.3 Design Project Prototype

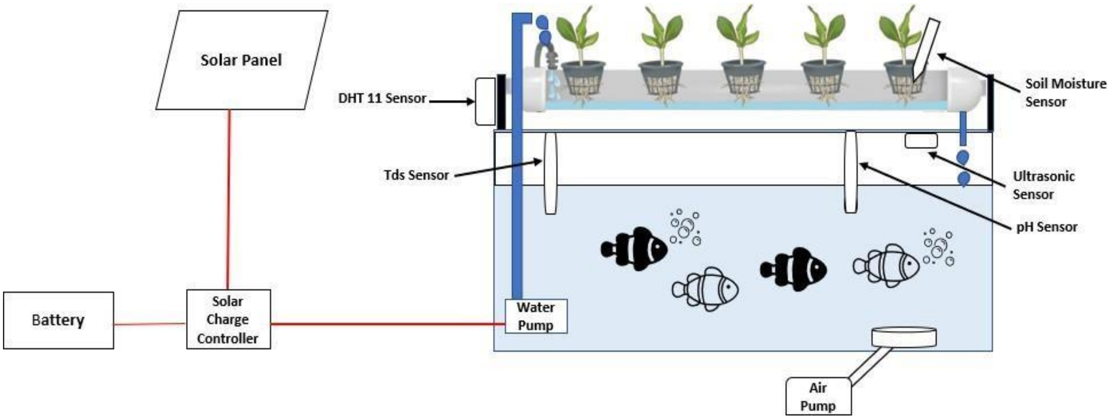

Figure 3.5.1 : Project Prototype Design

The design project prototype provides a detailed depiction of the system's flow, enhancing overall comprehension. Figure 3.5.1 delineates the project's hardware components, showcasing their interconnections and functionalities. Solar panels efficiently convert sunlight into electrical energy, overseen by a solar charge controller, and stored in rechargeable batteries for future use. The aquaculture tank and hydroponic bed are interconnected by a water pump, and an air pump ensures adequate aeration in the fish tank. At the heart of the system is the IoT development board, ESP32, functioning as the central control unit. It facilitates the connection of various sensors, enabling data collection and wireless communication. The pH sensor monitors water acidity/alkaline levels, a soil moisture sensor gauges moisture in the grow bed, an ultrasonic sensor measures water levels in the fish tank, a DHT11 sensor tracks temperature and humidity, and a TDS sensor is incorporated to monitor Total Dissolved Solids. The ESP32 collects, processes, and wirelessly transmits the sensor data for monitoring and control. Users can access real-time data, adjust system parameters, and receive notifications through specific interfaces, providing a comprehensive and interactive approach to aquaponics system management.

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3.4 Limitation of proposed methodology

Each system or project designed must have the limitation of proposed methodology. Limitation of proposed methodology is a design feature or methodology that affects a system or project to be designed. First, the cost of deploying IoT technology and solar power systems can be significant, which can be a financial hurdle for some individuals and organizations. Another limitation is technical complexity. Integrating the various components requires expertise in aquaponics, IoT technology, photovoltaic systems, and data analytics. A reliable internet connection is essential for real-time monitoring and control, but reliance on connectivity can become a limitation in the face of frequent interruptions or unreliable connections. Maintenance and support are critical for complex systems such as automated aquaponics setups, requiring regular monitoring, troubleshooting and technical expertise. Solar power is affected by environmental factors and may be unstable, affecting system operation. Securing IoT devices and data transmission requires addressing security and privacy issues. Finally, for optimal performance, the adaptability of the system to local conditions and regional differences should be considered. Despite these limitations, with careful planning, adequate resources, and ongoing maintenance, the benefits of automated aquaponics systems powered by IoT, and solar power can outweigh the challenges.

3.5 Summary

In conclusion, chapter 3 discusses the methodology that includes the project flow chart, as well as the software and hardware used for the purpose of creating this project. At the same time, the results of all these methodology discussions facilitate understanding as to how the process works, as well as how to plan and execute projects properly.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents the results and analysis for this project. As described in chapter 3 regarding the methodology of how the project was produced once the hardware had been described, the results and analysis need to be made. With the results taken by the data as has been programmed get the desired results. Therefore, the results are very necessary to know whether the results will be the same when the project is fully completed.

