

Faculty of Electrical and Electronic Engineering Technology



LIM YOU QI

Bachelor of Electronics Engineering Technology (Industrial Electronics) with Honours

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DEVELOPMENT OF IOT BASED SMART AGRICULTURE MONITORING SYSTEM

LIM YOU QI

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



UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DECLARATION

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



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 (Industrial Electronics) with Honours.

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DEDICATION

Appreciation to my beloved parents, Lim Boon Kim and Tam Lee Lin who give me moral support and motivation when this study is being done. I would also like to dedicate my friends to help me with this project as I face trouble.



ABSTRACT

Agriculture has long been the primary occupation in our country, intending to improve rural household income, farm productivity, and local market demand. Due to people migrating from rural to urban areas, the Malaysian government proposes that agriculture can be done in a residential area without engaging big regions by combining plants and fish production in an integrated recirculating system known as aquaponics system. But there have hindrances in agriculture. As a result, the purpose of the project is to develop a smart aquaponics system in a small space and due to today's modern technology, it is necessary to include automation in aquaponics to reduce labour involvement. The objective of this project is to design and develop IoT based smart aquaponics system by using Arduino, to determine the growth effect of vegetable and fish distribution on the wastewater quality and reuse water respectively and monitor water level, water temperature, pH value, light and fish feeder automatically through a sensor that can be connected to the cloud. An Arduino Uno is utilised in this aquaponics system to regulate the system's input and output as well as a WiFi module as a transmitter to send the data and current situation to the mobile application. The system covers pH level, water temperature, water level, and light maintenance by using a pH sensor, water temperature sensor, water level sensor, and a light-dependent resistor (LDR) respectively. Moreover, it also automated a fish feeder as an additional feature. In the meanwhile, users can use the mobile application to monitor and manage smart aquaponics remotely. In contrast to the standalone recirculating aquaculture system (RAS), this project is unique, sustainable and environmentally friendly operational procedures in the aquaponics system to reduced environmental pollution and less water consumption which directly increases the profit of farmers.

ABSTRAK

Pertanian adalah pekerjaan utama di negara kita selama bertahun-tahun untuk meningkatkan pendapatan isi rumah luar bandar, produktiviti yang lebih tinggi di ladang, dan permintaan yang lebih besar di pasaran tempatan. Oleh kerana migrasi orang dari luar bandar ke bandar dari semasa ke semasa, Pemerintah Malaysia menyarankan agar pertanian dapat dilakukan di kawasan perumahan tanpa melibatkan kawasan yang luas dengan caranya kombinasi pengeluaran ikan dan tanaman dalam sistem peredaran semula bersepadu sebagai sistem akuaponik. Tetapi terdapat halangan dalam pertanian. Oleh itu, tujuan projek ini adalah untuk mengembangkan sistem akuaponik pintar di ruang terhad dan dengan teknologi canggih hari ini, automasi diperlukan dalam akuaponik untuk mengurangkan penglibatan tenaga kerja. Objektif projek ini adalah untuk merancang dan mengembangkan sistem akuaponik pintar berasaskan IoT dengan menggunakan Arduino, menentukan kesan pertumbuhan taburan sayur dan ikan terhadap kualiti air sisa dan menggunakan semula air masing-masing dan memantau nilai pH, tahap air, suhu air, nilai pH, cahaya dan pengumpan ikan secara automatik melalui sensor yang dapat disambungkan ke awan. Sistem akuaponik ini menggunakan Arduino Uno sebagai pengawal mikro untuk mengawal input dan output sistem dan modul WiFi sebagai pemancar untuk menghantar data dan keadaan semasa ke aplikasi mudah alih. Sistem ini meliputi tahap pH, suhu air, permukaan air, dan pemeliharaan cahaya dengan menggunakan sensor pH, sensor suhu air, sensor ultrasonik dan perintang bergantung cahaya (LDR) masing-masing. Selain itu, ia juga mengautomasikan pengumpan ikan sebagai ciri tambahan. Sementara itu, pengguna dapat menggunakan aplikasi mudah alih untuk memantau pengguna dapat menggunakan aplikasi mudah alih untuk memantau dan mengendalikan akuaponik pintar dari jarak jauh. Projek ini mudah digunakan dan mesra alam kerana memperkenalkan peningkatan yang lebih baik pada sistem akuaponik

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LIST OF SYMBOLS

- °C Degree Celcius Percentage _
- % _



LIST OF ABBREVIATIONS

C.	
It	- Feet
g	- Gram
kg	- Kılogram
cm	- Centimeter
m	- Meter
ADC	- Analog to Digital Converter
BDP	- Bachelor Degree Project
DWC	- Deep Water Culture
GUI	- Graphical User Interface
IDE	- Integrated Development Environment
IoT	- Internet of Things
I/O	- Input/Output
kB	- Kilobyte
LCD	- Liquid Crystal Display
LDR	- Light Dependent Resistor
LED	- Light Emitting Diode
NC	- Normally Closed
NO	- Normally Open
NFT	💈 - Nutrient Film Technique
pН	- Power of Hydrogen
PPFD	- Photon Flux Density
PVC	- Polyvinyl Chloride
RAS	- Recirculating Aquaculture system
V	- Voltage
VAC	- Voltage Alternating Current
VDC	UN-VEVoltage Direct Current-MALAYSIA MELAKA
VCC	- Voltage Common Collector
TAN	- Total Ammonia Nitrogen
BOD	- Biological Oxygen Demand
TP	- Total Phosphorus
TN	- Total Nitrogen
TOC	- Total Organic Carbon

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CHAPTER 1

INTRODUCTION

1.1 Background

Aquaponics is a term that combines the name of aquaculture and hydroponics. It's a closed recirculating multi-trophic system that incorporates aquaculture and hydroponics elements [1]. The New Alchemy Institute and the Aztec developed agricultural islands are known as chinampas, and aquaponics began in the 1970s with a couple from the institute (the earliest 1150–1350CE) [2]. Plants were raised on stationary islands in lake shallows approximately 1000 A.D where nutrient rich mud and water could be dredged from the chinampa canals to support plant growth [3]. This is a natural, environmentally friendly food-growing system that captures the best qualities without the need to discard any water or filter or add chemical fertilizer [1]. In the early 90's the hydroponics company saw the potential of aquaponic farming, a natural and sustainable method of growing fish and vegetables using a water based mineral nutrient solution without soil year-round, and embarked on a path to develop the science of aquaponics into an industry [4]. Aquaponics as an alternative has proven to be more effective than hydroponics. With a plot of land on the outskirts of Milwaukee, Will Allen's successful experiments proved the potential of aquaponics and sustainable agriculture in improving the surrounding urban community [5].

In this age of globalization, agriculture was the key development of a country and providing the primary source of food, income and employment for rural communities [6] but the global food system is starting to sag as the world population is predicted to reach 9.7 billion by 2050 [7]. In addition to population growth also increases the demand for food.

Food demand is anticipated to rise between 59% to 98% by 2050 [7] hence the planet's arable land is estimated to be half of what it was in the 1970s by that period. Land use change reflected in land cover change is the main component of global environmental change [8], affecting climate, biodiversity, and ecosystem services, affecting the land-use decision. To come up with the solution, aquaponics system is one of the techniques to replace arable land.

Aquaponics is a modern agricultural production technology that integrated hydroponics plant production into recirculating fish aquaculture system uses natural bacterial cycles to convert fish waste to plants nutrients [9]. In this context, a hydroponics system is a method of cultivating plants without soil but by using a water-based mineral nutrient solution. Hydroponics means water working or water activating [10]. On the other hand, aquaculture refers to aquafarming that controlled the process of cultivating aquatic organisms, particularly for human consumption which similar concept to agriculture by fish instead of plants or livestock [11]. In aquaponics, waste produced by the fish either by direct excretion or uneaten feed as aquaculture effluent contains many nutrients that promote plants cultured hydroponically for growth and not released to the environment. This can be more productive and economically feasible in certain situations, especially where land and water are limited on a family scale.

The Internet of Things (IoT) is an emerging paradigm that is a crucial part of our lives. The term "Internet of Things" was coined by Kevin Ashton in 1999 when he included it in the title of a presentation he made at Procter & Gamble [12]. It allows sensors and electronic devices to communicate with each other through the internet to facilitate maintenance management [13]. For example, with the implementation of smart devices, it able to automate aquaponics maintenance system. This show that IoT became essential to our life. The two important words in IoT are "internet" and "things". The internet is an electronic communications network that connected computers network and lets people share

and receive information around the world. The definition of the term "things" in the dictionary is an object that eminent from a living being. Simply to said, the IoT means that a system interlinks devices, mechanical and digital equipment, objects or people to transmit data across the network without the need for human-to-human transmission [14]. General, IoT began with the best tools for communication. The devices can be monitored, operated by mobile phones or computers that connect through the Internet. Cloud serves as a great IoT partner as a forum for all sensors and it can store and access data.

Arduino is an open-source electronics based on accessible hardware and software. The Arduino project started in 2005 for students in Italy [15]. This project is launched to provide a low cost and a better way to create devices that can use sensors and actuators to communicate with their environments [16]. Arduino board can read digital inputs such as pulse on a push-button or analog input from the sensor and turn it into an output. With the development of Arduino, it has been used in a lot of different projects and applications. The Arduino software is reasonably flexible for advanced users. This is because it can run on Mac, Windows and also Linux. Arduino widely used in the education region because it is simple, clear programming environment, inexpensive and it also open-source software.

Smartphones have become a highly frequent source and primary means of communication for everyone in the world to communicate or update most of the farming community as development of technology. A smart agriculture system with IoT based system helps to monitor and maintain the optimal condition for aquaponics system. IoT based smart agriculture able to help users to control the pH value, water level, water temperature, light and fish feeder through the internet with improve services. Users allow to manually control it by using smartphone and it also can be automated by controlling the aquaponics system to reduces the manpower in process of care and planting of fish and vegetables respectively. This may seem like saving their time.

The rate of growing fish and vegetables is increasing proportionally to the good maintain of optimal condition. Smartphone development encourages users to prefer using mobile app. Growth of IoT allows the communication between the networking devices based on requirements. This mobile application develops to allow the users can check the current situation of aquaponics system whenever they are.

1.2 Problem Statement

House and townhouse gardens provide endless flexibility when it comes to garden design and style but most residential areas without involved large areas for planting especially condominiums didn't provide the land space for planting. The existing system developed was full-on manual bases which required a lot of labour in process of care and planting of vegetables and the fish feeding which constraints the time of people. Furthermore no medium provided to connect the system with the internet or data server, where it was a lack of information regarding fish health and vegetables. Ammonia is excreted from the fish via the gills [17] which toxic to aquatic life hence people always changed the water to keep it clean, which wastes the water. According to Randall and Tsui [18], acute ammonia toxicity affects the central nervous system of fish and manifests as a neurological disease. In addition, uncontrolled pH value, temperature and light intensity may result in the death of fish and deficiencies occur toward vegetables. Thus, smart agriculture system provides an intelligent solution to rear fish and plants together in limited space and controlled growing conditions to reduce the use of chemical pesticides.

1.3 Project Objective

The objectives of this project are:

 a) To design and develop an IoT based smart aquaponics system by using Arduino Uno.

- b) To determine the growth effect of vegetable and fish distribution on the wastewater quality and reuse water respectively.
- c) To monitor water level, water temperature, pH value, light and fish feeder automatically through sensor that can be connected to the cloud.

