3D Fish Culture and Monitoring System

by

Tan Khang Lim

15905

Dissertation submitted in partial fulfilment of
the requirements for the
Bachelor of Engineering (Hons)
(Electrical and Electronic)

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CERTIFICATION OF APPROVAL

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Approved by,

____

(Dr. Ho Tatt Wei)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
January 2016

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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Tan Khang Lim

ABSTRACT

Fish farming have been so widely develop in all around the world to overcome the raise in demand towards protein product. Traditional methods of fish farming take up a lot of space and need a lot of manpower in monitoring and maintenance job. In this project, an automated system is to be developed to take over the manpower and monitoring job. Sensors and actuators are used to monitor the water parameters of the fish tank and some automated system like automatic food dispenser and water current maker are to use to fulfill the basic needs of the fish in terms of feeding and water movement. Bio filter is also added to filter the waste product produce by fish from time to time.

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ABBREVIATIONS AND NOMENCLATURES

FAO - Fish and Agriculture Organization of United Nation

ROR - Rate of Return

RAS - Recirculating Aquaculture Systems

DO - Dissolved Oxygen

I/O pins - Input or Output pins

LPH – Liters per Hours

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

There has been renewed interest in urban agriculture and 3D farming. This is due to increasing cost of food, lack of food security and toxicity. Urban agriculture has several benefits and also challenges. It is envisioned that innovative use of technology may make large scale urban farming cost effective popular. Protein sources or fish products have become one of the most important food sources for humans. With the increasing of world populations, it is crucial to overcome the expanding in demand and shrinking in supply problem in food sources. Different sector have different way in sustain their consistency of supplies. For fish products, the alternative way to supply products is by farming those food sources instead of fully depending on marine capture

The increase in demand for protein sources, have created a trend in fish farming agriculture. According to the data from Bloomberg Philanthropies, in the last 10 years, the global demand on this sector has grew by 16.5 million tons but the supply to support the needs of the world has fell by 1.3 million tons until 2011[1]. The predicted amount of demand will continues rises and projected to 154 million tons by 2030. To match the current demand ramp on protein sources, many of the entrepreneurs have come out with new ideas or new ways to do fish farming to increase the efficiency and productivity. Fish culture or farming has contributed a lot to help in meeting the world demands on fish products. Fish and Agriculture Organization of United Nation (FAO) report that, there are 158 million tons been produce from fisheries and agriculture in 2012, 10 million tons more than 2011[2]. This prove that the contribution of fish farming cannot be overlook as the world demands on fish products is increasing gradually.

Beside than increasing the scales of fish farming, the sustainability of this sector also need to be considered. Most of the fish are farmed in suburbanized area which is far from the city or town. These area include river, moving streams (freshwater fish), in the middle of ocean (saltwater fish) and even in a man-made pond near out skirt of a town. All of these methods might environmentally harm the marine life in the particular farming area. This may happen due to over exploit on certain area after fish farming or even depletion happened after long period of over exploit and waiting for the place to recover. Therefore, sustainability in fish farming is very important to maintain the continuity of the supply of food sources.

As a result, a sustainable, high productivity, stable system is needed to make sure this food sources would not stop as the increasing of demands in protein sources over the years. This is because once the rate of demand ramping higher than the rate of supply, it will cause the increasing in protein sources equilibrium price.

1.2 PROBLEM STATEMENT

Traditional method of fish culture involves static ponds which require a lot of land space but do not provide sufficient area for fish to swim healthily. To maintain the water quality and feeding the fish, manpower is needed. This will cause the maintaining cost to increase and provide a not very efficient and productivity system. Overexploit on a certain area to build a fish farm will also harm the environment. Besides that, toxicity of the stream or river will directly affect the fish quality and safety of those consumers.

1.3 OBJECTIVES AND SCOPE OF STUDY

Objectives

- Develop a 3D fish culture system with sensors and actuators to monitor and control the microclimate

Scope of Study

- Design a fully automated system by using microcontroller, sensors and feedback system which can farm fish in a large scale
- The most important aspect in this system is:
    - Space saving
    - Efficient or high productivity
    - Cost saving
    - Environmental friendly

CHAPTER 2: LITERATURE REVIEW OR THEORY

2.1 WORLD DEMANDS

Nowadays, fish has become more and more important as a food sources and protein source for human being. A raise in demand for this source has been reported by a lot of agriculture government organization and non-government organization. And to overcome this problem, much country has started to farm those protein sources rather than depending on the marine capture. As reported by FAO in the World Review of Fisheries and Aquaculture, the largest aquaculture producer and exporter in the world is China where the country alone has produced 43.5 million tons of fish out of 66.6 million of global production**[3]**. And World Bank also mention that the seafood that human consume daily, 62% of the protein sources is come from fish farming culture, the most is around Asia region where 70% of the fish will end up being in people's plate**[4]**. To overcome the raising in demands, high productivity with low cost need to be emphasize in fish farming and below par fish farm need to be warn to prevent from low quality fish being sell into the market.

2012 Ranking	Country	Continent	2003	2011	2012	Variation 2003–2012	Variation 2011–2012
			(Tonnes)			(Percentage)	
1	China	Asia	12 212 188	13 536 409	13 869 604	13.6	2.4
2	Indonesia	Asia	4 275 115	5 332 862	5 420 247	27.0	1.7
3	United States of America	Americas	4 912 627	5 131 087	5 107 559	4.0	–0.5
4	Peru	Americas	6 053 120	8 211 716	4 807 923	–20.6	–41.5
5	Russian Federation	Asia/ Europe	3 090 798	4 005 737	4 068 850	31.6	1.6
6	Japan	Asia	4 626 904	3 741 222	3 611 384	–21.9	–3.5
7	India	Asia	2 954 796	3 250 099	3 402 405	15.1	4.7
8	Chile	Americas	3 612 048	3 063 467	2 572 881	–28.8	–16.0
9	Viet Nam	Asia	1 647 133	2 308 200	2 418 700	46.8	4.8
10	Myanmar	Asia	1 053 720	2 169 820	2 332 790	121.4	7.5
11	Norway	Europe	2 548 353	2 281 856	2 149 802	–15.6	–5.8
12	Philippines	Asia	2 033 325	2 171 327	2 127 046	4.6	–2.0
13	Republic of Korea	Asia	1 649 061	1 737 870	1 660 165	0.7	–4.5
14	Thailand	Asia	2 651 223	1 610 418	1 612 073	–39.2	0.1
15	Malaysia	Asia	1 283 256	1 373 105	1 472 239	14.7	7.2
16	Mexico	Americas	1 257 699	1 452 970	1 467 790	16.7	1.0
17	Iceland	Europe	1 986 314	1 138 274	1 449 452	–27.0	27.3
18	Morocco	Africa	916 988	949 881	1 158 474	26.3	22.0
Total 18 major countries			**58 764 668**	**63 466 320**	**60 709 384**	**3.3**	**–4.3**
World total			**79 674 875**	**82 609 926**	**79 705 910**	**0.0**	**–3.5**
Share 18 major countries (percentage)			**73.8**	**76.8**	**76.2**		

Figure 1: Fish produce by each country

2.2 TYPES OF FISH

In fish farming, fish can be categories into 2 types: freshwater fish and saltwater fish. Freshwater fish is the fish that survive in a normal pond or river where the water sources is either flow from the mountain or rainwater while saltwater/seawater fish is the fish that only live in the ocean or sea where the water contain certain level of salinity. There are a lot of species in both freshwater and saltwater fish. Only certain species of fish can be used as a protein sources. According to ANNEX III - Hand Book on Fish Culture, freshwater fish can be differential by 2 types. The first type is Cyprinids where the fish contain scales covering its skin and the second type is fish without any scales on its body, called Silurids[5]. From all this fish, it can be grouped into 2 different group based on the water temperature either is warm water fish or Coldwater fish. A warm water fish can live in the surround temperature which is in the range of 28-30℃ while a Coldwater fish live in a water temperature typically below 20 ℃. Temperature also is a factor to consider in fish farming because it will affect the quality of the fish and the suitability of weather in the farming area. Freshwater fish normally have higher immune system and more resilient against fighting disease compare to saltwater fish as the fish can survive in a filthy water. The popular species of fish suitable for fish farming include tilapia, catfish, carp, catfish, trout and etc. All of these species can adapt the environment easily and high growth rate. In term of size, freshwater fish growth smaller compare to saltwater fish.