4.2 Results and Analysis

The Results and Analysis chapter thoroughly examines the outcomes stemming from the completion of design iterations and prototype developments outlined in Chapter 3. Special attention is given to ensuring the precision and accuracy of data collection methods to uphold the reliability of findings and prevent any potential discrepancies that might undermine the product's credibility. This chapter particularly focuses on Figure 4.2.1, which illustrates the intricately designed system in detail, demonstrating the seamless integration of components and hardware as per project specifications. Alongside this visual representation, an explanatory narrative clarifies the functionality of the prototype, highlighting the incorporation of sensors, motors, and solar panels in creating an automated aquaponics system powered by IoT and solar energy. The subsequent analysis delves into the practical implementation of the system, providing a comprehensive assessment of collected data to offer insights into its performance, efficiency, and overall effectiveness in meeting project objectives.

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This chapter offers an intricate analysis of a system that has been designed, shedding light on its physical execution and intricate operational aspects. It furnishes a comprehensive comprehension of how the system functions, its areas of strength and weakness, as well as possibilities for improvement. Furthermore, the analysis delves into the interplay among the various components and how they influence the system's overall performance. The overarching objective of the chapter is to provide guidance for future advancements in automated aquaponics technology while also advocating for sustainable agricultural practices, underscoring the pivotal role of IoT and renewable energy sources in augmenting productivity and efficiency.