1.4 Scope of Project

An aquaponics system is my conducted research in this proposed study. The scope of this project are as follows :

- a) Using Arduino UNO microcontroller as a brain to control the components in this project.
- b) WiFi module was used for communication between the Arduino UNO and the mobile application developed using the MIT App Inventer
- Mobile application is developed to display the information received and perform monitoring toward Arduino UNO
- d) To determine the growth effect of spinach and catfish distribution on the wastewater quality and reuse water respectively, a weighing scale is used.
- e) pH sensor is used to detect the pH value of fish tank.
- f) DS18B20 water temperature sensor is used to measuare the water temperature of fish tank to make automatic exhaust fan or white LED T5 tube light.
- g) LDR sensor was used to detect light during the day and night to make automatic red LED T5 tube light by control either ON or OFF
- h) A water pump cindition depending to an water level sensor either to fill the water until the desired water level or in off condition.
- i) Servo motor is used to control the fish feed automatically.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, the basic aquaponics system has been discussed such as types of aquaponics, hydroponics, aquaculture, parameters and energy supply. Several aquaponics systems have been done by other research hence comparison of their trade off also has been made toward other aquaponics systems to provide an improvement to the existing aquaponics system. Lastly, the outcome of the evaluation were then summarized and written at the last part of this section.

Besides that, in this section several studies that are also related to previous researches on aquaponics system and parameter controlling were conducted. The flow of study started from collecting sources for instance journal articles, books, documents of website and conference papers and analyzing them to extract useful information. The information collected were tabulated to show the comparison between each findings clearly. After that, synthesize was made on the findings to derive new information by integrating them. Lastly, the analyzed and synthesized information were evaluated by comparing their trade off to find the best approach that can applied in this project. The outcome of the evaluation were then summarized and written at the last part of this section.

The summary of information gathered from various papers were searched online based on several keyword such as aquaponics, hydroponics and aquaculture. All these papers were precisely chosen to be included as a reference for this research because of their content that has properly covered all the information needed. Moreover, these papers were also downloaded from good databases such as Google Scholar, IEEE Access, Sematic Scholar and Science Direct. These database cater high quality papers which provide trustable information to be used by other. Table 2.1 shows the important findings that were analyzed from those papers.

2.2 Aquaponics in General

Aquaponics with its comprehensive biological processes among fish, bacteria, and plants known as a sustainable agricultural production system. That's why the close nutrient cycle is an important characteristic of designing the aquaponics system [19]. It's a hybrid of a recirculating aquaculture system (RAS) and a hydroponics system, in which these two technologies are combined uneas [20]. Another reason to combined them is aquaponics has a better economic benefit in contrat to standalone RAS and hydroponics systems [19]. In Figure 2.1 the aquaponic system is explained in more detail.



Figure 2.1: Visualisation of an aquaponics system [21]

Fish excrete organic wastes as a nutrition supply in the form of ammonia, which dissolved in the water and converted to ammonium [19]. A pump drives the circulation of the water in the system. The water leaves the fish tank and enters bacteria-filled hydroponics stage. By nitrification, ammonium converts to nitrite and utimately to nitrate. Nitrate is a form of nitrogen that is directly taken by plants roots and used in photosynthesis for development of leaves, flowers or fruit. After water passed though hydroponic stage, it is

mostly purified of nutrients by plants, which then recirculated into the fish tank. As a result, the fish fed freshwater via natural filtration [21].

2.3 Types of Aquaponics

Aquaponics is the type of agriculture that blends recirculating aquaculture with soilless plant culture. Aquaponics can seem as overwhelming as it is exciting. The most challenging part of the experience is design production. Meanwhile, numerous varie Aquaponics is the type of agriculture that blends recirculating aquaculture with soilless plant culture. Aquaponics can seem as overwhelming as it is exciting. The most challenging part of the experience is design production. Meanwhile, numerous varie soft the experience is design production. Meanwhile, numerous varies are the experience is design production. Meanwhile, numerous varies are the experience is design production. Meanwhile, numerous varies are the experience is design production. Meanwhile, numerous varies such as media bed, nutrient film technique (NFT) and deep water culture (DWC) [20] are discussed in this chapter.

2.3.1 Media Bed

Plants are planted in containers packed with gravel, lava rock or expanded clay pebbles to support their root in a samll-scale aquaponics system. The media is a filtration without having separate biofilters [19] because the bed is constantly flooded and drained with nutrient-rich water from the fish tank [22].



Figure 2.2: Media Bed [23]

Strengths

During biological processes in aquaponics, the media-based bed supported the plants and provided a large surface area for microbial growth [19]. It also acts as a mechanical and biofilter in plant bed to capture and break down wastes from fish tank. This design is most popular among home gardeners and beginners in aquaponics since it's easy and relatively simple to operate [19]. Moreover, the media bed is suitable for high root density plants like fruit species and flowering plants [24] due to the possibility of a recirculating flow blockage [19].

Weaknesses

AALAYSIA

Where compared to Nutrition Film Technique or the Deep Water Culture, this media bed method is produced less frequent yields. Moreover, it is a placeholder and requires more labour than the other types of aquaponics because it's not a soilless planting [25]. However, on a large scale, the media bed techniques can become unwieldy and can be very expensive [24].

2.3.2 UNIVERSITI TEKNIKAL MALAYSIA MELAKA Nutrient Film Technique

Nutrient Film Technique (NFT) is also a fairly popular hydroponic irrigation technique. A nutrient-rich stream flows constantly over the plants' bare roots in a watertight channel for plant growth. The basic purpose of this system is to maintain a thin film of water but not soaked completely [26]. In this method, the roots' upper section should remain moist and in contact with the oxygen in the air, as can be seen in Figure 2.3 [27].



Figure 2.3: Nutrient Film Technique [27]

Strengths

The main advantage of growing the plants in narrow channels is to provide an ample supply of oxygen, nutrients and water to the plants' roots. Therefore, these arrangements produce high-quality yield over a long period of cropping and comparatively cheap to grow a broad range of leafy vegetables and herbs such as lettuce [20] [26] and spinach [19]. Due to their space economy, fewer materials and easy access for set up for a newbie and less labour used, hence NFT popular in the commercial market. The absence of a medium makes it easy to check roots for signs of illness that could harm the plant's health and growth [46]. Furthermore, they offer the possibility of future food production expansion by contributing to the continued development of these systems into commercial aquaponics [28].

Weaknesses

This design is great for small rooting plants and leafy greens but not suitable for large flowering or fruiting plants. The roots may be deprived of water when the water pump fails to function or the pipes and channels clogged owing to the overgrowth of plant roots [29]. Hence, routine maintenance is important to ensure the flow rate remains steady for the plants to thrive. [28]

2.3.3 Deep Water Culture or Floating Raft

Deep water culture (DWC) also known as the floating raft [19] that is one of the most efficient aquaponics system designs. The plants for DWC are grown on polystyrene or rafts on top of the water without a substrate media as shown in Figure 2.4 [25]. A tank is separated from the fish tank and a filtering component is used to create a continuous flow between them. If it carries a very low stocking density of fish and then relies mainly on the plant root space and interior area of the canals as the surface area to house the nitrifying bacteria hence do not require external additional filtration [30].



Figure 2.4: Deep Water Culture (DWC) [31]

Strengths

The enormous volume of water utilized in this method provides a buffer, allowing the temperature to be more consistent to reduced stress on the fish and water quality issues [32]. Subsequently, DWC method allows the plant roots to freely absorb the nutrients in the water and optimizes floor space by generating a process line, hence it resulting in high productivity of crops [19]. Plants also easier to harvest than the media bed technique since the roots are submerged in the water without any media. [28]

Weaknesses

This DWC technique is limited to growing one specific crop of small leafy greens like lettuce or mint [19]. Besides that, the larger volume of water in the system necessitates the usage of energy to heat or chill it if necessary. To have enough nutrients diffused in the enormous volume of water, this technique demands a higher feed input which means more fish to rear than the other methods [33]. As the design lack media and the roots are submerged in water, they may not receive the right amount of oxygen. Therefore, this setup requires a larger space to set up external filtration for supplemental oxygen and nutrient-rich food to the plants to ensure that nutrients are not depleted and plants don't drown [28] hence this process increases costs and complication of adding to aquaponics setup just does not make sense for a backyard gardener [32].

2.4 Hydroponics

Hydroponics is the method of cultivating plants in a nutrient solution without soil [20]. The plants' roots are constantly seeped into nutrient-rich water and bathed in highly oxygen generated. Almost every plant can be cultivated hydroponically in theory, however some plants will always grow better than others. In general, if plants are put to the system later in the start-up process while the proper nutrient levels are established, it is possible to avoid using expensive chemical fertiliser [34].

2.4.1 Type of Plants

Almost all plants can be grown in an aquaponic system but some of the plants tend to die in the new aquaponic system since bacteria take time to develop in such a system. However, the types of plants that choose to grow in the aquaponics system are very important due to different plants have different needs to thrive under different conditions [35]. More than 60 different food crops and varieties were tested in the Alberta greenhouse, including herb crops, leafy green vegetables, fruiting crops, flowers and beans [36].

The classification of plants should be based on system design. Suitable plants for NFT are spinach, cabbage and lettuce also. Spinach belongs to the amaranth family be a classic superfood and is one of the best leafy vegetables that can be grown in this NFT system because they are shallow roots to avoid clogging the pipes in this system [25]. Spinach growing as a perennial which can be cut back to ground level each year and having a short-duration production cycle of 30 to 48 days in a soilless partial shade culture with growing as tall as 30cm with appropriate cultivars and manipulation of the temperature [37]. The new leaf is encouraged to grow if using a downward pulling motion to harvest the plant. It is rich in minerals such as iron nutrients as an essential trace element required by the human body for red blood cell production. Spinach is also a quite rich source of polyphenolic antioxidants vitamin like vitamin-A and vitamin-C which able to help the eyes to maintain the clarity of eyesight [38].

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2.4.2 Growing Media ITI TEKNIKAL MALAYSIA MELAKA

Another important part of the hydroponic part of aquaponics, is to choose the right type of growing media. There are several conventional substrates for hydroponic seedling production for instance DWC and NFT as shown in Figure 2.5 and Figure 2.6 respectively [39]. Every material's goal is to make good physical contact with seeds. Organic and mineral components, as well as synthetic media such as plugs, cubes, and blocks, could be used as substrate sources. The choice is frequently determined by local availability, decomposition speed, and the number of extra solids required. Mineral components and synthetic media should be included in the growing media. Some systems, such as DWC or NFT, necessitate the use of a container and grow-up material for the plants to retain them in place and ensure root support. Plastic cups, pots, and nets with an extra-wide lip are commonly used for this. Additionally, there should be both enough holes to hold back the substrate and enough holes to ensure optimal root growth.



Figure 2.6: Nutrient Film Technique (NFT). [39]

2.5 Aquaculture

The term aquaculture refers to the cultivation and rearing of aquatic plants and animals in a fully or semi-controlled environment for recreational, commercial or public purposes. Aquaculture is one of the fastest growing food production sectors in the world. Globally aquaculture already supplies 62.5 percent of the world's fish consumed by humans, a proportion that continues to rise with the growing world population. In the 1970s, 3 million tons of food were produced by aquaculture and increased steadily to over 100 million tons in 2018 [40]. Meanwhile, annual global fishing harvests have been flat for 40 years and are not expected to increase in the future as shown in Figure 2.7 [41]. Hence, aquaculture is widely recognized as an effective way to meet the food demands of population growth. A rule of thumb has been developed in an attempt to show the advantage of connecting aquaculture with hydroponics to the system aquaponic. In aquaculture, 1kg of fish meat produce by given each kg of fish food, but in aquaponics 1 kg of fish meat and 5-10 kg of vegetables can produce by given each kg of fish food.