The typical seawater fish like salmon are rarely being farmed due to the sensitivity of the species toward disease especially toward sea lice. Most of the farmed salmon are pre vaccinated before it put in a sea cage (in the middle of the sea) or pond system (extract seawater to be filled into the pond) and salmon typically live in Coldwater which is 8-14℃.

2.3 FISH FARMING METHOD

There are many types of method being used in farming fish around the globe which include:

- Cage system
- Pond system
- Composite fish culture
- Integrated recycling system
- Classic fry farming
- Aquaponics

Each of the method has their pros and cons but the most significant cons in cage system are the escapees issue compare to pond or isolated water system. This will directly affect the productivity of the certain farm in achieving high rate of return (ROR) with high quality fish.

Figure 2: Cage system

When talk about green or environmental friendly system, the optimum system for this will be aquaponics where aquaculture and hydroponic system combine together to form a complementary system. Fish excrete ammonia and it will be oxidized by bacteria in hydroponic system to form nitrate which is needed by hydroponic plants. The plant will then absorb the entire nitrate, filter the water while releasing oxygen into the filtered water and flow back the clean and oxygenated water into the aquaculture. This system is widely used in country around Europe compare to in Asia. The types of hydroponic plant use are any leafy lettuce, pak choi, basil, mint, salad greens, tomatoes and most common house plants.

Integrated recycling system is almost similar to aquaponics. The only different is integrated recycling system is a closed loop system where, livestock, vegetables and fish depends on each other in a farm.

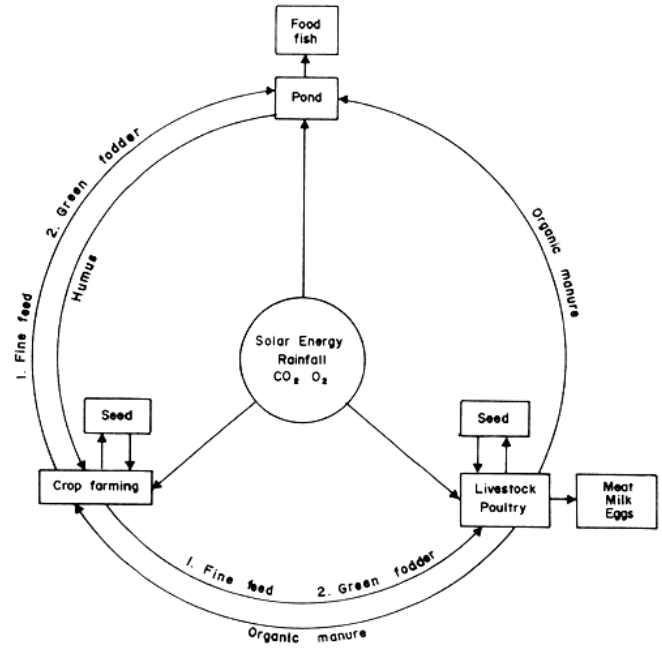


Figure 3: Integrated recycling system

Other fish farming system like pond system are widely use as well. Pond system typically builds inland near suburban area where ponds are being dig and fish are being farm inside the pond. The pond can prevent escapee happened but is very dependent on the help of financial and manpower to sustain them. There is also another type of system which very similar to pond system which is composite fish culture. The only different is that more than 1 species of fish coexisted in the same pond and normally is 6 different species of fish in a same pond.

Figure 4: Pond system

The most recent technology in fish farming sector is recirculating aquaculture systems (RAS). RAS is basically built inland with circulating system to filter the water. The water is circulated out from the tank to filter system and flow back the filtered water back to the tank. In saltwater fish farming using RAS, the saltwater is circulated between the filtration systems over and over again which means the seawater only need to be fill in once in a while due to evaporation factor.

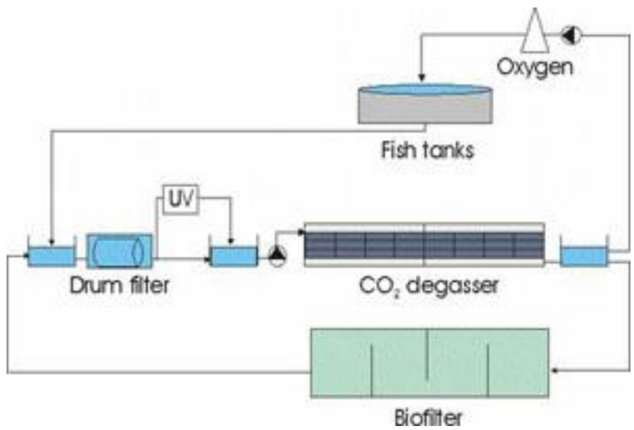


Figure 5: Schematic of RAS

2.4 MONITORING SYSTEM

In managing a fish farm, there are few factors to be considering which include sources of water, water quality, food, and space for movement. Under the water quality, there are few branches such as water's physical and chemical factors. Physical factor of water include temperature, cleanliness of water, water level and chemical factors include, dissolve oxygen, pH value and etc. To monitor all these factors, sensors and controller are needed to add into the system.

Temperature in a tank is the most important factor after oxygen level when comes to fish farming. the temperature of the tank will influence the fish quality due to the metabolic rate of fish as the rate will double up for each 7-8℃ increase in the temperature[6]. Temperature also affects the quantity of dissolve gases in the water. The different in temperature will result in different in water density and water density will affect the solubility of the gases (carbon dioxide, nitrogen, oxygen, etc.) in the water itself[6]. For example, the lower the temperature the higher the water density, the solubility of gas will be lower. Monitoring the temperature play a key parts in the process called thermal stratification which will affect the dissolved oxygen (DO).

Table 1: Solubility of oxygen (mg/l) in water[6]

Temperature (℃)	**20**	**22**	**26**	**28**	**30**
Solubility of oxygen (mg/l)	9.2	8.8	8.2	7.9	7.6

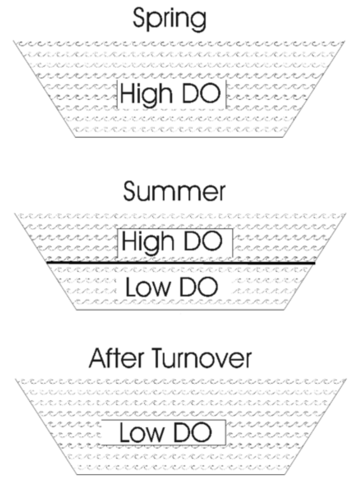


Figure 6: Thermal Stratification

Besides than temperature, the waste products in the pond also need to be monitor to maintain the cleanliness of the water. Waste products such as clay, plankton, fish waste, and suspended solid are example can be found in a fish farming pond. The most common waste product excreted from fish is ammonia and less amount of urea. Typically, the level of unionized ammonia are safe for fish to live is 0.02mg/l but it may varies depends on types of fish being farmed. For the pH value, the tolerable range for fish to live in is in between 6.5-9.0 on pH scales. PH value will vary according to the surrounding temperature and rate of photosynthesis of plankton due to change of oxygen and carbon dioxide level.

Table 2: Percentage of un-ionized at different temperatures with different pH value[6].