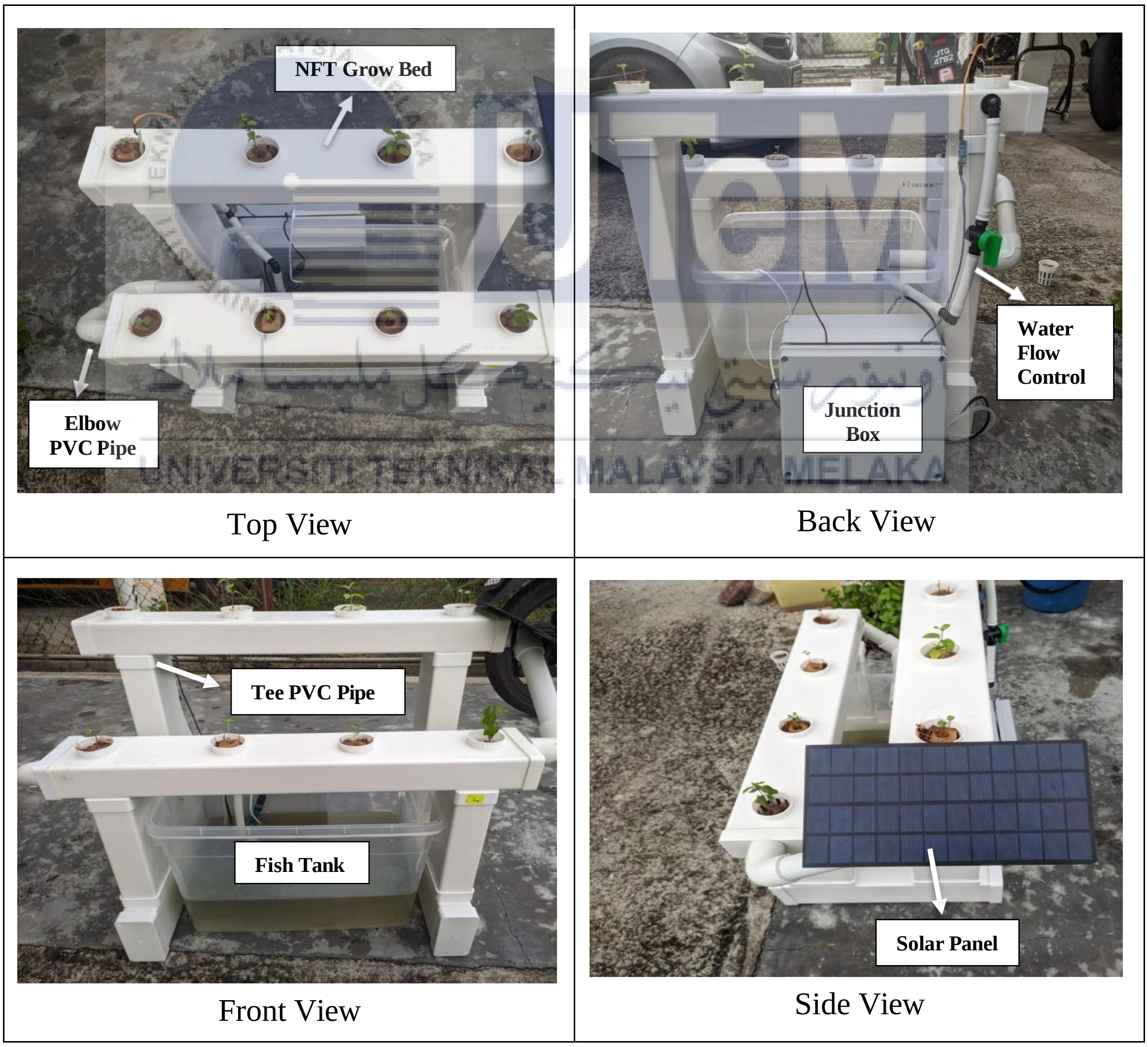

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Figure 4.2.1 : Prototype Design

Figure 4.2.2 is the design proposed in chapter 3. Thus, all the hardware and components proposed in the methodology have been completed on the prototype. The picture will show the labels for the components and hardware used.

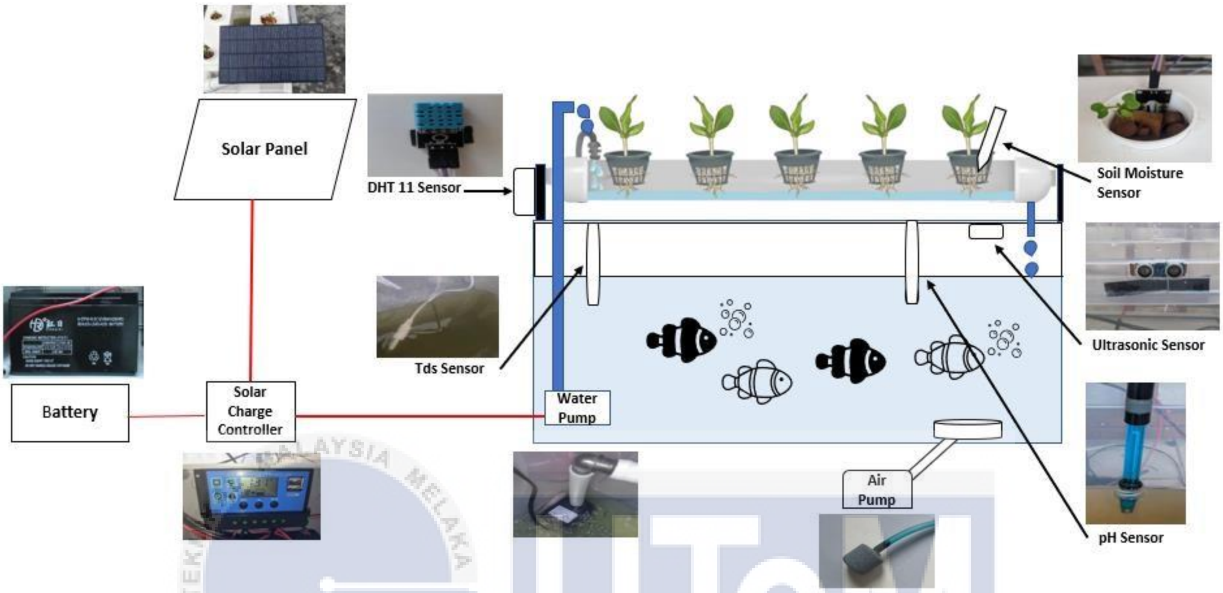

Figure 4.2.2: The proposed design is complete with component and hardware.

The design prototype for the project offers a comprehensive illustration of the system's workflow, significantly enhancing overall understanding. In Figure 4.2.2, the hardware components of the project are intricately detailed, showcasing their interconnections and individual functionalities. The solar panels play a pivotal role, efficiently converting sunlight into electrical energy, overseen by a solar charge controller, and stored in rechargeable batteries for subsequent use. The aquaculture tank and hydroponic bed are linked through a water pump, while an air pump ensures optimal aeration in the fish tank. Central to the system is the IoT development board, ESP32, which serves as the central control unit. This board facilitates the connection of various sensors, enabling the collection of data and wireless communication.

Specific sensors include the pH sensor for monitoring water acidity/alkaline levels, a soil moisture sensor to gauge moisture in the grow bed, an ultrasonic sensor for measuring water levels in the fish tank, a DHT11 sensor to track temperature and humidity, and a TDS sensor for monitoring Total Dissolved Solids. The ESP32 efficiently collects, processes, and wirelessly transmits the sensor data, enabling real-time monitoring and control. Users have the capability to access real-time data, adjust system parameters, and receive notifications through dedicated interfaces, providing a comprehensive and interactive approach to managing the aquaponics system.