Figure 2.7: The Global Production [41]

2.5.1 Types of Fish

Fish play a vital role in an aquaponic system that is the source of natural fertilizer for the plants to grow, which means fish is the starting point of the cycle. To determine which type of fish is the best for sustainable development, it must first be determined whether they are merely to support the plants and similar needs with plants as far as temperature and ph. This implies that the aquaponics system's economics and marketing possibilities must be considered. As well as how much management the species requires, how much it is desirable to raise and market, and what climate conditions exist. Catfish is one of the most emblematic and important freshwater aquaculture species in Southeast Asia. This air-breathing catfish feeding behavior results in the accumulation of feed and feces as excretory wastes in water. This nutrient-rich catfish wastewater has the opportunity to be used as an agricultural fertilizer additive [42].

2.5.1.1 Fish Decision

The sorts of fish chosen are based several factors, including the plants that are willing to grow, the water temperature, and the fish's ability to reproduce. It is critical to select the most appropriate species for each system. Catfish is one of the popular species that is ideal for beginners. They are disease-resistant and can withstand and can withstand changes in water quality, water temperature, and pH. Some catfish can breathe air and will not perish if the water supply or the air supply is interrupted. They thrive in highly stocked aquaponics systems and are polyculture-friendly [43]. Hence, it is likely that the fingerlings for stocking will have to be imported and often in huge quantities because it may be opted to use locally accessible fish species in a certain instance.

Another benefit of local fish its cost-effectiveness. Buying local fingerlings may eventually be less expensive than importing common catfish. Although high-producing countries like Thailand and Vietnam export catfish, the commodity is mostly consumed in Asia's local market. Catfish has two primary markets, live fish and processed fish. When compared to processed forms such as fillet, live fish demands a greater premium [44]. In aquaponics, the optimal temperature for catfish is 26°C to 30°C [45]. Since aquaponics is one closed water cycle, it's worth noting that cooler temperatures limit metabolism and food consumption, lowering the nutrients available to plants and decreasing the efficiency of the catfish aquaponics system. Therefore, the growth of fish and plants is aided by a warm environment. However, catfish are a hardy species that can thrive in most climates.

2.5.2 Fish Feed

Changes in all parameters are possible in an aquaponic system because it is not always easy to maintain. But catfish can survive in a wide range of environments that are frequently utilized to reduce the risk of high fish losses. In general, the amount of feed feeding the catfish is 3 percent of their body weight and three times per day is recommended for maximum growth [29]. Of course, won't be able to weigh them all, but can make an educated guess. Excess food floating or dropping to the bottom of the tank indicates that we are feeding them too much. If feeding them enough, they may be particularly anxious to eat, or they may swim in areas of the tank where don't normally see them. If each of these things occurs, the feed should be adjusted slightly until the correct balance is achieved [22]. Because proteins, fats, vitamins, carbohydrates and minerals must all be in the right proportions for fish to thrive. For small-scale aquaponics systems, commercial feed pellets are highly recommended, especially in the beginning [26]. Users can preset timings fish feeder dispenses fish feed of the day to increase fish growth [46].

2.6 Water Treatment

In traditional fish farming depletes natural resources and pollutes the environment, but it also has other problems, such as water treatment challenges and inefficient aquaculture [47]. In general, the input to the aquaponic system is completely turned into fish and plant growth, therefore water treatment is only necessary to convert surplus nutrients from the fish to a form that plants can utilize. As a result, bacteria in the biofilter perform this function [20]. Some inorganic chemicals found in fish food are also a source of solids. Before the inorganic compounds enter the system must exist as dead matter. Hence to prevent uncharged particles from accumulating in other sections of the system, a mechanical filter is used to remove solids and biofiltration converts toxic nitrogenous wastes to non-toxic nitrate [48].

2.6.1 Mechanical Filtration

Mechanical filtration is the process of removing unwanted particles and solid waste from a system in order to keep the system healthy. Approximately 25 percent of feed given to fish will be excreted as solid waste. If the solid waste is left to decompose inside the fish tank, then anaerobic bacteria will generate toxic gases which harm the fish [48]. Furthermore, the wasted solids can restrict water flow and clog systems, resulting in the plant roots in anoxic conditions or adhere to the roots decrease oxygen levels as they decay and affect the uptake of water and nutrients. The easiest way with the function of removing solids is to locate a screen or filter between the fish tank and the grow bed or use a settling tank. These methods are valid for some small-scale aquaponic units [49].

2.6.2 Biofiltration

Biofiltration is the conversion of nitrite and ammonia into nitrate by living bacteria. Since aquaponics is a closed-loop recycling freshwater system that combines aquaculture with hydroponics. After the nitrification process, the wastes produced by the fish become nutrients for the plants to grow [46]. However, several other bacteria are usually involved in transforming nutritional sources or supporting the primary functioning bacteria. This bacterial collection is known as biofilm, and it can grow on almost any non-antibacterial
surface. Hence it's necessary to control the pH value to ensure ideal quality standards of water otherwise the accumulate of ammonia in the water deadly for the fish [20].

2.7 Parameters

It is critical to monitor and maintain various parameters in the aquaponics system to ensure that the fish and plants remain healthy. Parameters are quantifiable, measurable, constant or variable characteristics, dimensions, properties, or values are chosen from a set of data or population because they are considered essential to comprehending a situation or addressing a problem. The ideal parameters for aquaponics as a negotiation between pH and temperature.

2.7.1 Water Temperature

Every type of fish has a different origin to live in a different environment. All aspects of aquaponics systems will affect by water temperature. Water temperature also is critical for bacteria. The range from 25 °C to 34 °C is the ideal temperature for nitrifying bacterial growth and productivity [20] [19]. While the temperature between 20 °C and 30 °C is suitable for most plants and fish to absorb nutrients and grow respectively [26] while acceptable water temperature for spinach is from 16 °C to 33 °C [22]. Hence the suitable water temperature for aquaponics is in the range of 25 °C to 30 °C [26]. The water temperature should be controlled and maintain depending on the type of fish is used, otherwise fish can suffer and stop feeding until death [50] [22] then plants will start to wilt [22] and their growth is inhibited [26] . The most common way to measure the varied water temperature is with a DS1820 temperature sensor. The temperature range is from -55°C to 125 °C with ± 0.5 °C of resolution. The accuracy of the sensors used compared with the reading of thermometer is

quite high with an average success rate of 97.907% [26]. This sensor also must not only be waterproof but also capable of being submerged for long durations. [20].

2.7.2 Power of Hydrogen

The power of hydrogen (pH) is one of the most important water parameters in aquaponics systems refers to the concentration of hydrogen ions, acidity or alkalinity in a solution because it regulated microbial activities, fish metabolism and nitrogen availability to plants. At the same time, it needs to maintain a balance among fish, plants and bacteria [19]. The range of pH is from 0 to 14. Value 7 is being neutral, while pH levels below 7 being acidic and value between 7 and 14 being alkaline or basic. pH levels will fluctuate daily due to the photosynthesis and respiration of fish in water. Recent studies inferred to maintain pH levels around 6.0 are acceptable for most plants to grow [20] [19] but spinach growth best in pH 6.0 to 9.0 and aquaculture tank can under wide range from pH 5.5 until 10. On the other hand, the range in 7.5-8.5 is optimal pH for nitrification in biological processes [19]. Moreover, the aquaponics system can set at a stable level from 6.5 to 7.5

[20]. UNIVERSITI TEKNIKAL MALAYSIA MELAKA

If the pH value out of the appropriate range, the nitrification will slow down or stop to accumulate ammonium in acidic solution become toxic to the fish, injured plant roots even lead to the death of living components in the system [20]. pH measurements can be obtained using a pH meter sensor [33]. This sensor is suitable to test with different degrees of acidity due to its reading matched to the reading on digital pH meter up to 92.353% of average success, meanwhile, only 7.67% is average error [26], hence all reseach have used this sensor to test to pH level to ensure they are suitable for plants and fish to grow. By using carbonate-based rock like crushed coral can safely rase pH and buffering. While decorating generously with natural driftwood help reducing pH value but it takes a fair amount of driftwood to have

the desired effect or can be added with rainwater hydroponics acids to maintain optimum pH levels [51].

2.7.3 Light Intensity

Sunlight is required for the wellbeing of the plants in the aquaponics system but it unavailable or limited in indoor facilities [20]. Therefore artificial lighting is placed in aquaponics systems to provide light to the plants enhance photosynthesis [20] [22]. Therefore, plants require specific light frequencies, intensities, and hours of light every day [33]. Plants required 12 to 16 hours of light every day as the energy source of photosynthesis. Contrary to plants, water does not require direct light for preventing grow of algae and maintaining water temperature [20]. The light spectrum called photosynthetically active radiation (PAR) is used for plants to process photosynthetic organisms. If the PAR level too low, plants will become bitter else if too high of PAR will greatly diminish the growth of plants. Hence component light dependent resistor (LDR) can uses to measure the light intensity [33] [2] by vary the photon flux density (PPFD) and light intensity (lux or lumens).

2.7.4 Water Level

Three major reasons for water losses occur in every aquaponics system are evaporation, plant evapotranspiration, and fish splashing when feeding [20]. Ultrasonic sensor is advanced for measuring the fluid at the same time it also can check if there anything blocked of water flow since it functions to measured distance [33] [20]. It also is proved only 0.43% measurement results error with measurement results of manual procedures using a ruler [26]. Subsequently, the amount of water needed in aquaponics system depends on the size of fish tanks [20].

2.7.5 Quality and Growth Rate

The health of the fishes based on the known physical reactions, for example, red areas in the eyes when the ph level is too high [20]. Except for the weight be a growth rate, the parameter used for fish and plants are length or height respectively by using a ruler [26].

2.8 Controlling Aquaponics

Regularly inspecting and controlling the aquaponic system is critical for detecting possible problems and resolving them before they harm the plants or fish. Plants and fish must be checked visually, while by helped of sensors, people without having to be physically near the aquaponic and monitoring could be performed using smartphone application programs for time savings and reduced workload [33]. The control system of the project can be divided into five modules such as data acquisition, a system rectification unit, processing units, a graphical user interface (GUI), internet of things (IoT) and cloud based solutions.

اونيوبرسيتي تيڪنيڪل Data Acquisition Unit

The data acquisition units are made up of numerous sensors that collect data from the aquaponics system on a continual basis [33]. Data visualization and analysis in real time will be provided after uploaded the data acquisition from the sensor to IoT analytics platform [2]. The aquaponics system used 90% less water than traditional farming if monitoring these data and making appropriate modifications to the system [2].

2.8.2 System Rectification Unit

The smart agriculture system is then designed by linking a mobile application with an internet network. The system can either rectify on its own or notify the user through their mobile application. For the moment of rectification, the system may make adjustments by activating the outputs. [46].

2.8.3 **Processing Units**

Sensors are transformed physical quantity into electrical current. Therefore microcontroller must be used in order to transform it into information that understandable for the user. Arduino acts as a microcontroller with a 5V energy supply and it was simply uploaded via a USB cable and utilizes a simplified form of C++ to program it [33]. For the electric equipment which more than 5V can use with relays therefore the higher voltage actuators to be controlled by turning on or off appropriate electric circuits.

Although microcontrollers are great at reading sensor data, they aren't designed to present or store the data to the user. So, an actual computer must serve as the system's Central Control Unit to accomplish it. A popular solution is to use a Rasberry Pi [20] because recent versions of build-in Bluetooth and Wi-Fi allow the microprocessor to send the data. Then a Graphical User Interface is needed for the user to see the data after connected to the Pi or a website can be hosted on it. But the Rasberry Pi is more expensive than arduino, hence a low-cost Wi-Fi module ESP8266-01 or Bluetooth module could be used as the communication medium between arduino and dashboard online [33]. The arduino allows the user to receive a message, do the data logging and more through the implementation of IoT. Hence, people can control their system whenever they are in the world [2]. But first, arduino must be programmed with software Arduino Integrated Development Environment (IDE) to specific instructions for all hardware, as required by the project.