Temperature (°C)	12.2	16.7	20	23.9	27.8	32.2
pH						
7.0	0.2	0.3	0.4	0.5	0.7	1.0
7.4	0.5	0.7	1.0	1.3	1.7	2.4
7.8	1.4	1.8	2.5	3.2	4.2	5.7
8.2	3.3	4.5	5.9	7.7	11.0	13.2
8.6	7.9	10.6	13.7	17.3	21.8	27.7
9.0	17.8	22.9	28.5	34.4	41.2	49.0
9.2	35.2	42.7	50.0	56.9	63.8	70.8
9.6	57.7	65.2	71.5	76.8	81.6	85.9
10.0	68.4	74.8	79.9	84.0	87.5	90.6

For the feeding part, timer will be added into the system and feedback to some control block to control the feeding of fish in every certain period of time. A tilapia is normally fed in between 0-30 percent of their body weight per day using normal moderate protein pellets. Different age of the fish have different diet, so the selection of fish food and timer setting need to be decide after the type of fish being chose. Beside the fish pellet, aquatic plant can be used as a food sources for fish. Aquatic plant not only can provide food sources, but I can also provide oxygen to the water.

2.5 MICROCONTROLLER

To control those sensors, a suitable microcontroller is to fit into the system. One of the main aim of this project is to create green and efficient system and when discuss about the words green, the most suitable power sources is solar power. A low power consuming microcontroller is needed to create an efficient and productivity system. The preliminarily selections would be either a Raspberry Pi or Intel® Galileo Gen 2 microcontroller. Based on the features that require, Intel® Galileo microcontroller has enough features and cheap module to control all the sensors in the system.

Figure 7: Intel® Galileo

The specification the selected microcontroller is as below:[7]

# of QPI Links	0
Supported FSBs	NA
FSB Parity	No
Board Form Factor	Arduino
Socket	Quark 393pin FCPGA
Extended Life Program (XLP)	No
Embedded Options Available	No
Lithography	32 nm
TDP	12.5 W
DC Input Voltage Supported	7-15
Back-to-BIOS Button	No
Recommended Customer Price	N/A
Description	Arduino Compatible development board
Processor Included	Intel® Quark™ SoC X1000 (16K Cache, 400 MHz)

It has enough I/O pins to handles all the require sensors shield and modules. With small in size and low in power consumption, it allows us to achieve the space saving in creating this system. The disadvantages of this microcontroller are slow in term of processing speed (low clock speed) and low in memory compare to Raspberry Pi. This may become the main constraint afterwards if want to do this system in larger scale or add up more features in future development.

2.6 CRITICAL ANALYSIS

The type of fish that choose as a sample in this project is Red Nile Tilapia. Tilapia has been ranked 5th in most consumed food by National Marine Fisheries Service. Due to near the equator weather condition, tilapia consider on of the most suitable fish to be farming in Malaysia as it ideally grow in warm water. High tolerance toward rough situation and resilient toward diseases makes this species easier to take care of. The details below show some important water parameters for tilapia.

	Optimum	Range
Water temperature	29-31℃	22-37℃
pH value	7-8	3.7-11
Dissolved Oxygen(DO)	5mg/L-7.5mg/L	>1 mg/L
Water exchange rate (if needed)		6 to 12 gallons/minute/100 pounds of tilapia (support the oxygen required)
Carbon dioxide (CO2)	<40 mg/L	
Ammonia production from fish		average 10 grams/100 pounds of fish/day
Ammonia level	<0.05mg/L	<7.1 mg/L
Nitrite level	<0.3mg/L	<27 mg/L
Nitrate level	<27 mg/L	<300-400 mg/L
Chloride concentrations	100-150 mg/L	>10mg/L

Table 3: Optimum and Range of the condition in water tank

Effect of Ammonia on Tilapia[8]

Ammonia Level	Effect on Tilapia
0.08 mg/L or above	Depressed feeding
0.2 mg/L or above	Some mortality occurs
1 mg/L or above	Mortalities, particularly among fry and juveniles
2 mg/L or above	Massive mortality

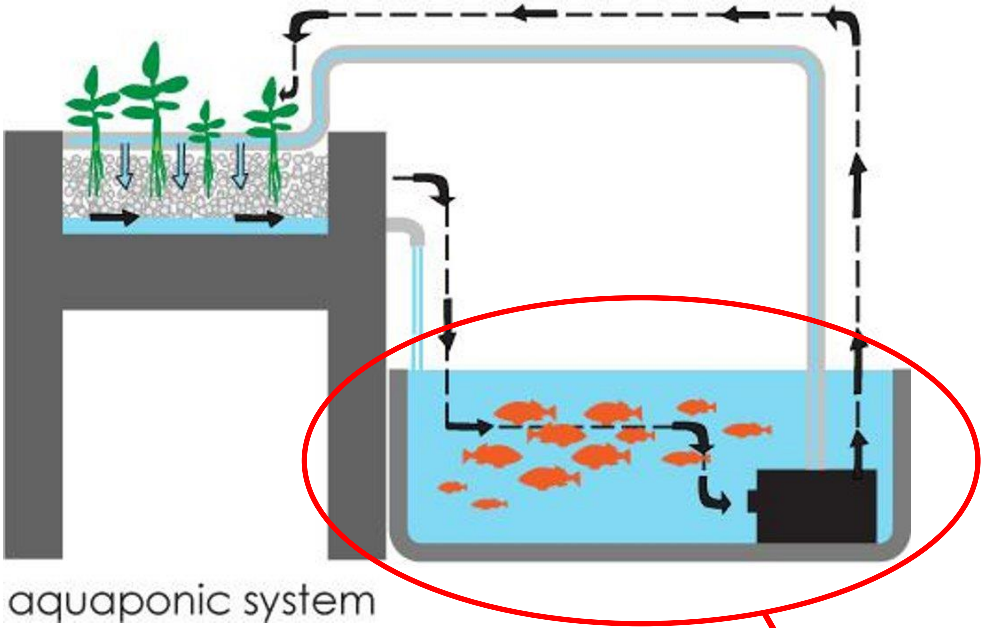
The fish farming system will be used is a combination of aquaculture (fish farm) with hydroponics or called aquaponics. Hydroponics plants act as a natural filter to clean the water through the absorption of fish waste product. The types of hydroponics plant that suitable are leafy plant, lettuce or fruit plant, tomatoes depends on the stocking number. This is because high nitrate stimulate growth rate of leafy plant, while low nitrate stimulate fruiting plant.

CHAPTER 3: METHODOLOGY/PROJECT WORK

In this project, there are 2 parts to work it out, hardware and software implementation or interfacing. In hardware implementation, survey the market for the component or module that is needed. The cheapest module that available in the market with same performance is the main concern in creating an efficient and productivity system.

After confirming the module and microcontroller to buy, a small scale workable model will be built to test the whole system before a prototype is produce. This is to make sure every part in the system is working as expectation before make it into a larger scale.

3.1 BASIC DESIGN



Replacing a tedious and large tank to a more space saving design of tank

Features to include in the tank:

- Mimic a stream like condition by adding water current into the tank with the help of water pump.
- Monitoring system with specific feedback on each detection parts.

3.1.1 Tank Design

Figure 8: PVC gutter

The gutter will be built in square shape with desired length on each side of the tank. This will mimic the condition in a river to give an illusion of unlimited space for the fish to live in.

Number of fish to stock (small scale model)

Plan to stock 10-30 tilapia fingerlings into the small scales model to try out the whole system . According to the good rule of thumb, a normal rectangular tank should have 1 inch of fish for 1 gallon (3.79 liters) of water.