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Figure 4.2.3: Blynk Interface

The Blynk interface for the automated aquaponics system based on IoT and solar technologies offers an interactive and user-friendly platform for efficient management. Users log in to the Blynk app, connecting their ESP32 boards to the Blynk cloud server. The interface is configured with various widgets such as gauges, buttons, sliders, graphs, and LED indicators. Real-time data from sensors, including pH, temperature, and water levels, is visually presented, allowing users to monitor critical parameters. The system enables manual control through buttons and sliders, facilitating adjustments to optimize performance. Notifications and alerts are implemented to inform users of critical conditions or system updates, ensuring timely intervention. The Blynk interface also includes a timer widget for scheduling automated tasks and a terminal widget for displaying system logs. Historical data is graphically represented, enabling users to analyze trends and assess long-term system performance. This remote access feature allows users to control and monitor the aquaponics system from anywhere with an internet connection. The Blynk interface serves as a comprehensive tool for managing the system, providing insights, and enhancing user interaction in a streamlined manner.

4.3 Water Levels Test with Ultrasonic Sensors

The Ultrasonic Sensor test water level a significant advancement in automated aquaponics systems, highlighting its superiority over traditional hydroponics techniques. Through precise alignment of ultrasonic sensor readings with manual measurements, the project not only enhances accuracy and reliability but also establishes a new benchmark for precision in agricultural technology. Over a rigorous week-long testing period characterized by thorough data collection, the initiative aims to quantify and analyze the complexities of error introduced by ultrasonic sensors, thereby refining their performance across various conditions. This meticulous approach underscores a commitment to excellence and innovation, positioning the automated aquaponics system as a leader in modern agriculture.

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Utilizing error values derived from simultaneous sensor and manual measurements, the project provides valuable insights for evaluating precision and reliability. By identifying patterns within these errors, the endeavor not only adjusts calibration factors but also advances our understanding of ultrasonic sensor behavior, laying the foundation for continuous improvement. Ultimately, the optimization of ultrasonic sensor readings is poised to revolutionize the aquaponics system's performance, ensuring precise control of water levels within the aquaculture tank. This optimization not only creates optimal conditions for plant growth and fish health but also underscores the system's dedication to sustainability and resource efficiency. In essence, this calibration process embodies the fundamental principles of the automated aquaponics system, rooted in solar and IoT technologies, surpassing traditional hydroponics methods and establishing itself as a beacon of innovation and excellence in modern agriculture.

Table 4.3.1 Results of Water Level Reading

Day	Water Level Reading (cm)		Deviation (cm)
	Ultrasonic Sensor	Manual Measure	
1	14cm	13cm	1cm
2	13cm	12cm	1cm
3	13cm	11cm	2cm
4	12cm	11cm	1cm
5	11cm	10cm	1cm
6	10cm	9cm	1cm
7	9cm	7cm	2cm

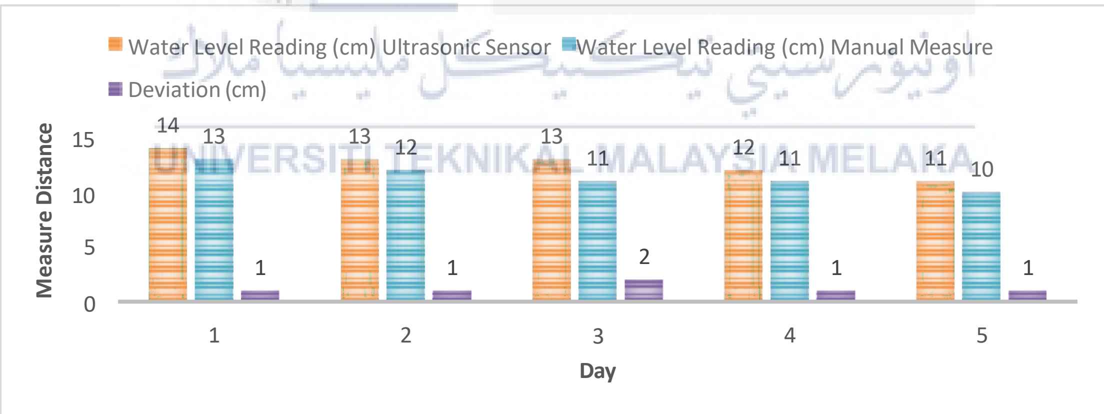

Figure 4.3.2 Graph Data of Water Level Reading

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4.4 Monitoring Water Quality: pH and Total Dissolved Solids (TDS)