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2.8.4 Graphical User Interface

The Graphical User Interface (GUI) is the interface of the user with aquaponic system and sensors. A GUI can display the status of several sensors and the capacity to control various actuators. On the other hand, it's an option to allow the group to accomplish the same goal with spending less time learning the language. The main precaution to design a GUI is ensure it to be accessed via the internet.

2.8.5 Internet of Things and Cloud-Based Solutions

In today's culture, smart and linked objects are becoming increasingly prevalent. The main objective of Internet of Things (IoT) is to enable industrial machinery to communicate with one another and to create a framework for data-driven choices to be made without the need for human intervention [20]. Various components used to make the IoT such as Wi-Fi module ESP8266 ESP-01 [26] [33] [20], GSM shield [22] and Bluetooth module HC-06 [52]. Whereas MQTT broker [33], Node-RED [33], Ubuntu IoT Cloud [26], ThingSpeak [20] and MIT app [33] [52]exist solutions to monitor the IoT elements in real time via internet network. The primary benefit of utilizing these technologies is that the majority of the programming work has already been completed. There are existing portions of code developed to execute various functions that may be merged and utilized as needed for the project like monitoring interfaces, remote applications and wireless technologies [20]. The ability of remote control applications is to signal system actuators to interact or alter certain parameters [2]. Open-source solutions are frequently preferred since they are extensively documented, updated on a regular basis, and do not rely on a corporate firm to function.

2.9 Overview of Studies

In this section, several studies that are related to previous researches on aquaponics system. Table 2.1 shows the summary of information gathered from previous various paper.

Element	Approach	
	Nutrient film technique (NFT) [19] [20] [26] [29] [46]	
Types of aquaponics	Media bed [2] [19] [22] [53] [24]	
	Deep water culture (DWC) or Raft [19] [33]	
	Arduino MEGA [33] [22]	
Transis of comparison line	Arduino Nano [2]	
Types of controller	Arduino Uno [20] [53]	
	Raspberry Pi [46] [2] [20]	
Parameters	pH level [2] [20] [26] [42] [22] [46] [53] [24]	
	DS18B20 Water temperature [26] [42] [22] [46] [33] [53]	
MALAYSI	[24] [20]	
(F)	Water level [2] [26] [22] [20]	
a de la companya de	Light intensity [20] [22] [46]	
pH sensor	pH meter sensor [2] [20] [26] [22] [46] [53] [24]	
Water temperature sensor	Water temperature sensor, D18B20 [26] [22] [46] [33]	
	[53] [24] [20]	
* d a a	Thermometer [26] [46]	
Water level sensor	Ultrasonic sensor [2] [20] [26] [22] [46]	
511.	Radar sensor [20]	
Light sensor	Light dependent resistor, LDR [20] [22] [46]	
Actuators	Exhaust Fan [22]	
UNIVERSIT	LED [46] KAL MALAYSIA MELAKA	
	Lamp [22] [33]	
	LCD [2] [20] [26] [22]	
	Servo motor with fish feeder [26] [44] [22] [46] [53]	
	Water pump [26] [22] [33] [53] [24]	
Types of fish	Goldfish [24]	
	Tilapia [26] [22] [46] [53]	
	Catfish [33] [42]	
	Koi-Carp [2]	
Type of plants	Lettuce [20] [26] [22] [33] [42]	
	Spinach [46] [22] [29]	
	Basil [24]	
	Cabbage [20]	
	Parsley [24]	
	Tomato plants [2]	
	Coriander plants [2]	
	Mint [19]	

Table 2.1: Findings from various paper

For types of aquaponics, the methods of media bed and NFT are used for five different types of research to propose their system. The mainboard that was used by a majority of researchers was Raspberry Pi microprocessor because its built-in Bluetooth and Wi-Fi allow the microcontrollers to send the data without using another module as the communication medium between the microcontroller and dashboard online. Subsequently, both the number of research to measure and monitor the parameters of pH level and water temperature are eight types of research. Seven out of eight researches are use pH meter sensor to measure and obtain the pH level of aquaponics. There also seven out of the eight research are used D18B20 temperature sensor to measure the varied water temperature. But, two out of the seven research have to be used a thermometer to compare the accurate reading of the sensor.

On top of that, major of the researches are mainly controlling the servo motor combined with fish feeder due to it's the main input source to maintain the whole system under healthy and sustainable condition due to the uneaten feed in aquaculture effluent contains many nutrients that promote plants cultured hydroponically for growth. Meanwhile, plants and fish species reared by numerous research are Tilapia and Lettuce. Table 2.2 and Table 2.3 show the trade-off of types of aquaponics types and board respectively. Then Table 2.4 shows the parameters range and potential effects in aquaponics system.

Types of aquaponics	Types of plants	Advantages	Disadvantages	
Nutrient film technique	Lettuce [20] [26]	 The system has some flexibility. High yields and quality production. Minimal use of materials. 	 It cannot withstand unexpected power loss. Water susceptible to temperature fluctuations 	
(NFT) [19] [20] [26] [46] [29] Cabbage [20] Spinach [46] [29]	4. Easy to check roots for signs of disease.	 Not suitable for large fruiting plants. Requires additional filtration to remove solids. Easily cause blockages in water flow. 		
	Wanno -	1. Resistant to unexpected power failure.	1. The environment is relatively closed and diseases are liable to spread.	
Media bed [2] [19] [22] [53] [24]	Spinach [22] Tomato plant [2] Coriander plant [2] Basil [24]	 Self-cleaning to filters out the fish waste. Performs filtering functions such as 	 Facilities investment is relatively high. Low yields and quality production. 	
	JNIVERSIT	mechanical and biofiltration.	4. Expensive growing media	
Deep water culture (DWC) or Raft [19] [46] [33]	Lettuce [22] [33] Mint [19]	 High yields and quality production. Resistant against water temperature and pH fluctuations. 	 Not suitable large fruiting plants. Requires additional filtration to remove solids. 	

Table 2.2: Trade-off of aquaponics types

Table 2.3: Trade-off of controller

Types of controller	Price	Connectivity	I/O pins	Flash Memory	Ethernet/ Wi-Fi/ Bluetooth	Programming Language	Power failure safe
Arduino MEGA [46] [33]	RM75	USB	 54 digital pins with15 of them have PWM. 16 analog input pins. 	256kB	No (a shield or module can enable it)	C, C++	Yes
Arduino Nano [2]	RM32	Mini USB	 14 Digital pins with 6 of them having PWM 8 analog input pins 	32kB	No(a shield or module can enable it)	C ++	Yes
Arduino Uno [53]	RM50	USB	 14 Digital pins with 6 of them having PWM. 6 analog input pins. 	32kB	No (a shield or module can enable it)	C++	Yes
Raspberry Pi [46] [2] [20]	RM114-RM164 (depending on version	Power adapter and USB	• 40 GPIO pins	None (SD card)	Yes	C, C++, Python, Java, HTML	No



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Parameters	Aquaculture range	Hydroponics	Aquaponics	Low level effect	High level effect	Species
		range	range			
pH level	• 6.5-9.5 [20]	5.5-7.5 [19]	• 7-7.5 [26]	Slower the rate of	Plants suffer	Spinach [22]
[2] [20]	• 7.1-7.4 [42]	[20] [22]	• 5.5-8.0 [22]	fish reproduction.	from nutrient	Tilapia [22]
[26] [42]	• 6.0-9.0 [22]	Winger	• 6.0-7.0 [19]	Plants suffer from	deficiency [20]	Lettuce [26]
[22] [46]			• 6.5-7.5 [20]	nutritional deficits as		Catfish [42]
[53] [24]	3			a result of root		All types of fish and plants
	3		1	damage. [20]		[19] [20]
Water	• 25-32 °C [20]	18-30°C	• 25-30 °C [26]	Increase the risk of	Increase the risk	Spinach [22]
temperature	• 28.9-30.9 °C [42]	[20]		vulnerable to illness	of vulnerable to	Lettuce [20]
[26] [42]	• 16-33 °C [22]			in fish [20] [22].	illness in fish	Catfish [42]
[22] [46]				Stop working of	.Fish stop	Tropical fish [20]
[33] [53]	8	· · ·		nitrification bacteria.	feeding and plant	All types of fish and plants
[24] [20]		Alter		[22]	growth be	[26]
		CONTRACT OF THE OWNER OWNER OF THE OWNER OWNE OWNER OWNE			inhibited [22]	
Water level	1000 litre per 20kg		11/	Fish stress is causing	Nutrient	All types of fish
[2] [26]	of fish [20]	La Lun	-1- al	a rise in health	deficiency for	4 6
[22] [20]			. 0	problems [2].	plants [20].	
Light		600-900		Slow rate of	Plants begin to	All types of plants
intensity	LIMI	(PPFD)	TEZMIL	photosynthesis [20]	wilt and roots	
[20] [22]		VEROII	I I E-MINIP	[33].	begin to	INA
[46]				LJ'	discolour. [20].	
L ~J						

Table 2.4: Parameters range and potential effects in aquaponics systems.

From all the information gathered above and the scope of the plant is spinach, the NFT method is chosen because it only used minimal materials to set up and the roots of spinach easily to check for signs of disease. Besides, the root of spinach cannot submerge too much due to it might decay and die of plants. Although the media bed appears to be competitively good, it is not chosen because of its expensive media and low yields and quality production. However, the Arduino Uno microcontroller is chosen as only 5 actuators be controlled such as exhaust fan, two tube lights, servo motors, water pump, besides that only requires 4 sensors to control these parameters. Therefore the I/O pins of Arduino Uno suitable for this agriculture system. Even many researchers used the Rasberry Pi due to its built-in Bluetooth and Wi-Fi allow the microprocessor to send the data for the user but the WiFi function in Rasberry Pi can be replaced by a low-cost WiFi module NodeMCU be a communication medium between Arduino Uno and dashboard online.

Water temperature and pH are the two most crucial parameters to balance. The ideal water temperature range is from 25 °C until 30 °C for aquaponics system to all target plants and fish species being cultivated. It is suggested that the pH be kept at a compromised level of 6.5–7.5 around neutral. The overall purpose of temperature and pH is to keep a sustainable system with water quality parameters that allow for simultaneous growth of plants, fish and microorganisms. Therefore the water quality is always actively controlled and maintained to achieve these criteria and keep the system operating properly. Subsequently, the maximum water level for aquaculture depends on the size of fish. But the decreasing water level due to evaporation, plant evapotranspiration and fish splashing, an water level sensor can be used as liquid level measurement since it is partially waterproof while ultrasonic sensor is totally unwaterproof. Light is compulsory for plants to do photosynthesis. An undeniable LDR sensor is used to detect the light, hence in dark conditions, tube light will automatically turn on to supply light energy to plants for growth.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter aim to discuss the project's methodology. In the project methodology, a few steps are taken to achieve the project's objective. As mention before, the selection of fish and plants will be catfish and spinach with the NFT method. The parameters that are taken in this system are water temperature, pH water, light sources, water level and growth rate (g/week). The project's hardware and approach will also be discussed in this chapter. Moreover, this chapter also includes a flow chart, hardware and software implementation and a block diagram.

3.2 Project Workflow

The progress of this research was started by understanding the title given. Then, the argument, discussion and flaws of the various thesis were studied. After that started to do research canvas based on previous paper and journals that related to the title and discussed with the supervisor for approval. Once the research canvases were approved, the problems, objectives, questions, theoretical or conceptual framework, a method to answers the question part, expected findings, conclusion and future work based on own title were determined and get approval from the supervisor again. Following the approval of the findings, studies on previous researches based on the title were carried out. For better comprehension, the fundamental knowledge of the project's elements was revised. Furthermore, the system's flow, design and construction were planned and discussed with the supervisor. After everything was agreed upon, the scheduled experiments were carried out to acquire the

desired result. Finally, a proper conclusion was reached about the investigation, and the general findings will in BDP 2. Figure 3.1 depicts the above-mentioned explanations as a flow chart.