For tropical fish, 1 inch fish/0.5 gallon or 2.5cm / 2.25 liters

A normal adult tilapia size = approximately 38.1cm

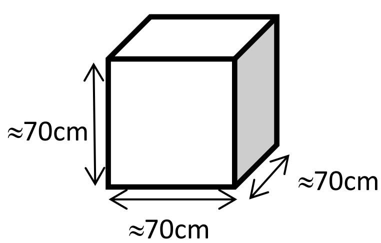
*10 tilapias: 38.1*10 = 381cm*

*The water needed: 381cm *0.9 = 342.9 liters*

Convert liters to cm^3

342.9 liters= $342900cm^3$

∴ The typical rectangular of 70cm X 70cm X 70cm tank is need to stock 10 tilapias until it can be harvest



=343000 cm^3

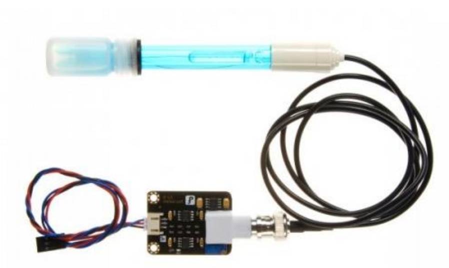
For irregular shape tank, there is no optimum ratio in stocking fish, so the prototype will be use to experiment on how much ratio this tank can be filled. For this tank, fish will be stock with as many tilapias initially and observe the condition of the fish throughout the month.

3.1.2 Monitoring system

Temperature

This Thermistor temperature sensor 10K Waterproof Probe can help in monitoring the water temperature in the water tank and maintaining the optimum temperature of the water inside the tank. The advantage of this sensor is it available in Malaysia and easy to purchase via online. Besides that, the price is cheaper compare to sensor found from other supplier. It is a variable resistor which will change value depends on the temperature with the detection range from -20 to 105 ℃.

PH value



Besides than temperature, pH value also can affect the growth rate and healthiness of the fish. The pH kit that used in this system is Analog pH Sensor. It can be easily interface with suitable microcontroller with generating analog output to be compute and used. It is designed for any types of controllers with analog I/O pin. The pH electrode will be connected via BNC connector to PH2.0 sensor interface and plug into the analog input port of any controller. The analog values will then gather and process inside the controller.

Dissolved Oxygen

For a tank to maintain it dissolved oxygen level at optimum level, aeration is needed. Aeration means to dissolve oxygen into a tank or ecosystem. Natural aeration happens on the surface area of the water where gases diffuse into the water through the water surface into the water. There larger the surface area, the more chance natural aeration happened. But all of the natural aeration is not enough to supply optimum oxygen level to the fish itself, so a pump is needed to circulate the water and creating air bubble by hitting the water surface to dissolve more oxygen into the tank. According to J. E. Rakocy, a circulation of water around 22.7- 45.4 liter (6-12 gallon) per minute is needed sustain the oxygen requirement by 45.36 kg of tilapia[9]. For the small scale model, if to stock 10 tilapias into the tank, the calculation of pump needed is:

***6-12 gallon/ minute for 100 pound of tilapia**

A normal adult tilapia weight = approximately 5.3lbs

*10 tilapias: 5.3*10 = 53lbs*

Take the lowest gallon/min which is 6 gallon/min for the calculation,

So, flow rate for 10 tilapia = 6 gallon/min $\times \frac{53}{100}$

= 3.18 gallon/min

= 190.8 gallon/hour

Convert gallon to liters

190.8 gallon/hour = 722.3 liters/hours

Aquatic will be added into the tank for extra oxygen beside than depending on the pump. These plants will be added to the bottom part of the tank as a base where all the solid waste product will be precipitated. Those solid will be than absorb by the aquatic plant in return creating more oxygen during the day.

A pump which have flow rate higher than 722.3 LPH for the tank to maintain the oxygen level is maintain at optimum level especially at night.

Aquatic plant will be use as a solid precipitate area to absorb and collect solid waste.

Power Source

The propose power source for this system is solar power. Due to the weather in equator, it is suitable to use solar power as the main source for this tank. Photovoltaic cell sizing can calculated by determine the final load of the system.

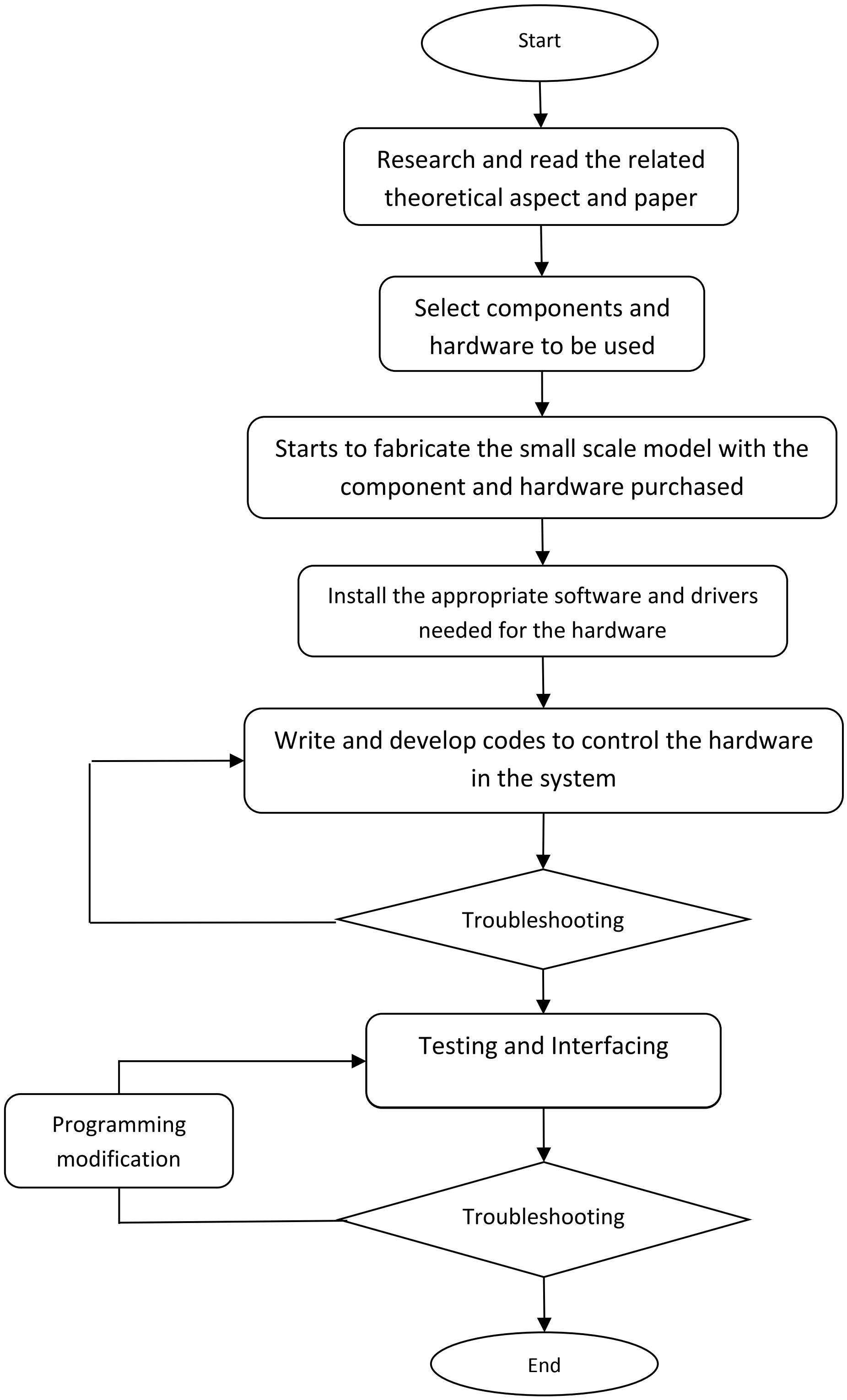
Cleanliness of water

The most important natural filter to filter the water is hydroponics grow bed. The recommendation on internet is grow bed to tank ratio is 1:1. Beside than hydroponics grow bed; aquatic plant which will be added into the tank will also help in cleaning the tank by absorbing fish waste material as fertilizer. This will need help of water pump to transfer the water from tank up to the grow bed. On the other hand, scavenger fish also can be added into the tank to help to clean the algae.