Table 4.4.1 Results of pH and TDS Sensor Testing

Day	Ph Level	TDS level (ppm)	Number of Fish Alive
1	7.2	208	20
2	7.1	215	19
3	6.8	223	18
4	7.0	218	18
5	6.9	237	18
6	7.0	219	17
7	7.3	203	17

During a thorough 7-day evaluation of our automated aquaponics system, we carefully tracked pH and TDS levels in addition to the growing fish population, demonstrating the system's flexibility in response to shifting environmental circumstances. Notably, the fish population remained strong, with numbers maintaining between 20 and 17 individuals, despite slight pH fluctuations ranging from 6.8 to 7.3, with an average measurement of 7.0, and a steady TDS range of 203 to 237 ppm, averaging at 215 ppm. This resilience, which is enhanced by the integration of cutting-edge IoT and solar technologies, highlights the system's capacity to offer the ideal conditions for the growth of plants and aquatic life.

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Furthermore, our thorough recording of a range of meteorological conditions, including sunny spells, partially overcast sky, and sporadic downpours, provided insight into possible associations with variations in pH and TDS. Remarkably stable even in the face of light rain, the system proved its dependability in a variety of circumstances. Based on the extensive data gathered, our system not only maintains pH and nutrient levels in an efficient manner, but it also creates an environment that is favorable for the healthy growth of fish and plants. The system's performance will be further improved by ongoing study and improvement work, bolstering its standing as an effective and sustainable option for integrated plant and fish farming in a variety of weather scenarios.

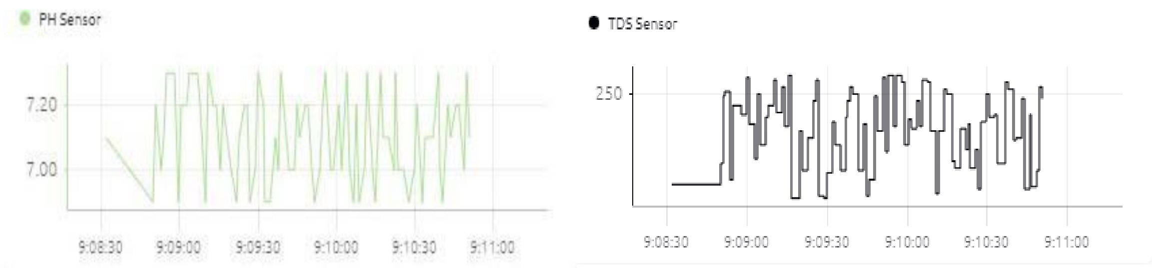

Figure 4.4.2 Live Blynk Data for pH and TDS Sensor

4.5 Environmental Monitoring in Aquaponics

Table 4.5.1 Data Environment Monitoring

Time / Parameter	8:00 AM	10:00 AM	2:00 PM	5:00 PM	8:00 PM
Temperature	27	29	28	27	25
Humidity	68	63	64	73	78
Soil Moisture	23	18	27	24	22
Relay Status	Off	On	Off	Off	Off
Pump	Off	On	Off	Off	Off

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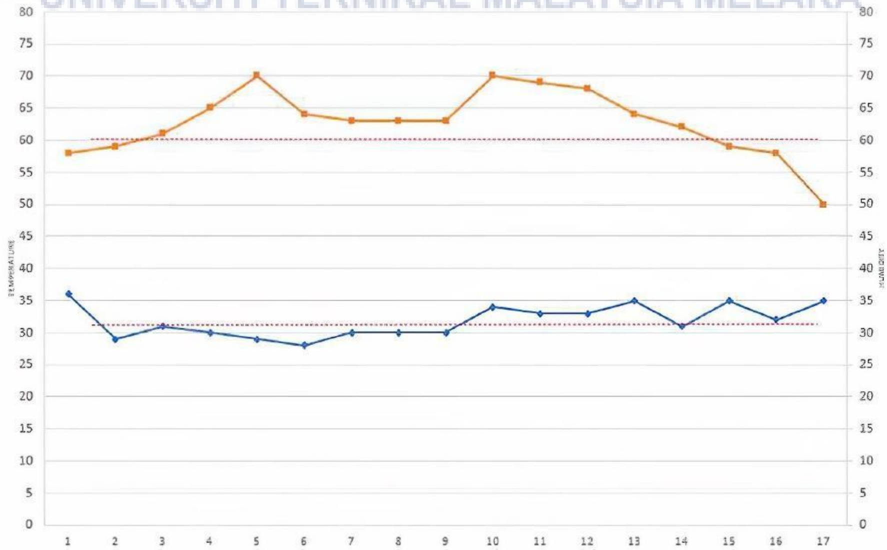