Figure 3.1: General flow chart of the project

3.3 Process Flow of the System

The Figure 3.2 show the flow chart of the smart agriculture monitoring system. With the ON water pump, the smart agriculture system will begin. Then LCD will display "Smart Agriculture Monitoring System". There have three conditions of pH value, either less than 6.5, more than 7.5 or between both of the values. Depending on the pH value, LCD will display either too low, too high or normal. After that, light is the main source for plants to do photosynthesis, so if the analog input of LDR is less than 200, the red led on top of plants will turn ON to provide the light for plant growth, otherwise, the tube light will always OFF. Hence LCD will display the condition of tube light either on or off and the light condition either dark or

Furthermore, the water temperature sensor, DS18B20 used controls and maintains the water temperature. If the water temperature is less than 26, the white tube light will turn ON to provide the heat energy to water in a fish tank. If the water temperature more 35°C, the tube light will turn OFF and turn ON the exhaust fan behind the fish tank to decrease the temperature value. The LCD also will display the current temperature and condition of the light and exhaust fan. Moreover, due to evaporation, plant evapotranspiration, and fish splashing when feeding, the water of the fish tank will be decreased from time to time, hence water level sensor plays a role to maintain the water level by turn ON the second water pump when the distance between surface water and that sensor is less than the desired level, 260. Next the servo motor turn on every 6 hours. All data only displayed on LCD also display on the mobile application. Hence, for additional, the user able to control all the actuators use the mobile application. When all parameters and devices are satisfied, the catfish will be placed inside the fish tank and the spinach with a pot placed in PVC pipe. Both of them are measured every week using a weighing scale and ruler.



Figure 3.2 Flow chart of smart agriculture monitoring system

3.4 System Design



Figure 3.3: Illustration front view of smart agriculture monitoring system



Figure 3.4: Illustration side view of smart agriculture monitoring system

A water pail with 4 gallons is filled with spare water for the fish tank. Then, the owned fish tank with the size of 57cm x 28cm x 34cm is used for this prototype without buying the new fish tank. Then two PVC pipes with 6.5cm diameter and 55cm long are used to plant the spinach. On top of PVC have 4 holes of the same size with the diameter of the pot around 5.5cm. While the gap in between each hole is 7cm ensure the spinach can grow in an optimal size of 2.5cm to 4cm if the gap too small will affect the growth rate of plants. The bottom tank will be filled with water and fish. Plants will be in the pipe at the top. Vegetables can be planted in pots and placed in the PVC pipe's holes, or directly placed in the holes. It is important to ensure that the roots of the plants can accept the water flowing from the fish tank. Using a submersible pump, the water in the fish tank will be pumped up to the PVC pipe. The nutrient-rich water travels through the roots of vegetables, allowing them to absorb what they require. The fresh water will then spill out of the PVC pile and into the fish tank. There would be no need for an external aerator for the fish tank because the water is oxygen-rich. As the system runs, the water in the fish tank is cleaned automatically, so the user does not have to clean the water in the fish tank regularly.

This prototype is placed indoor due to avoid direct light toward the fish tank for preventing grow of algae and easy maintaining water temperature. The hydroponics system is placed above the fish tank to ensure the plants absorb enough light to grow. Red T5 tube light is chosen as prototype to provide light to spinach to do photosynthesis while normal white T5 tube light is only used to provide heat energy to warm the water temperature in the fish tank.

3.5 Block Diagram

All the sensors' data will send to the microcontroller. Then microcontroller will send signal to the actuators to monitor or maintain the system. Since the Arduino use as a

microcontroller, it only with a 5V energy supply therefore relays are used in between microcontroller and actuators. All the situation of actuators will display by the LCD and the data will store to the cloud. User can check the current situation of aquaponics by mobile application. WiFi module act as a transceiver in this project. It allows microcontroller Aruduino Uno to access the WiFi and updated the data to cloud. Lastly, the WiFi module builds a connection between user and the microcontroller with it component.



Figure 3.5: Block diagram of proposed system.

3.6 Hardware and Software

In this project covering microcontroller, sensors, actuators, web interfaces and mobile application for monitoring agriculture system. The function and application of each of the components are discussed in this subchapter.

3.6.1 Microcontroller

In this aquaponics system, the total pins used for analog inputs is 5 which are one pin for the LDR sensor, one pin for pH sensor, another 1 pin for water level sensor and the 2 left pins for IC2 LCD. Then for digital pins only used up to 10 pins in this proposal. Most of the standard voltage required for actuators are below 5 V except the motor pump in the range 220V to 240V. Figure below clearly shows the pins requirement and connection. The Arduino is chosen for this prototype due to it has 6 analog pins and 14 I/O digital pins, hence still has some pins that are unused be backup pins. Compared to the Rasberry Pi which more expensive, using Arduino Uno also can reduce the expenses. Besides that, the operating voltage of this Arduino is 5V by simply connect with a USB cable to the device without any other adapter. Meanwhile for high voltage of actuator only added relay to trigger them. The Arduino built in analog to digital converter (ADC), then convert the analog voltage from 0 to 5V into a digital value in the range of 0 to 1024. It easy to operate by using the software Arduino Integrated Development Environment (IDE) to write the source code and run the program. The Arduino pinout board is shown in Figure 3.6.



Figure 3.6: Arduino Uno pinout [54]

3.6.2 WiFi Module

The WiFi module is used for controlling the microcontroller toward the actuator through a mobile application. Microcontroller, WiFi module and mobile phone are used as master to set up a successful wireless connection. Since Arduino Uno is used therefore the operation voltage for the interface module is under 5V. NodeMCU module is chosen to interface and to communicate with the microcontroller and the user. This module is the most cost-effective solution for all types of wireless communication currently available on the market. It consumes very little power to operate which in 3.3V or 5V. WiFi module has safety features due to authentication and encryption.



The following code is to connect the WiFi and using the serial monitor. To handle this module, the library SoftwareSerial.h should be used to define the Serial port on the microcontroller board.



Figure 3.8: Souce code NodeMCU connect the WiFi and using the serial monitor

3.6.3 Relay

Relay is known as a programmable electrical switch controlled by the microcontroller. Relays can trigger high voltage and high current actuators such as water pumps and tube lights that are used in this aquaponics system. Simple to say, it is a bridge between the microcontroller and high voltage devices. Therefore 3 digital 5V output controllable relay is chosen as shown in Figure 3.9 due to arduino only powered up to 5V. This module delay has a relay rated up to 10A per channel at a maximum 250VAC or 30VDC. After connection, the red power LED will light up, while the green status LED only light up when activated. Furthermore, the relay has two groups of pins such as the low voltage group and high voltage group. In the high voltage group only use two of them either use COM pin and NO pin if used normally open mode or used only COM pin and NC pin if the normally closed mode is used. Table 3.1 and

Table 3.2 show the connection of relay between microcontroller and actuators.



Figure 3.9: Relay pinout [55]

Table 3.1: Low	voltage	group
----------------	---------	-------

Relay	Microcontroller
Ground pin	Ground (0V)
VCC pin	VCC (5V)
Input pin	Receives the control signal

Relay	High voltage device
Common contact	Used in both normally open and closed mode
Normally open	Used in normally open mode
Normally closed	Used in normally closed mode

Table 3.2: High voltage group

3.6.4 Light Sensor

Light dependent resistor (LDR) sensors are electronic devices that indicate the intensity of daylight or artificial light. They convert light energy to electrical signal output. The voltage input for LDR is 5V hence it can straight aways connector to the analog input of the microcontroller through a resistor. When there is sufficient light on the LDR sensor surface, the microcontroller will read the analog input and convert it to a digital value in the usual range of 600-1024 and then trigger the relay to OFF Red LED T5 light tube. When the brightness is low meaning that the digital values less than the usual range, the tube light will turn ON.

The red light tube provides wavelengths of 400nm and 700nm to contribute photosynthesis hence the red LED T5 light tube is chosen for my prototype to provide light to spinach to do photosynthesis. It also provides more brightness than the type of T8. There has various length of T5 light tubes such as 1ft, 2ft and 3ft are commonly version, while 1ft length is chosen to match the hydroponic growing bed size gives the most bang for the buck. Compared to cheaper fixtures like LED on the market which does not have an attractive spectrum selection and many are rather weak for growing plants hence tube light is more suitable..



Figure 3.10: Light Dependent Resistor [56]



The pH scale is used to determine the acidic or basic a liquid is. It has a range of values from 1 to 14, with 1 indicating the most acidic liquid and 14 indicating the most basic liquid. A neutral material with a pH of 7. The pH plays a very important role in the aquaponics system because it regulated microbial activities, fish metabolism and nitrogen availability to plants. Since the aquaponics system requires continuous pH monitoring to identify and record changes, low-cost test strips are not used because of the limited resolution. It has less potential to be accurate when compared to pH meters sensor. Besides that, test strips only are manually used for one measurement, but pH meter can automated report the pH value continuously. Once the pH out of the desired range, then the notification will alert the user adding specific material to correct the pH to provide optimal growing

condition. Without using the chemical substance, crushed coral and driftwood are the best choices to safely rise or drop pH.



Figure 3.12: Glass-electrode pH sensor [53]



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The water temperature supply to plants and fish can be mesuared just using the water temperature sensor in the fish tank since the aquaponics system is a recirculation system. The optimal water temperature range for both fish and plants is from 26°C to 35°C. This proposal project uses the DS18B20 that comes in a waterproof temperature probe form. The DS18B20 temperature sensor is a one-wire communication protocol and provides 9 to 12-bit temperature readings with a maximum 750ms conversion time over a 1-wire bus. The operational temperature ranges from -55°C to +125°C with accuracy±5. This sensor can be powered with 3V to 5.5V power supply without any external power supply and consumed only 1mA during active temperature conversions.

Furthermore, before uploading the source code, need to set up the two libraries such as OneWire and DallasTemperature for running in Arduino IDE. Then, arduino will read the analog input of the temperature sensor and convert it to digital value to trigger a relay, correspondingly turn on White LED T5 light tube to provide heat energy to increase the temperature water when the temperature value less than 26°C. While the water temperature more than 35°C, the exhaust fan turns on to decrease the heat energy. This light tube is chosen because it more fits the tank size compared which the cheaper fixtures LED on the market. It just uses the normal white colour to provide heat energy maintaining the water temperature due to water does not require direct sunlight for the preventing growth of algae.

The main reason for using the DS18B20 water temperature sensor is because it's waterproof and DS18B20 is a digital temperature sensor without affecting the output reading by input value and the signal will not degradation even over long distances. Besides that, a mercury-in-glass thermometer is not used due to it cannot give the input to the microcontroller, undeniable users can receive the temperature value through the mobile application with the help of WiFi module.

```
#include <OneWire.h>EKNIKAL MALAYSIA MELAKA
#include <DallasTemperature.h>
OneWire oneWire(ONE_WIRE_BUS);
DallasTemperature sensors(&oneWire);
Void setup(){
   Serial.begin(9600);
   sensors.begin();
}
void loop(){
   sensors.requestTemperatures();//get water temperature value
   float tempC=sensors.getTempCByIndex(0);
   float tempF=sensor.toFahrenheit(tempC);
}
```

Figure 3.14: Source code get reading of water temperature sensor



Figure 3.15: DS18B20 Temperature sensor pinout [57]



rigure 5.10. ritaunio temperature sensor workin

3.6.7 Water Level Sensor

Water losses always occur in every aquaponics system due to evaporation, plant evapotranspiration, and fish splashing when feeding. A sensor must be used to measure the water level of the fish tank. One of the good choices is the water level sensor being the traces can be submerged, not worry about the splashing compared with the ultrasonic sensor which is not waterproof. The resistance changed corresponds to the distance between the water's surface and the top of the sensor. If the more water immersed the sensor trace, the lower resistance. When the sensor is immersed in less water, poor conductivity becomes lower and result in higher resistance. The output level value gives by the sensor is from 0 when there is dry until 520 when it is completely submerged. Hence the 50% of the maximum value is set as the limit to trigger the actuator water pump. When level less than 260, the sensor will give a signal to the microcontroller and trigger the relay to turn on the water pump to fill the water until the desired water level otherwise the motor pump always off.