Fish food

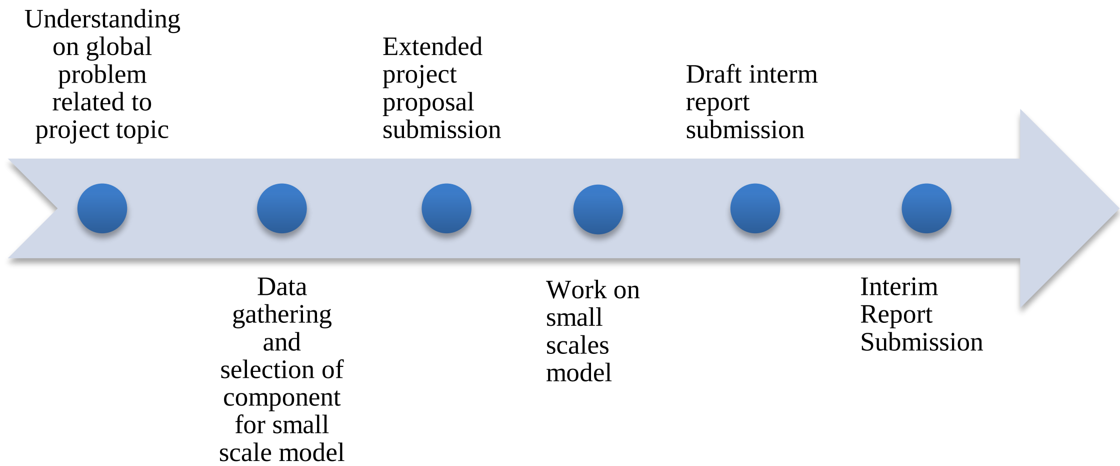
To create an efficient system, fish food plays important role to influence the growth rate of the fish. Different dietary are depending on the types of fish, water temperature and other factor. To get the optimum growth rate in tilapia, the nutrition level of the food, size of the food, feeding rate and the interval need to be maintaining at optimum level. An automatic food dispenser will be built and control the frequency of feeding by using Intel Galileo board.

3.2 PROJECT FLOWCHART

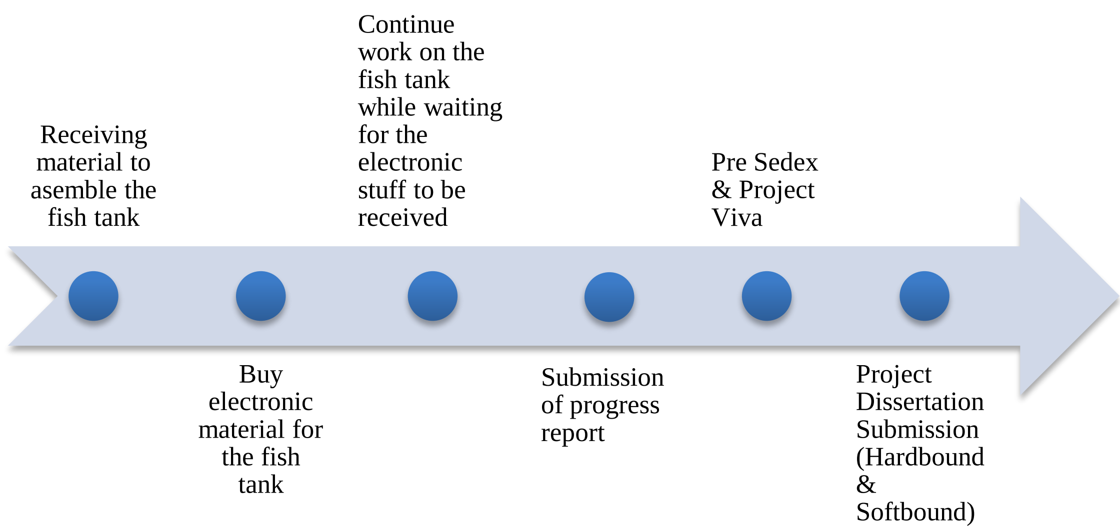


3.3 KEY MILESTONES

FYP 1



FYP 2



3.4 GANTT CHART

FYP 1

No	Detail /Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Understanding the topic and problem related	■	■	■											
2	Data gathering and component selection				■	■	■								
3	Extended proposal submission						■								
4	Work on small scale model							■	■	■	■	■	■	■	■
5	Proposal defence									■					
6	Draft report submission													■	
7	Submission of final report														■

Table 4: FYP 1 Gantt Chart

FYP 2

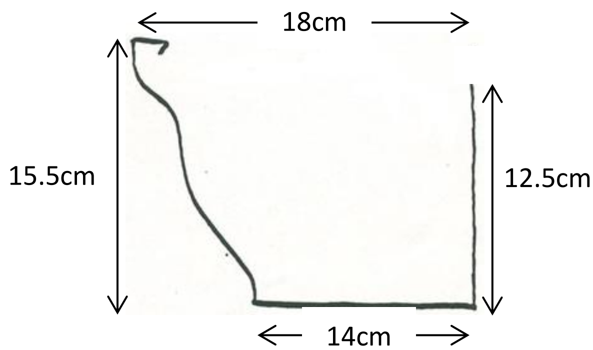
No	Detail /Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Received material and assemble the fish tank	■	■												
2	Buy electronic material for the fish tank			■											
3	Continue work on the fish tank while waiting for the electronic stuff to be received	■	■	■	■	■	■	■	■	■	■				
4	Submission of progress report								■						
5	Pre Sedex & Project Viva										■				
6	Submission of final report											■			
7	Project Dissertation Submission (Hardbound & Softbound												■	■	■

Table 5: FYP 2 Gantt Chart

CHAPTER 4: RESULT AND DISCUSSION

4.1 DESIGN APPROACH

The finalized the dimension of the small scale model is as below diagram. The proposed tank is built by using a gutter in square shape with each side length of 1.37 meter. The size of the gutter is 19 centimeter wide with the height of 12.5cm centimeter on the inner side and 15.5 centimeter on the outer side.



So, the total volume of the tank would be:

$$\begin{aligned} \text{v} &= cross\ section\ area \times length\ of\ the\ tank \\ &= 12.5\text{cm} \times 14cm \times 482cm \\ &= 84350\text{cm}^3 \\ &\approx 84.35 \text{ liters} \end{aligned}$$

The volume of tank is use to determine the size of grow bed by water volume to grow bed ratio.

4.2 SAMPLE FISH

A Red Nile Tilapia will be used as the sample in this tank.

Figure 9: Red Nile Tilapia

Reason

Red Nile Tilapia has been ranked 5th in most consumed food by National Marine Fisheries Service. Since this fish is a warm water fish, it is suitable farming in Malaysia. High tolerance toward rough situation and resilient toward diseases make this fish to be have higher survive rate compare to other species of fish.