Figure 4.5.1 Live Blynk Data for Temperature and Humidity Sensor

The aquaponic system incorporates a sophisticated control mechanism facilitated by the integration of an ESP32 microcontroller and various sensors, particularly the DHT11 for temperature and humidity, and a soil moisture sensor. The ESP32 serves as the central processing unit, orchestrating the actuation of a relay that controls the water pump based on soil moisture levels. In the system, the relay operates as an actuator, responsible for activating or deactivating the water pump. The actuation logic dictates that the relay is activated (turned ON) when the soil moisture sensor records levels below 20%, signifying a need for irrigation. Conversely, the relay is deactivated (turned OFF) when the soil moisture reaches or exceeds 20%, indicating sufficient soil moisture for plant growth. This meticulous control mechanism ensures that the water pump is judiciously engaged to maintain optimal soil moisture levels, contributing to the well-being of plants within the aquaponic system. Additionally, the ESP32 generates real-time notifications, providing users with timely information about the system's status, including temperature, humidity, and soil moisture conditions. This comprehensive approach underscores the efficiency of the automated aquaponic system in responding to environmental parameters and optimizing plant growth.

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4.6 Summary

To conclude, this chapter presents the analysis and initial findings of the project. Building upon the methodology outlined in chapter 3, several components discussed in that chapter were utilized and implemented in the circuit simulation design presented in chapter 4. The data and analysis indicate that the designed system successfully meets the requirements and specifications discussed earlier. Through the result, it was demonstrated that the aquaponic system can be effectively monitored and controlled, creating an optimal environment for the aquatic life and plants involved. The successful integration of the components and the ability to monitor and regulate the system's parameters are promising indicators for the project's future implementation and success.

CHAPTER 5

CONCLUSION

5.1 Conclusion

In conclusion, the completed chapters of the report (1, 2, and 3) and parts of chapters 4 and 5 showcase the development of an automated aquaponics system based on IoT and solar power. The integration of IoT technology allows for efficient monitoring and control, leading to improved resource management, remote accessibility, and data-driven decision making. By incorporating solar power, the system becomes more sustainable and cost-effective by reducing reliance on traditional electricity sources. The system's ability to maintain optimal environmental conditions and precise nutrient control promotes healthier plant growth and faster fish growth rates, resulting in increased crop yields and higher-quality produce. Additionally, the project presents educational and research opportunities, fostering innovation and knowledge sharing within the aquaponics community. The project will continue in the next semester as part of the bachelor's degree Project II, where real tools will be employed to further enhance and refine the system. Overall, this project contributes to the advancement of aquaponics and sustainable agricultural practices, promising a brighter future for the field.

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5.2 Potential for Commercialization

The automated aquaponic system has been described as having great commercial potential due to its many benefits and the growing demand for sustainable agricultural solutions. Consumer awareness of the environmental impact of food production is growing, creating a favorable market environment for innovative solutions such as automated aquaponic systems. In addition, the integration of solar energy and IoT technologies can save a lot of money for farmers, improving the system and its commercial appeal. Companies can serve a variety of market segments, from small facilities to large commercial facilities. In addition, inspections and controls allow farmers to optimize environmental conditions and nutrient levels to increase yields and improve the quality of agricultural products. The system and remote controls improve operational efficiency while providing access to resources, expertise and market opportunities through collaboration and collaboration to accelerate the go-to-market process. Overall, with the right strategy and business practice, companies can take advantage of these opportunities to successfully bring their products to market and promote the growth of the sustainable agriculture sector.