3.6.8 Liquid Crystal Display

The 16x2 I2C liquid crystal display (LCD) is a normal screen incorporated with the I2C module for displaying text and numbers. The usual LCD usually requires a lot more line coding and complicated wire soldering and connection, they will be a problem if do not have many I/O pins available like Arduino Uno. Therefore I2C LCD use 4 pins only such as SDA and SCL. SDA is the serial data pin and SCL is the clock pin. The rest pins for the power supply, Vcc and ground. The pin connection uses a normal jumper wire and can be connected directly. Hence this is its advantage by doesn't complicate the design. The potentiometer is just to adjust the LED backlight. This LCD can display all the current situations of the I/O device.



Figure 3.18: I2C LCD pinout [57]

3.6.9 Water pump

Then the type of water pump is chosen is depended on the height of the system. the total height of aquaponics system is only around 55cm. Since the fish tank is placed at bottom of the growing bed, therefore to ensure the water can be pump from bottom to top, the maximum height of the water pump and the power must be bigger enough. The owned water pump is used to reduce the expenses since it can support up to 1.5m of height with 220-240V input voltage.



Figure 3.19: Water pump

3.6.10 Fish Feeder

A single conventional analog servo motor is used with few basic materials to feed the fish every six hours. First of all, a gel pen refill attaches with small container head using adhesive. Then two serial small holes make on the plastic cup and ensure the refill and servo gear head can go into the cup. After that, the bottom of the cup makes two hole as three fish feed size. At the same time, the refill also makes the same size of the hole and properly center with the bottom hole cup. If there is no feed is getting out from the hole, the hole size can be bigger a bit until fish feed starts falling. The servo motor is rotating at 180 degrees to ensure both holes of the cup and refill should meet once.



Figure 3.21: Fish feeder

3.6.11 Fishes

The fish rear in aquaponics system is catfish with the scientific name of Siluriformes. The number of tails to the rear is depended on the growth rate and lush of plants. This is due to the excrete organic wastes of fish as a nutrition supply towards the plants. In initial, five tails of catfish will rear in the fish tank with around 15cm of their body length. If the plants still wilt under good controller and maintenance condition the number of fish can be added to provide more nutrients for plants growth. Since the stocking density of fish is lower, the external additional filtration is no required as nitrifying bacteria relies mainly on the roots of plants and the interior area of the canals.

3.6.12 Plants

Spinach is a vegetable that is used in aquaponics system by using the NFT method. The specific name of spinach is Ipomoea. Eight same types of spinach are got from the market and the roots will cut and put inside the hole of PVC with a small pot to prevent them drop into the PVC pipe and avoid fully submerged. The measurement repeat in 3 times as appropriate to get an accurate value.

3.6.13 Ruler

The long ruler with 0.1cm sensitivity is used to measure the height and width of plants every week. The spinach will take out from the PVC together with the small pot to avoid breaking the roots that will affect the growth rate. Before taking out the plants, the width will be measured to ensure not tighten them. Continue with the measurement height of plants from the bottom of the pot until the top of plants.



Figure 3.22: Ruler 49

3.6.14 Weighing Scales

The analog weighing scale is relatively low price than digital weighing machines. A scale is a device to measure the weight of plants of fish to determine their growth. The weighing scale 3kg with 100g sensitivity is chosen to get more accuracy compared with the analog body weight scale. The first step to measure the weight of fish is to fill a small bucket with the fish tank's water then weigh and record. After that by using a landing net, scoop the fish into the bucket but before put inside the bucket drain the landing net from the excess water for a few seconds to weigh again and record the gross weight. Furthermore, the total weight of fish can be calculated by subtracting the bucket weight that without fish. Lastly, repeat steps 3 times as appropriate to get an accurate value.



Figure 3.23: Weighing scales

3.6.15 Mobile Application

The live development environment for mobile applications is a significant element of MIT App Inventor. MIT App Inventor is a platform that allows the construction of a Java application without coding but using a block-based programming language. These platforms offer free drag-and-drop app builders that let people design Android applications. This App Inventor provides an excellent opportunity for inexperienced users to create and build a functional mobile app. The MIT app creator's aim in this project is to view the firebase in a real-time database. The real-time database in this smart agriculture project derives from sensor data. The MIT App served as the GUI of the system that allowed the user to control all the actuators of the aquaponics setup. Sensors values also will be displayed from the microcontroller as long as the smartphone connected to the Internet,

3.6.16 Cloud

Firebase is chosen for the cloud in this project. Firebase is a real-time database that also serves as a backend service. The service provides application developers with an API that allows application data to be synchronised with Firebase data stored in the cloud. Users who want to create immersive experiences can use this firebase as a cloud without worry about networking code.



Figure 3.24: Block diagram of Firebase

3.7 Software Design



This is the preliminary circuit for the smart agriculture system

Figure 3.25: Software design of the project

3.8 Summary

The overall design of the aquaponics system can be seen in Figure 3.3 and Figure 3.4. The fish tank will be placed at the bottom of the growing bed. The growing bed is designed using method NFT since the roots of spinach can't be submerged in water and the media bed is highly cost. The PVC is placed inclination to allow water pumped from the fish

tank to flow through the plants' roots and back to the tank to be a recirculation system. The specific dimension is discussed in part 3.3. The best choices of all the sensors detection are chosen properly to ensure the plants and fish can growing in heath condition.



CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This project works to develop an IoT based system to monitor and control the aquaponics system of spinach farms and catfish in good condition. This aim of this chapter is to discuss the design and the hardware implementation for the Smart Agriculture System. The results analysis on the performance of the system is observed when the system is out of the desired condition. Therefore motor pumps, LEDs and exhaust fan will be tested and the analysis is carried out by weighing and measuring the catfish and spinach respectively.

4.2 The Developed Smart Agriculture System

The design of the smart agriculture system had been discussed in this section. Figure 4.1 and Figure 4.2 show the development of the prototype in the smart agriculture system. The PVC design is rounded because it can be supported more readily by small PVC tubing than the initial design in **Figure 3.3**, which is supported by an iron rod. Due to longer PVC pipe hence there have ten same type of spinach plant in PVC pipe and five tails of catfish inside the aquarium. This aquaponic system is to be expected to have the healthy and fresh spinach as well as a good size of catfish based on their percentages increases in high and weight parameter respectively. For the smart agriculture system, Arduino Uno is used as the microcontroller to receive the signal from sensor, NodeMCU as the communication devices between hardware and the software and MIT App inventor and LCD is used to display the result. All the data collected from sensors will store in Firebase's cloud. Then for this project,
the aquaponics system has been placed in a shaded area without being directly exposed to sunlight for the preventing growth of algae.



Figure 4.2: Isometric view of prototype project 55



Figure 4.3: Enclosed box

The result of mobile application and the real-time situation are synchronized. Initially, users should sign up before login into the data page as show in Figure 4.4 and Figure 4.5 respectively. This is due to the reason that, Firebase's cloud can store the user enters credentials before validating them. The second reason is to secure the control page since there has manually control button as show in Figure 4.7. All the actuators turn ON only when the sensors' value out of predetermined value, however, the user can be manually operate the actuators by pressing the manual button on mobile app for additional part. The control button will not appear when pressing the Auto button on the main page of the mobile app to avoid overlapping the automation and manual functions toward the actuator. When the actuator is turned on, the icon in mobile app does not include the "/" symbol as shown in Figure 4.7. As a result, the current situation can be observed by going to the main page of the mobile app.

	Login
	Don't have an account? Sign Up
Figure 4.4	The login page of the mobile application
يسيا ملاك UNIVERSITI	اونيومرسيتي تيڪنيڪل ما Sign Up TEKNIKAL MALAYSIA MELAKA
	Username Username Password Create Account
	Already have an account? Login

Figure 4.5: The sign up page of the mobile application

	Screen1			
	loT Agri	culture Sy	stem	
	AU	TO MANUAL		
	Brightness	Normal		
	Plant Light	*		
	Water Temperature	28.69C		
	Aquarium Light	*		
	Fan	×.		
		•		
	Water level	Normal		
	2nd Motor	X		
	pH Level	6.97		
	Alkaline Solution	8		
	Acid Solution	X		
MALAYSI				
ST	190			
S.	Pr 1	Back		
ž –	>			
		C		
Figure 4.6: The	e main menu	of automati	cally mo	bile application



Figure 4.7: The main menu of manually mobile application 58



Figure 4.8: The real-time database of the project

When creating a new account, the username and password must have at least five characters and six characters recpectively as indicated in Figure 4.9 and Figure 4.10. At the same time, the username also cannot be repeated. While login the username or password must then match the registered account otherwise the mobile app will display' Wrong Username or Password' as seen in Figure 4.12. Once successful login, the mobile app will display the Success notification and welcome the user to IoT Smart Agriculture System as shows in Figure 4.13.

Sign Up Username must have at least 5 characters
▲ ^{abc}
0
Create Account Already have an account? Login

Figure 4.9: Username must have at least 5 characters

Scre	en1	
	Sign Up	
	Password must have at least 6 characters	
	abcdef	
	Create Account	
MALAYSIA	Already have an account? Login	
Figure 4.10: 1	Password must have at least 6	characters
For Seren		
ليسيأ ملاك	بتي تيڪر Sign Up	اونيومرس
UNIVERSITI T	EKNTry a different username_AYS1/	MELAKA
	Limyouqi	
	Username already exists.	
	Create Account	
	Already have an account? Login	

Figure 4.11: Username exists 60

	Screen1	
	Login Wrong Username or Password	
	▲ ^{aaaaaaa}	
	Don't have an account? Sign Up	
ALAYSIA	Don't have an account? Sign op	
and the second se	ANT ANT	
ـــــ		
Figur	e 4.12: Wrong username or passwo	ord
مسبا ملاك	IoT Agriculture System	وينوس
14 14		v - 4-
UNIVERSITI	Priortness NIK Aormal MALAYSIA	MELAKA
	Water Temperature 28.69C	
	Aqualium Lioh	
	Success!	
	Hi limyouqi. Welcome to IOT Smart Agriculture System	
	Wate	
	2nd Motor	
	pH Level 6.97	
	Alkaline Solution	
	Acid Solution	
	Back	

Figure 4.13: Login successfully 61

4.3 Result Analysis

4.3.1 Time Response

This section will go over the time it takes for updated results to be sent to Firebase and mobile app. The time responses for the agriculture system had been observed by comparing the time data sent and received from the sensor to Arduino Uno and then to NodeMCU. The time it took to receive data was recorded three times. The average of the time response of sent and received data was calculated and recorded in Table 4.1 based on the results obtained. The data are sent and received around 10 seconds to avoid the code sequence being too fast and making harder to interrupt. These 10 seconds still accessible to update the data because the agriculture system is not overly influenced.



Figure 4.14: Time response

Test	Time(s)
1	10
2	10
3	11
4	10
5	10

Table 4.1: Average time response

4.3.2 Accuracy Sensor and Actuators

This section is to discuss the accuracy of various types of sensor, including pH sensor, water level sensor, water temperature sensor, and LDR in both automated and manual settings. The accuracy of sensors had been observed by using mobile app and Firebase' data.