4.3 MONITORING SYSTEM

In this system, sensors and actuator are included to create a fully automated system. In the monitoring system there are:

- PH sensor
- Water Pump
- Intel® Galileo microcontroller
- Temperature Sensor

PH sensor

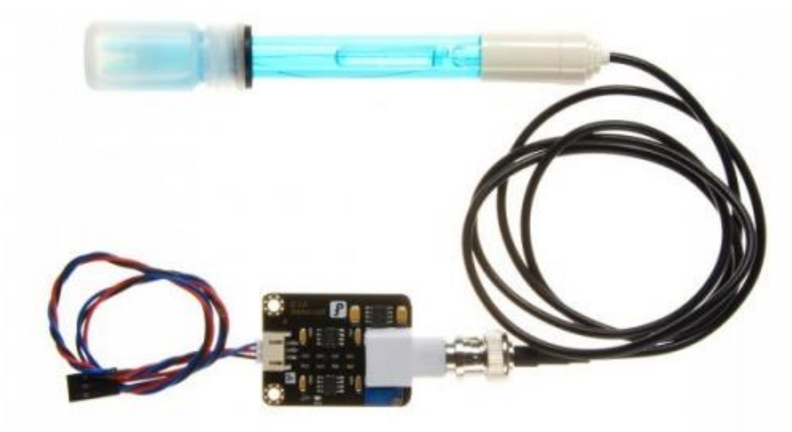


Figure 10: PH sensor

The type of PH sensor to be purchase is analog pH sensor kit. The range of this pH sensor is from 0 to 14pH. It can operate in temperature range from 0 to 60 °C. This pH kit is suitable for most of the microcontroller such as Intel Galileo, Arduino Uno and etc. This electrode allows direct connection through pH interface to the controller, or any pH device which compatible with the output terminal of the pH probe. The probe can give almost instantaneous readings in monitoring the quality of the water.

To actuate the pH value, a pH actuator system is created to filter water through acidic material in a container. The pump that use in this subsystem is 400 LPH pump which as shown in below diagram.

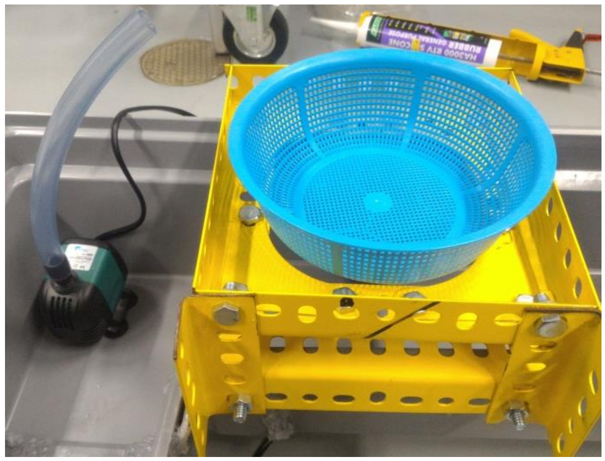


Figure 11: pH actuator

The result from the pH sensor is then process in the microcontroller and makes decision whether to actuate the pH value in the water or do nothing when the pH is at optimum value. The pH value received from the sensor can be clearly seen in the serial monitor from IDE where the processed data is send from microcontroller to the monitor with the interval of one second each data.

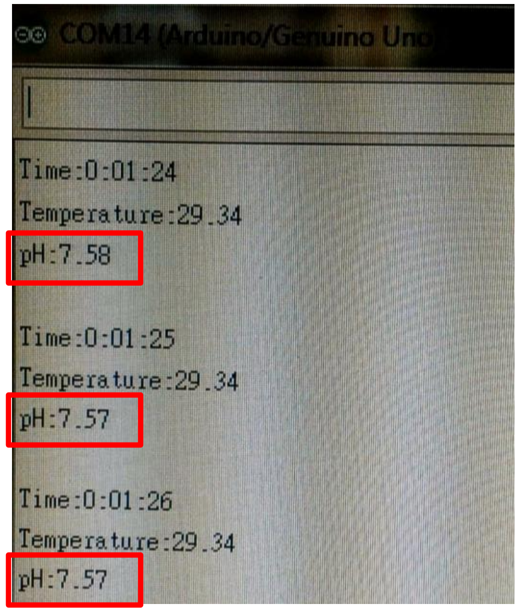


Figure 12: Data process from the microcontroller

Dissolved Oxygen

Water Pump

Based on the earlier calculation, if want to stock 10 tilapias in the tank a pump which have flow rate higher than 722.3 LPH for the small scales tank is needed to maintain the oxygen level is at optimum level especially at night. So any pump with the high value than 722 liter per hours would be suitable. A normal 1200 LPH available in the market is around RM26. A 1200 LPH pump will be used to pump the water into the grow bed (bio filter) and the overflow of the grow bed will circulate out the clean or filtered water back to the tank.

Figure 13: 1200 LPH pump

Other than that, another 800 LPH water pump also will be use in creating water current for forcing the movement of the water or fish itself and mimic a stream like condition. The movement of water will indirectly let oxygen dissolve in the water through the surface of the water by the process call aeration.

Figure 14: Water current creator

Intel® Galileo Gen 2 Microcontroller

The microcontroller used in the system is Intel® Galileo Gen 2. It has wide application in controlling a system and the functions are almost similar to Arduino controller. The accessibility also becomes a factor in using this controller.

Temperature

Thermistor temperature sensor 10K can be easily interface with any microcontroller by using Analog-to-Digital converter contain inside the board. This sensor will channel out different value of resistance influence by the temperature it detects by the probe. By collecting the output from this probe, it can easily monitor the temperature of the water inside the tank.

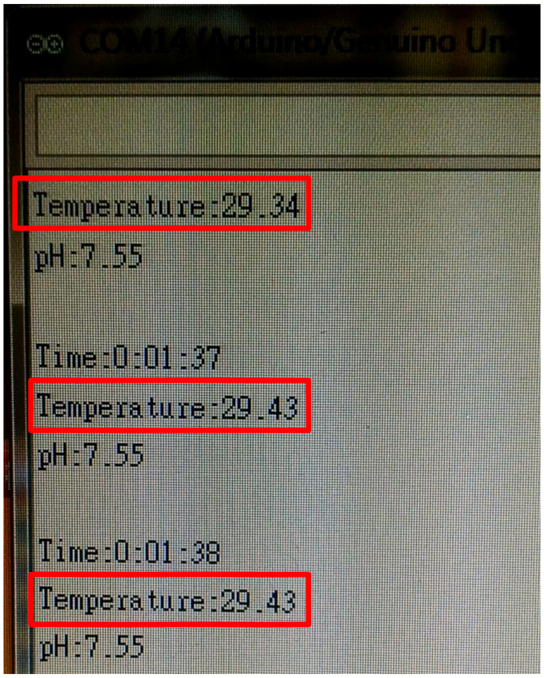


Figure 15: Temperature value processed in the microcontroller

The temperature value will be process and update at the interval of every one second instantaneously. This will actually give the user a real time update on the current water temperature reading.

Power Consumption

First total load need to be determine.

$minimum\ AH\ capacity = \frac{kWh \times loss\ factor}{Voltage}$, assume loss factor =2

5V module:

$= \ pH\ Sensor(24\ hrs) + Servo\ Motor(1\ hrs)$

$= (1W \times 24) + (1.5W \times 1)$

$= 25.5Wh$

$$minimum\ Amp \cdot h\ capacity = \frac{25.5Wh \times 2}{5V}$$

$$= \mathbf{10.2}\boldsymbol{Ah}$$

220-240V, 50Hz module:

$= Water\ Filter\ Pump(24\ hrs) + Water\ current\ pump(12\ hrs) + pH\ actuator\ Pump(3\ hrs) + Intel\ Galileo(24\ hrs)$

$Usage\ of\ power = (7.2W \times 24) + (4.8W \times 12) + (3W \times 3) + (3W \times 24)$

$= 311.4Wh$

$minimum\ Amp \cdot h\ capacity = \frac{311.4Wh \times 2}{220V} = \mathbf{2.83}\ \boldsymbol{Ah}$

Total power consumption

Total appliance use = 25.5 Wh +311.4 Wh

= 336.9 Wh/day

From the calculation above, worst case situation is considered and all the electronic appliances used in this prototype consume 336.9 Watt hour per day.

Solar Sizing

Total appliance use = 336.9 Wh/day

Total PV panels energy needed = 336.9 x 1.3

= 437.97 Wh/day.