5.3 Future Works

There is a lot of potential to improve the automated aquaponics system in the future. Using adaptive methods and predictive analytics to proactively address problems, the integration of sophisticated control algorithms would maximize system performance in real-time. Adding other metrics to the sensor network, including dissolved oxygen and ammonia levels, would provide a thorough understanding of the state of the system and enable accurate control and optimization. Creating an intuitive mobile or web interface for remote monitoring and control would increase user comfort and accessibility. Additionally, automating regular maintenance chores like fertilizer replenishment and filter cleaning might reduce the need for user intervention and guarantee reliable system performance. Further efficiency increases might result from using machine learning techniques for the analysis of historical data and the fine-tuning of system settings. Sustainability and resilience might be improved by expanding the system for commercial usage and investigating other energy sources like geothermal or wind power. To enhance the effectiveness and sustainability of automated aquaponics systems, future research should focus on developing control strategies, expanding sensor capabilities, improving remote monitoring, automating maintenance, utilizing machine learning, looking into scalability, and investigating alternative energy sources.

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APPENDICES

Appendix A Gantt Chart for PSM 2

WEEKS	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
Activities														
PSM 2 Briefing with SV	■													
Start searching journal		■												
Progress Work 1			■	■	■	■								
Project Research			■	■	■	■	■	■						
Research on literature review					■	■	■	■	■	■	■	■		
Report Preparation						■	■	■	■	■	■	■		
Progress Work 2												■		
PSM 2 Report Submission													■	
PSM 2 Presentation														■

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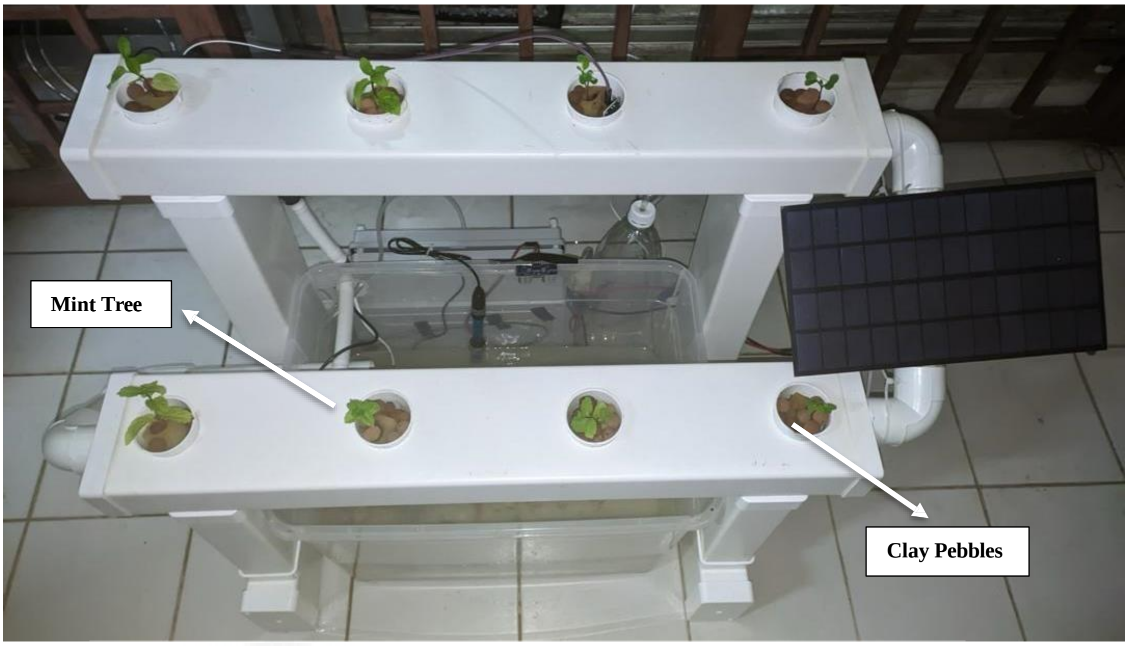
Appendix B Seedling Mint Leaves