Figure 4.15: Result 1 of automation controller



Figure 4.17: Result 3 of automation control



Figure 4.18: Accuracy of sensors in automation control



Figure 4.19: Accuracy of actuators and button in automation control

The graphs in Figure 4.18 and Figure 4.19 show the accuracy of all sensors, actuators and the auto button. The scenario on mobile app is same as the data in Firebase as seen in Figure 4.15, Figure 4.16 and Figure 4.17. The pH level in between the predetermined ranges from 6.5 to 7.5, thus the alkaline and acid solution motor pump is off. For the water temperature that desired values for Albino Clarias Catfish is between 26 and 35, thus the both LED aquarium light and the exhaust fan are in off situation. After that, when touch light

is directed toward the LDR, the Brightness on the mobile app displays 'Normal' since the sensor value (Value_LDR) in Figure 4.15, Figure 4.16 is 945 and 933 respectively, hence the LED representing plant light is in off condition. When the LDR is covered by black plastic, the mobile app display 'Dark', which corresponds to data 43 in Firebase, and it trigger the LED plant light turns on. Then for the water level is always normal due to the sensor value are in 433, 431 and 430 hence water pump is always off in that three result. As a result, for all sensors, actuators and the auto button are accurate to 100%. Then below is the additional part for manually control.



Figure 4.20: Result 1 of manually control



Figure 4.22: Accuracy of actuators and button in manually control

The graphs in Figure 4.22 depicts the accuracy of actuators and the manual button. Based on the Figure 4.20 and Figure 4.21, when the user turns on and off the control button of actuators, the Firebase's data shows '1' when on and '0' when off. In conclude that, all the actuators are perfectly accurate.

4.3.3 Parameters Result

The monitoring section has been designed and developed with the goal of detecting and measuring the aquaponics system's parameters. The technologies utilized to develop this section has made it easier to percept ideal circumstances for fish and plants to thrive and grow healthy. Different sensors have shown different types of readings when compared for three weeks, the data that has been acquired through the used sensors have been shown below.



4.3.3.1 pH Level

Figure 4.23: Control chart of pH

The pH sensor is used to check the fish tank's pH. Within the system, the ideal pH range for catfish development and survival is between 6.4 and 7.6. As above graph, readings were taken over a three-week period, and the system proved to be quite beneficial in the development of a healthy system.



Figure 4.24: Control chart of water temperature

A water temperature sensor is used to measure the temperature of the aquarium's water. The readings were obtained throughout a three week period, and the system was found still acceptable in terms of developing a healthy system. Because the ideal water temperature for the growth and survival of aquarium fish is between 24 and 36degrees Celsius.

```
4.3.3.3 Water Level
```



Figure 4.25: Control chart of water temperature

The fish tank's water level was measured using the water level sensor. According to the graph above, the water level only drops little in the first two weeks owing to evaporation. They were raised on day 15 because the water in the fish tank is changed in order for the fish to survive in clean water.



4.3.3.4 LDR Value

Figure 4.26 depicts when the LDR sensor detects light at different times of the day and night. Brightness is sufficient for the plant during the day for the entire 14-day period. Because natural light is not available at night, the LDR value is lower than the ideal level (200). As a result, artificial light will be used to allow the plant to do photosynthesis and thrive.

4.3.4 Fish Feeder

The fish feeder is located in the aquarium's middle, right above the water level. It's a container with two little holes, in it that container is the food for the catfish that are present there. It's attached to a DC servo motor, which can rotate the container to feed fish. Each

time the fish is fed is with a six-hour gap and each feeding is rotated two cycle. The looping of feeder's rotation number refers to the percentage rises of catfish and spinach as indicated in Figure 4.30 and Figure 4.32. If the percentages do not increase, the looping rotation will increase until the fish can plants are able grow healthily with the amount of food dispersed.

4.3.5 Growth of Fishes and Plants

The assessment of this project will be weight of catfish and height of Spinach. To obtain the percenatge of growth rate, the final data is subtracted with initial data and divide by initial data, and lastly multiple with hundred percent as shown in formula below.



Five tails of catfish with specific name of Albino Clarias Catfish are raised in aquarium due to these kind of catfish can be kept at room temperature. The weight of fish is weighed before placed into aquarium by using weighing scales. When the small bucket with the fish tank's water is on top, the weighing scales are adjusted to zero error. The fish are then scooped into the small bucket using a landing net. However, before being placed in the bucket drain, the landing net is drained for a few seconds to remove any surplus water, after which it is weighed and recorded in the . To acquire an accurate value, repeat the weighing step three times as needed. Then, for the following 7 week the fish are weighted again and recorded in Table 4.2.



Figure 4.28: Weighing fish



Figure 4.29: Scooping fish by using a landing net

Week	Average Weight (g)	Increase (%)					
1	27.5	-					
2	2 27.5						
3	28	2%					
4	31	11%					
5	34	10%					
6	38	12%					
7	45	18%					



Figure 4.30: Growth of catfish

Refer to the Figure 4.30, the weight of the catfish did not vary in the first two weeks, the loop for rotating the fish feeder was increased in order to increase the feeder's volume. Starting in week 3, the catfish weight has raised in tandem with the increase in feed amount. As a result, an increase in the amount of feed will result in an increase n the weight of the fish.Aside from that, it could indicate that the fish has adapted to its surroundings.

When the agriculture system is being set up, spinach is planted in the soil. Once the system is fully set up, the spinach are moved from the soil to a PVC pipe hole with a small pot to prevent them falling into the pipe and avoid fully submerged. The height of plant also be measured three times with a ruler. To measure the plant, the spinach pot is take out from PVC pipe hole to avoid breaking the roots which would affect the growth rate. The height is measured from the bottom of pot until the top of plant. But if the height of spinach is lower than pot, then it will be moved carefully and measured its height. Next, for following 7 week the spinach will be measure again and place back to PVC pipe. The height and growth is recorded in Table 4.3.



Figure 4.31: Meauring height of spinach

Table 4.3: Height of spinach

	Week	Aver	age height (cm)	Increase (%)
4	1 1	1. A.	5.00	-
N	2	No.	5.81	16.2%
KW	3	KA	6.73	16%
	4		8.32	24%
E	5		10.49	26%
0	6		12.66	21%
	MALWn7		15.25	20%



Figure 4.32: Growth of spinach

In week 4, the plant's height increases rapidly. As a result, the increased of amount fish feed amount, resulting in more nitrogen being supplied to the plant. At the same time, the plant is under good situation because it is always absorbing light in order to perform photosynthesis and grow.

4.4 Summary

It is concluded that this project was successful in designing and developing an aquaponic system prototype. The aquaponic prototype has an aquarium and PVC pipe connected. Water usage can be optimized by adopting this prototype because the fish waste provided nutrients for the plant while the plant filtered the water for the fish. The system has sensors that measure important parameters and display them on the user's mobile for monitoring purposes. Thus, the user does not need to manually check on the plant and fish in their current location. All of the important parameters' data is analyzed in real-time as it is collected from the sensors and sent through the internet via the WiFi module. This system's design has been registered as an Internet of Things-based Smart Agriculture Monitoring System.

CHAPTER 5

CONCLUSION

5.1 Introduction

This chapter discuss the conclusion and future work for the Smart Agriculture Monitoring System.

5.2 Conclusion

This project consists of both hardware and software development. The hardware part provided information to the user for remote monitoring of aquaponic' status. Then, with the development of a monitoring system, it has healthier and fresher spinach as well as a good size of catfish. The hardware prototype is constructed by Arduino Uno, NodeMCU WiFi module, water temperature sensor, pH sensor, LDR sensor and water level sensor to monitor the actuators of LEDs, submersible water pumps, fan and additionally fish feeder. For the software part, the language used in this project is C++ programming. Then MIT app inventor was used to construct the mobile app, while Firebase was used as the cloud database for this project. Mobile application allowed users to preview the aquaponics system in a remote place. Firebase's cloud database is used to store data from the sensor and update the control from users through the mobile app.

In addition, the Smart Agriculture System's effectiveness was evaluated by comparing the average growth of catfish and spinach. The results reveal that when the parameters are maintained in an ideal state, the fish and plants are healthier. Furthermore, the performance of the sensors was also analyzed in this project. The accuracy of the sensors and actuators showed 100% when comparing the mobile application and cloud' data. Lastly, the objective of this project had been achieved successfully.

5.3 Future Works

For future works, the agriculture of aquaponics system can be enhanced as follow:

- Use an indexing value to sequentially irrigate several grow beds as the values are to expand the amount of grow beds and increase the crops without adding extra fish tanks.
- ii) Include Total Ammonia Nitrogen (TAN), Biological Oxygen Demand (BOD), Total Phosphorus (TP), Total Nitrogen (TN), Total Organic Carbon (TOC), Total Coliforms, Fecal Coliforms and Escherichia coli tests. These testing should be carried out over a longer period of time and more frequently each day if possible.

iii) Incorporating solar panels to absorb solar energy to power the actuators and give live video streaming of the aquaponics system via the mobile app.

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APPENDICES

Appendix A Gantt Chart BDP 1 and BDP 2

	Weeks (Semester1)															
BDP 1		MARCH				AP	RIL					JUNI	E			
Task / Activity	2	19	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Talk introduction BDF	P	1				_										
Project titile submissi	ion	7				1.7	_			/						
Meeting supervisor																
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First draft submission	ı															
Log-book submission																
Thesis submission																
Thesis presentation																

Weeks (Semester2)														
OCTOBER 1			N	NOVEMBER			DECEMBER				JANUARY			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	
				1										
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1							1							
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Appendix B Coding for Arduino