Total Wpof PV panel capacity needed = 437.97 / 4.7

= **93.2 Wp**

Battery Sizing

$$\text{Battery Capacity (Ah)} = \frac{\text{Total Watt-hours per day used by appliances}}{(0.85 \times 0.6 \times \text{nominal battery voltage})} \times \text{Days of autonomy}$$

$$\textbf{Battery Capacity}(\boldsymbol{Ah}) = \frac{\mathbf{336.9}}{\mathbf{0.85 \times 0.6 \times 12}\boldsymbol{V}} \times \mathbf{1} = \mathbf{55.05}\ \boldsymbol{Ah}$$

	NiCd	NiMH	Lead Acid	Li-ion	Li-ion polymer	Reusable Alkaline
Gravimetric Energy Density (Wh/kg)	45-80	60-120	30-50	110-160	100-130	80 (initial)
Internal Resistance (includes peripheral circuits) in mΩ	100 to 200[1] 6V pack	200 to 300[1] 6V pack	<100[1] 12V pack	150 to 250[1] 7.2V pack	200 to 300[1] 7.2V pack	200 to 2000[1] 6V pack
Cycle Life (to 80% of initial capacity)	1500[2]	300 to 500[2,3]	200 to 300[2]	500 to 1000[3]	300 to 500	50[3] (to 50%)
Fast Charge Time	1h typical	2-4h	8-16h	2-4h	2-4h	2-3h
Overcharge Tolerance	moderate	low	high	very low	low	moderate
Self-discharge / Month (room temperature)	20%[4]	30%[4]	5%	10%[5]	~10%[5]	0.3%
Cell Voltage (nominal)	1.25V[6]	1.25V[6]	2V	3.6V	3.6V	1.5V
Load Current - peak - best result	20C 1C	5C 0.5C or lower	5C[7] 0.2C	>2C 1C or lower	>2C 1C or lower	0.5C 0.2C or lower
Operating Temperature (discharge only)	-40 to 60°C	-20 to 60°C	-20 to 60°C	-20 to 60°C	0 to 60°C	0 to 65°C
Maintenance Requirement	30 to 60 days	60 to 90 days	3 to 6 months[9]	not req.	not req.	not req.
Typical Battery Cost (US$, reference only)	$50 (7.2V)	$60 (7.2V)	$25 (6V)	$100 (7.2V)	$100 (7.2V)	$5 (9V)
Cost per Cycle (US$)[11]	$0.04	$0.12	$0.10	$0.14	$0.29	$0.10-0.50

Figure 16: Different types of battery

Based on the calculation, a 100W solar module is needed to run the whole system. The size of battery need to maintain the system to work 1 day without solar is 12V with 55.05Ah capacity.

Inverter sizing

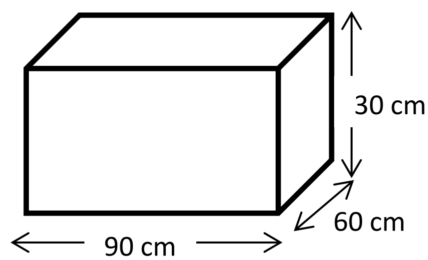
Total power usage of all appliances (in Watt) = 18 W

25-30% more size should be considered for safety reason.

The inverter size should be equal or more than **23.4 W**.

Grow Bed

The ratio between grow bed to tank is 1:1.The tank has 84.35 liters of water, therefore, the size of grow bed should be the same size at the volume of water. The grow bed act as a bio filter to filter the ammonia that produce by fish waste.



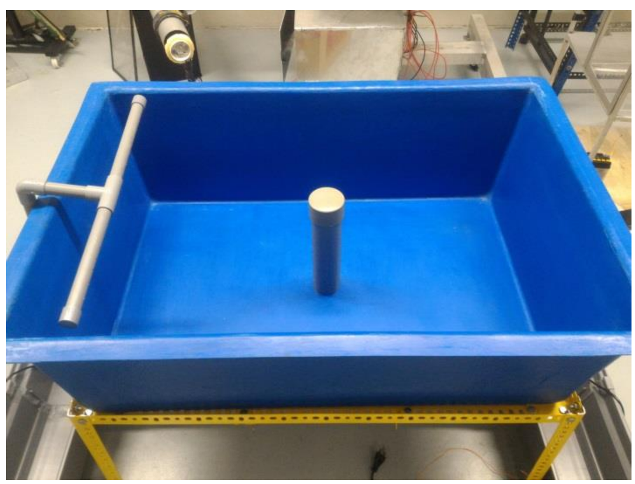


Figure 17: Grow Bed

Fish Food

After doing research on the internet, I found out there are specific dietary for the optimum grow rate in tilapia. Below is the different dietary influence by the size of fish and the size of fish determine the types of food to be fed, frequency, amount of food per time, optimum protein level and etc. Below are some of the dietary specifications for tilapia. As suggested in the table below, the size of fish food is depending on the size of fish.

Average weight (grams)	Standard feed size	Range of feeding rate (% biomass/day)
Post-hatch – 0.5	#00, #0, #1 Crumble	20 – 15
0.5 – 5	#2 Crumble	15 – 10
5 – 18	#3 Crumble	10 – 5
18 – 75	#4 Crumble (1 mm)	5 – 3
75 – 150	1/8 inch (3 mm)	3 – 1.5
150 to market	3/16 inch (5 mm)	3 – 1.5

[10]

Table 6: Suggested feeding size and feeding rate of tank-cultured tilapia

The feeding interval and amount of daily feeding will also alter according the growth stage as suggested in the table below.

Size of fish	Feeding frequency
Fry	minimum of 4 times to 8 times a day
Fingerlings	2-4 times a day
Juveniles	2-4 times a day
Adult	2-4 times a day

Table 7: Feeding frequency for tilapia

Different in fish size will also affect the amount of daily feed. The daily amount feed for tilapia is as stated below in the table.

Size of fish (grams)	Amount of daily feed (% of fish weight)
0–1	30–10
1–5	10–6
5–20	6–4
20–100	4–3
larger than 100	3–1.5

[11]

Table 8: Amount of daily feeding

The most significant nutrition need by fish is protein, tilapia needs more protein when in fry and fingerlings age due to the high growth rate and metabolism rate. A normal fry can grow around to 50% in weight in 3 days.

Life stage	Weight (g)	Requirement (%)
First feeding larvae		45-50
Fry	0.02-1.0	40
Fingerlings	1.0-10.0	35-40
Juveniles	10.0-25.0	30-35
Adults	25-200	30-32
	>200	28-30
Broodstock		40-45

[12]

Table 9: Protein Requirement for freshwater fish in different stage

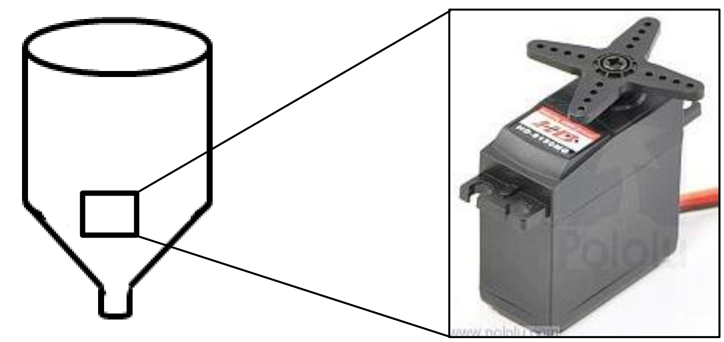


Figure 18: Servo Motor

The automatic food dispenser will be built by using recyclable 5L water bottle and a servo motor. At the outlet of the water bottle, a small outlet will be created so that the food would not come out on its own when no force is added. The servo motor will be act as a stirrer to force the food to go out from the small outlet when it is triggered. The servo motor will be connected to the controller to set period of feeding through programming the controller.