Appendix C Final Year Project Completion



Appendix D Blynk Coding

```
#define BLYNK_PRINT Serial
#define BLYNK_TEMPLATE_ID "TMPL68p0b4j0Y"
#define BLYNK_TEMPLATE_NAME "Quickstart Template"
#define  BLYNK_AUTH_TOKEN  "ltIUCFYYfJoUoLEshgV91XYV8SYDlvj-"

#include <Wire.h> #include
<WiFi.h>
#include <BlynkSimpleEsp32.h> #include
<EEPROM.h>
#include <DHT.h>

#define DHTPIN 26 #define
DHTTYPE DHT11 #define
ph_Pin 34

DHT dht(DHTPIN, DHTTYPE);

char auth[] = "ltIUCFYYfJoUoLEshgV91XYV8SYDlvj-"; char ssid[] =
"Harimau Tua";
char pass[] = "987654321";

const int sensor = 33;
const int relay1 = 4; // Connect relay1 to the first relay on the module (for soil moisture)
const int relay2 = 5; // Connect relay2 to the second relay on the
```

```
const int WATER_LEVEL_THRESHOLD2 = 7; // centimeter #define
TRIG_PIN 22
#define ECHO_PIN 23 BlynkTimer

timer;

bool relayState1 = false; bool
relayState2 = false;

void setup() { Serial.begin(9600);

  Blynk.begin(auth, ssid, pass);

  pinMode(relay1, OUTPUT);
  pinMode(relay2, OUTPUT);
  pinMode(TRIG_PIN, OUTPUT);
  pinMode(ECHO_PIN, INPUT);
  pinMode(ph_Pin, INPUT);

  dht.begin();

  timer.setInterval(200L, soilMoisture); timer.setInterval(1000L,
  myTimerEvent); timer.setInterval(100L, sendSensor);
}

void loop() { Blynk.run();
  timer.run();

  long duration; float
  distance_cm;

  digitalWrite(TRIG_PIN, HIGH);
  delayMicroseconds(10); digitalWrite(TRIG_PIN,
  LOW); duration = pulseIn(ECHO_PIN, HIGH);
  distance_cm = duration * 0.034 / 2;  // Speed of sound is 34 cm/ms

  Serial.print("Distance: "); Serial.println(distance_cm);

  // Control the water pump based on ultrasonic sensor if (distance_cm
  <= WATER_LEVEL_THRESHOLD2) {
    Serial.println("The water level is above 7 cm => activate the second relay");
    digitalWrite(relay2, LOW);
```

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```
    } else {
        Serial.println("The water level is below 7 cm => deactivate the second relay");
        digitalWrite(relay2, HIGH);
    }

    // Send the ultrasonic distance value to Blynk Blynk.virtualWrite(V2,
    distance_cm);

    delay(1000);
}

void soilMoisture() {
    int value = analogRead(sensor);  value =
    map(value, 0, 4095, 0, 100); value = (value -
    100) * -1; Blynk.virtualWrite(V7, value);
    Serial.print("Moisture: "); Serial.print(value);
    Serial.print("%");

    // Control the water pump based on soil moisture if (value < 15
    && !relayState1) {
        relayState1 = true; digitalWrite(relay1,
        LOW);
        Serial.println(" - Motor is ON (Soil Moisture)");
        Blynk.logEvent("soil_moisture_alert"); Blynk.notify("Soil is dry");
    } else if (value >= 15 && relayState1) { relayState1 =
        false; digitalWrite(relay1, HIGH);
        Serial.println(" - Motor is OFF (Soil Moisture)");
    }
}

void sendSensor() {
    float h = dht.readHumidity(); float t =
    dht.readTemperature();

    if (isnan(h) || isnan(t)) {
        Serial.println("Failed to read from DHT sensor!"); return;
    }

    Blynk.virtualWrite(V5, t);
    Blynk.virtualWrite(V6, h);

    Serial.print("Temperature : "); Serial.print(t);
```

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```
    Serial.print("                  Humidity : ");
    Serial.println(h);
}

void myTimerEvent() { Blynk.virtualWrite(V2, millis() /
    1000);

      // Read TDS sensor value
    int tdsValue = analogRead(tdsSensorPin);

    Serial.print("TDS Value: "); Serial.print(TdsValue);
    Serial.println(" ppm");

    Blynk.virtualWrite(V4,  TdsValue);

    // Send notification when TDS reading is greater than 500 if (TdsValue > 500) {
        Blynk.logEvent("tds_alert"); Blynk.notify("TDS
        reading is high");
    }

    float readpH() {
    // Read analog value from pH sensor
    int sensorValue = analogRead(pH_sensor_pin);

    // Convert the analog value to pH value using calibration data float pH =
    map(sensorValue, 0, 1023, 0, 14.00); // assuming pH
range from 0 to 14

    return pH;
}
    // Send notification when pH value is outside the desired range if (PHValue < 6.0 ||
    PHValue > 8.5) {
        Blynk.logEvent("ph_alert"); Blynk.notify("pH value is out
        of range");
    }

    Blynk.virtualWrite(V0,  PHValue);
```

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