#include <Wire.h> #include <LiquidCrystal_I2C.h> #include <OneWire.h> #include <DallasTemperature.h> #include <Servo.h> #define ONE_WIRE_BUS 2 OneWire oneWire(ONE_WIRE_BUS); DallasTemperature sensors(&oneWire); LiquidCrystal_I2C lcd(0x27, 16, 2); Servo myservo; unsigned long previous Millis = 0; const long interval = 21600000; //6hr=21600000millis, 2min=120000 int LDR =A0; int PH=A1; int WLS=A2; int buf[10]; int RedLight=13; int WhiteLight=12; int ExFan=11; int Pump2=9; int Feeder=8; int powerWLS_PIN=7; int alkaline=4: int acid=3; int LDRValue=0; int WLSValue; int pos=0; int a=0; UNIVERSITI TEKNIKAL MALAYSIA MELAKA int b=0; int c=1; int Flag=0; float pHValue=0; float Celcius=0; void setup() { sensors.begin(); myservo.attach(Feeder); pinMode(LDR,INPUT); pinMode(ExFan,OUTPUT); pinMode(acid,OUTPUT); pinMode(alkaline,OUTPUT); pinMode(RedLight,OUTPUT); pinMode(WhiteLight,OUTPUT); pinMode(Feeder,OUTPUT); pinMode(powerWLS_PIN,OUTPUT);

```
digitalWrite(RedLight,HIGH);
 digitalWrite(WhiteLight,HIGH);
 digitalWrite(powerWLS PIN,LOW);
 digitalWrite(acid,HIGH);//off motor acid
 digitalWrite(alkaline,HIGH);//off motor alkaline
 Serial.begin(9600);
 lcd.init();
 lcd.backlight();
 lcd.setCursor(6,0);
 lcd.print("Smart");
 lcd.setCursor(3,1);
 lcd.print("Agriculture");
 delay(1000);
}
void loop() {
 String get = "";
 while(Serial.available()>0) // read request nodeMCU
 {
  get += char(Serial.read());
 }
 get.trim(); //delete space of receive data
 if(get == "Yes")
 {
  dataSend();
 }
 get = ""; //empty variable getData
 delay(100);
              UNIVERSITI TEKNIKAL MALAYSIA MELAKA
}
void dataSend()
 LDRValue = analogRead(LDR); // read data LDR sensor
 for(int i=0;i<10;i++)
 ł
  buf[i]=analogRead(PH);
  delay(30);
 for(int i=0;i<9;i++)
  for(int j=i+1;j<10;j++)
  {
   if(buf[i]>buf[j])
```

```
buf[i]=buf[j];
   }
  }
 }
 float avgValue=0;
 for(int i=2;i<8;i++)
 avgValue+=buf[i];
 float voltagePH=5/1024.0*avgValue/8;
 pHValue = 7 + ((2.5 - voltagePH)/(0.18));
 digitalWrite(powerWLS_PIN,HIGH);
 delay(10);
 WLSValue = analogRead(WLS);
 digitalWrite(powerWLS PIN,LOW);
 sensors.requestTemperatures();
 Celcius=sensors.getTempCByIndex(0);
 Light();
 pH();
 WaterLv();
 WaterTmp();
 unsigned long currentMillis = millis();
 if(currentMillis - previousMillis >= interval)
 {
  previousMillis = currentMillis;
  FishFeeder();
 }
 String sendData = String(LDRValue) + "#"+ String(pHValue) + "#"+ String(Celcius)
+"#"+ String(WLSValue) ;//read request from NodeMCU
 Serial.println(sendData);
}
void Light()
{
 // light
 if(LDRValue<100)
 {
  lcd.init();
  lcd.backlight();
  lcd.setCursor(0,0);
  lcd.print("Light: DARK");
  lcd.setCursor(0,1);
  lcd.print("LED Tube: ON");
 }
 else
 {
  lcd.init();
  lcd.backlight();
```

```
lcd.setCursor(0,0);
  lcd.print("Light: NORMAL");
  lcd.setCursor(0,1);
  lcd.print("LED Tube: OFF");
 }
 delay(100);
}
void pH()
{
 //pH
 lcd.init();
 lcd.backlight();
 lcd.setCursor(0,0);
lcd.print("pH Value: ");
 lcd.setCursor(11,0);
 lcd.print(pHValue);
 if(pHValue<6.5)
                   WALAYSI,
 {
  if(c==0)
  {
  lcd.setCursor(0,1);
  lcd.print("Alkaline ON");
  }
  c=c+1;
  if(c=12)
  {
   c=0;
  }
 }
                               TEKNIKAL MALAYSIA MELAKA
 else if (pHValue>7.5)
 {
  if(c==0)
 {
  lcd.setCursor(0,1);
  lcd.print(" Acid ON ");
  }
  c=c+1;
  if(c=12)
  {
   c=0;
  }
 }
 else
 {
  lcd.setCursor(2,1);
  lcd.print(" Normal
                       ");
 }
 delay(200);
```
```
}
void WaterLv()
{
 // Water Level
 if(WLSValue<200)
 {
  lcd.init();
  lcd.backlight();
  lcd.setCursor(0,0);
  lcd.print("Water Level:Low");
  lcd.setCursor(0,1);
  lcd.print("Water Pump:ON");
 }
 else
 {
  lcd.init();
  lcd.backlight();
  lcd.setCursor(0,0);
  lcd.print("Water Level:OK");
  lcd.setCursor(0,1);
  lcd.print("Water Pump:OFF");
 }
 delay(200);
}
void WaterTmp()
{
              UNIVERSITI TEKNIKAL MALAYSIA MELAKA
 lcd.init();
 lcd.backlight();
 lcd.setCursor(0,0);
 lcd.print("Celcius:");
 lcd.setCursor(9,0);
 lcd.print(Celcius);
 // Water Temperature Sensor
 if(Celcius ==(-127.00))
 {
  lcd.print("No detector");
 }
 else if(Celcius<25)
 {
  lcd.setCursor(0,1);
  lcd.print("White Light:ON");
 }
 else if(Celcius>35)
 ł
  lcd.setCursor(0,1);
```

```
lcd.print("Eahaust Fan:ON");
 }
 else
 {
  lcd.setCursor(0,1);
  lcd.print("Normal Condition");
  digitalWrite(ExFan,LOW);
  digitalWrite(WhiteLight,HIGH);
 }
 delay(50);
}
void FishFeeder()
{
lcd.init();
 lcd.backlight();
 lcd.setCursor(0,0);
 lcd.print("Feeding.....");
 for(b==0;b<2;b++)
 {
  for(pos =0; pos<=180; pos+=1)
  {
   myservo.write(pos);
   delay(15);
  }
  for(pos=180; pos>=0; pos-=1)
  {
   myservo.write(pos);
   delay(25); 2
  }
 }
             UNIVERSITI TEKNIKAL MALAYSIA MELAKA
 b=0;
```

Appendix C Coding for NodeMCU



```
Serial.print("connecting");
 while (WiFi.status() != WL_CONNECTED) {
  Serial.print(".");
  delay(500);
 Serial.println();
 Serial.print("Connected WIFI: ");
 Serial.println(WiFi.localIP());
 Serial.println();
 Serial.println("Welcome to Smart Agriculture Monitoring System" );
 Firebase.begin(FIREBASE_HOST, FIREBASE_AUTH);
}
void loop() {
 if (Firebase.failed())
 ł
  Serial.print("setting /number failed:");
  Serial.println(Firebase.error());
  return;
 }
 unsigned long currentMillis = millis();
 if (currentMillis - previousMillis >= interval)
 {
  previousMillis = currentMillis;
  //Serial.println("previousMillis = currentMills");
  String data = ""; Vo lunu
  while (DataSerial.available() > 0)
  {
                                     KNIKAL MALAYSIA MELAKA
   data += char(DataSerial.read());
  }
  data.trim();
  if (data != "")
  {
   int index = 0;
   for (int i = 0; i \le data.length(); i++)
    {
    char delimiter = '\#';
    if (data[i] != delimiter)
      arrData[index] += data[i];
    else
      index++;
    }
   if (index == 3)
    ł
    Serial.println("
                            LDR : " + arrData[0]);
```

Serial.println(" pH value : " + arrData[1]); Serial.println("Water temperature : " + arrData[2]); Serial.println(" Water level :" + arrData[3]); Serial.println(); float LDR_Value = arrData[0].toFloat(); float pH_Value = arrData[1].toFloat(); float wtmp_Value = arrData[2].toFloat(); float wl_Value = arrData[3].toFloat(); float wl_Value = arrData[3].toFloat(); Firebase.setFloat("Value_LDR", LDR_Value); Firebase.setFloat("Value_pH", pH_Value); Firebase.setFloat("Value_WaterTemperature", wtmp_Value); Firebase.setFloat("Value_WaterLevel", wl_Value);

AUTO = Firebase.getString("AUTO"); light_aqua = Firebase.getString("LIGHT_AQUARIUM"); light_plant = Firebase.getString("LIGHT_PLANT"); acid_m = Firebase.getString("ACID"); alkaline_m = Firebase.getString("ALKALINE"); exFan = Firebase.getString("FAN"); water_pump = Firebase.getString("2ndMotor");

```
Serial.print("AUTO=");
Serial.println(AUTO);
Serial.print("light_aqua=");
Serial.println(light_aqua);
Serial.print("acid m=");
Serial.println(acid_m);
Serial.print("alkaline m=");
Serial.println(alkaline_m);
Serial.print("exFan=");
Serial.println(exFan);
                             EKNIKAL MALAYSIA MELAKA
Serial.print("water_pump=");
Serial.println(water_pump);
if (AUTO == "1")
{
 Serial.println();
 Serial.println("~ Automatically Control ~ ");
 //ldr
 if (arrData[0] < "200")
  Serial.println(" Brightness/Light : Dark");
  digitalWrite(RedLight, HIGH);
  Serial.println("
                       Red LED : On");
 }
 else
 ł
  Serial.println(" Brightness/Light : Normal");
  digitalWrite(RedLight, LOW);
```

```
Serial.println("
                     Red LED : Off");
}
//ph
if (arrData[1] < "6.5")
{
 if(c==0)
 ł
 Serial.println("
                     pH Level : Too Low");
 digitalWrite(alkaline, LOW);
 delay(6000);
 digitalWrite(alkaline, HIGH);
 Serial.println("Alkaline Solution : On");
 }
c=c+1;
if(c=12)
{
 c=0;
}
}
else if (arrData[1] > "7.5")
ł
 if(c==0)
 ł
 Serial.println("
                     pH Level : Too High");
 digitalWrite(acid, LOW);
 Serial.println(" Acid Solution : On");
 delay(6000);
 digitalWrite(acid, HIGH);
}
c=c+1;
                         TEKNIKAL MALAYSIA MELAKA
                  2SITI
if(c=12)
{
 c=0;
}
}
else
{
 Serial.println("
                     pH Level : Normal");
}
Serial.println("Water temperature : " + arrData[2]);
//tmp
if (arrData[2] < "25")
ł
 Serial.println("
                    White LED : On");
 digitalWrite(ExFan, LOW); //OFF fan
 digitalWrite(WhiteLight, HIGH); //ON led
}
else if (arrData[2] > "35")
```

```
ł
  Serial.println("
                    Exhaust Fan : On");
  digitalWrite(ExFan, HIGH); //ON fan
  digitalWrite(WhiteLight, LOW); //OFF led
 }
 else
 ł
  digitalWrite(ExFan, LOW);
  digitalWrite(WhiteLight, LOW);
 }
 //water level
 if (arrData[3] < "260")
 ł
  Serial.println("
                    Water Level : Low");
  digitalWrite(Pump2, HIGH);
  Serial.println("
                     Water Pump : On");
 }
 else
               WALAYS/A
 ł
  Serial.println("
                    Water Level : OK");
  digitalWrite(Pump2, LOW);
  Serial.println("
                     Water Pump : Off");
 }
}
if (AUTO == "0")
 //ldr
 Serial.println();
 Serial.println("~ Manually Control ~ ");
                                           MALAYSIA MELAKA
 if (light_plant == "0")
 {
  digitalWrite(RedLight, LOW);
  Serial.println("
                      Red LED : Off");
 if (light_plant == "1")
 ł
  digitalWrite(RedLight, HIGH);
  Serial.println("
                      Red LED : On");
 }
 if (exFan == "0")
 ł
  digitalWrite(ExFan, LOW);
  Serial.println("
                    Exhaust Fan : Off");
 }
 else if (exFan == "1")
 ł
  digitalWrite(ExFan, HIGH);
```

```
Serial.println(" Exhaust Fan : On");
  }
  if (light_aqua == "0")
  ł
   digitalWrite(WhiteLight, LOW);
   Serial.println("
                      White LED : Off");
  }
  else if (light_aqua == "1")
  ł
   digitalWrite(WhiteLight, HIGH);
   Serial.println("
                      White LED : On");
  }
  if (acid m == "0")
  Ł
   digitalWrite(acid, LOW);
   Serial.println(" Acid Solution : Off");
  }
  else if (acid_m == "1")
  {
   digitalWrite(acid, HIGH);
   Serial.println(" Acid Solution : On");
  }
  if (alkaline_m == "0")
  ł
   digitalWrite(alkaline, LOW);
   Serial.println("Alkaline Solution : Off");
  }
  else if (alkaline_m == "1")
                                  NIKAL MALAYSIA MELAKA
  ł
   digitalWrite(alkaline, HIGH);
   Serial.println("Alkaline Solution : On");
  }
  if (water_pump == "0")
  ł
   digitalWrite(Pump2, LOW); //off
   Serial.println(" Water Pump : Off");
  if (water_pump == "1")
  ł
   digitalWrite(Pump2, HIGH); //on
   Serial.println(" Water Pump : On");
  ł
 }
}
arrData[0] = "";
arrData[1] = "";
```

```
arrData[2] = "";
arrData[3] = "";
}
DataSerial.println("Yes");
Serial.println(".");
}
```



Appendix D Block of MIT App Inventor



Appendix E Block of MIT App Inventor





Appendix F Block of MIT App Inventor