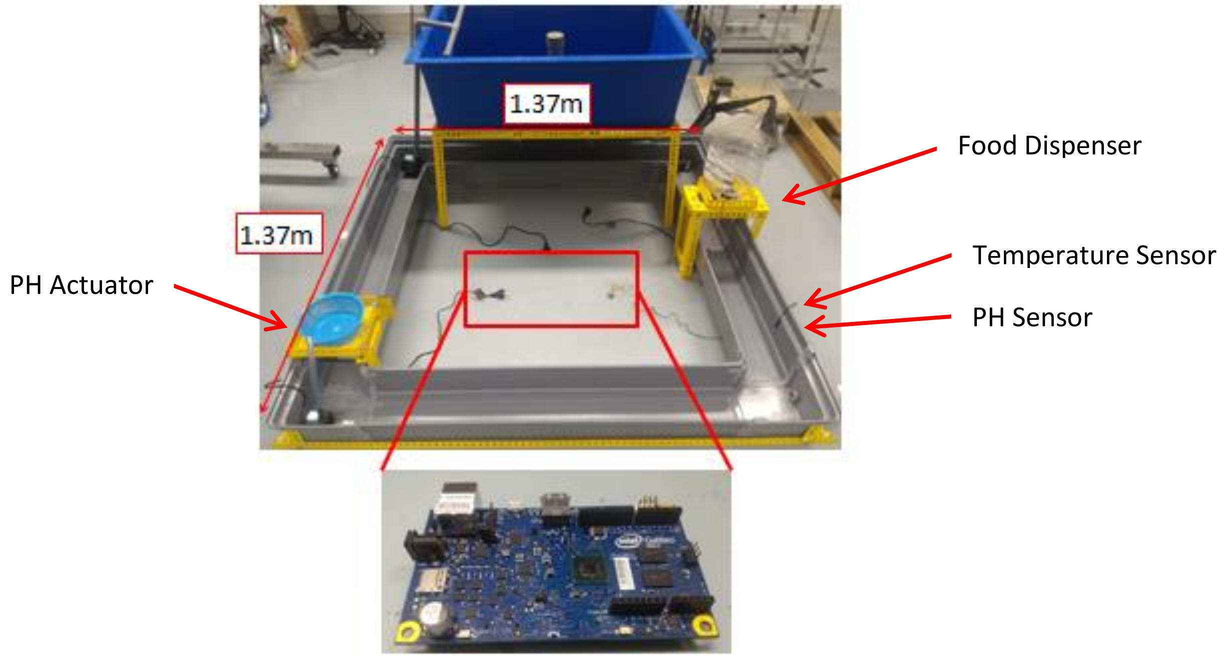


Figure 19: Final Design of the Fish Tank

***Intel Galileo will be put together with other electronic interface circuit in a waterproof container**

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The aim of the project is not only to come out with a low cost and productivity fish farming system but is to tackle the current global protein sources demand issue happens. The ramping in fish demands give an opportunity to this project if success to commercialize the technology. Not only ease the people who involve themselves in this sector, this project indirectly provide safer and more quality fish product to the market and benefit the user or customers. With using simple module or component to create a fish culture, it is easily do maintenance job in future and save a lot of manpower.

This project shows that engineering knowledge can be applied even in agriculture to simplify the process or work in this sector. A reliable monitoring system requires experiments and troubleshoots to get the best outcome for better future. Measuring water temperature and pH value of the water is in the monitoring system is important and this is where the engineering knowledge useful in this fish farming technology.

5.2 RECOMMENDATION

There are some more features can be added into the monitoring system. Those systems include dissolved oxygen monitoring, ammonia level monitoring, water level monitoring and etc. To make the whole system to be more dynamic, it can be powered by solar power. This will make a more portable system in fish farming. Besides that , the tank shape can be improve into a circular and more flexible material to make the tank to be more natural and easy to move in creating infinite space for the fish to keep swimming and portable system.

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APPENDICES

Program code

```
#include <TimeLib.h>
#include <TimeAlarms.h>
#include <Servo.h>
#include <math.h>
#define SensorPin 1         //pH meter Analog output to Arduino Analog Input 1

unsigned long int avgValue;  //Store the average value of the sensor feedback
float b;
int buf[10],temp;

Servo myservo;
int ph = 13; //PH pump control pin
int waterC = 12;    //water current pump control pin


void setup()
{
  Serial.begin(9600);
  pinMode(ph,OUTPUT);
  pinMode(waterC,OUTPUT);

  setTime(00,00,0,1,1,16); // set time to Saturday 12:00:00am Jan 1 2011
  Alarm.timerRepeat(20,servo);            // timer for every 20 seconds
  Alarm.timerRepeat(10,watercurrent);            // water current activate every 10 seconds
  Alarm.timerRepeat(10,phpump);            // water current activate every 10 seconds
}

void  loop(){
  digitalClockDisplay();
  Alarm.delay(1000); // wait one second between clock display
  ThermistorC();
  phcal();
  //if(phcal()>8){digitalWrite(ph,HIGH);}
  //else{digitalWrite(ph,LOW);}
  Serial.println("");
}

void servo()
{ myservo.attach(9);  // attaches the servo on pin 9 to the servo object
  myservo.write(180);                  // sets the servo position according to the scaled value
  delay(1000);                        //time servo turns
  myservo.detach();
}

double phcal(){
    for(int i=0;i<10;i++)       //Get 10 sample value from the sensor for smooth the value
  {
    buf[i]=analogRead(SensorPin);
    delay(10);
  }
  for(int i=0;i<9;i++)        //sort the analog from small to large
  {
    for(int j=i+1;j<10;j++)
    {
      if(buf[i]>buf[j])
      {
        temp=buf[i];
        buf[i]=buf[j];
        buf[j]=temp;
      }
    }
  }
  avgValue=0;
  for(int i=2;i<8;i++)                      //take the average value of 6 center sample
    avgValue+=buf[i];
```

```
  float phValue=(float)avgValue*5.0/1024/6; //convert the analog into millivolt
  phValue=3.5*phValue;                      //convert the millivolt into pH value
  Serial.print("pH:");
  Serial.print(phValue,2);
  Serial.println(" ");
  return phValue;
 }

double ThermistorC() {
 double Temp;
 int RawADC;
 RawADC = analogRead(0);
 Temp = log(10000.0*((1024.0/RawADC-1)));
 Temp = 1 / (0.001129148 + (0.000234125 + (0.0000000876741 * Temp * Temp ))* Temp );
 Temp = Temp - 273.15;
 Serial.print("Temperature:");
 Serial.println(Temp);
 return temp;
}

void watercurrent(){
   digitalWrite(waterC,HIGH);
   Serial.println("watercurrent on");
   delay(5000);
   watercurrent_stop();
}
void watercurrent_stop(){
   digitalWrite(waterC,LOW);
   Serial.println("watercurrent off");
}

void phpump(){
   digitalWrite(ph,HIGH);
   Serial.println("ph on");
   delay(5000);
   phpump_stop();
  }
void phpump_stop(){
   digitalWrite(ph,LOW);
   Serial.println("ph off");
}


void digitalClockDisplay()
{
  // digital clock display of the time
  Serial.print("Time:");
  Serial.print(hour());
  printDigits(minute());
  printDigits(second());
  Serial.println();
}

void printDigits(int digits)
{
  Serial.print(":");
  if(digits < 10)
    Serial.print('0');
  Serial.print(digits);
}
```

- Module Size : 43mmx32mm
- Measuring Range :0-14PH
- Measuring Temperature :0-60 ℃
- Accuracy : ± 0.1pH (25 ℃)
- Response Time : ≤ 1min
- pH Sensor with BNC Connector
- pH2.0 Interface (3 foot patch)
- Gain Adjustment Potentiometer
- Power Indicator LED