DEVELOPMENT OF AUTONOMOUS RC CATAMARAN FOR SURVEILLANCE

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UNIVERSITI TEKNOLOGI MALAYSIA

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DEVELOPMENT OF AUTONOMOUS RC CATAMARAN FOR SURVEILLANCE

MUHAMMAD FAISAL BIN ABD BAKI

A thesis submitted in partial fulfilment of the
requirements for the award of the degree of
Bachelor of Engineering (Mechanical-Aeronautics)

School of Mechanical Engineering
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DEDICATION

This thesis is dedicated to my father, who taught me that anything we learnt and encounter in life is a lesson and knowledge either we like it or not. It is also dedicated to my mother, who taught me that anything can be done one by one with a serious dedication and right attitude.

ACKNOWLEDGEMENT

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ABSTRACT

As the main resources in the world, water has been useful in many aspects in our daily life like drinking, farming resources, and some technology developments do really need water as their resource. However, growing of industrial activities and human population has made the water quality becoming a critical problem in Malaysia. Thus, it is important to always monitor the water quality regularly so that it can be safely used in our daily basis. In this study, we will develop a catamaran used for surveillance and water quality monitoring. The catamaran comprises a water quality monitoring system, autonomous and autopilot navigation system. The study must be included 1) Use an airboat propeller as a single propulsion system, 2) Using Pixhawk Autopilot for autonomous navigation, 3) The system must be powered by 6 cells 5200mAh Lithium Polymer batter. The data for water quality monitoring including pH, temperature, turbidity, and specific conductance. The result of data will be transfer to the operator computer for further analysis. Finally, the experiment will be taken around the lake inside the UTM Johor Bahru campus

ABSTRAK

Sebagai sumber utama didalam dunia, sumber air telah pun berguna didalam banyak aspek kehidupan seharian kita seperti sumber minuman, sumber pertanian and malah segelintir perkembangan teknologi terkini memerlukan sumber air. Akan tetapi, pertumbuhan aktivit industry teknologi dan peningkatan populasi manusia menyebabkan kualiti air semakin diambang kritikal di Malaysia. Oleh itu, ianya amatlah penting untuk sentiasa memerhati kualiti air agar ianya sentiasa selamat digunakan setiap hari. Di dalam kajian ini, kita akan mengembangkan teknologi pemantauan kualiti air berasaskan bot katamaran. Bot katamaran yang mengandungi system komunikasi, system pemantauan kualiti air, system unit kuasa, serta system navigasi dan kawalan. Kajian ini hendaklah mengandungi 1) Menggunakan satu unit kipas udara sebagai system dorongan, 2) Menggunakan Pixhawk Autopilot bagi system kawalan navigasi, 3) menggunakan bateri Litium Polimer 6 sel 5200mAh. Data bagi pemantauan kualiti air termasuklah ph, suhu, kekeruhan, and kekonduksian tertentu air. Keputusan data yang diperolehi akan dihantar kepada operator computer bagi analisa seterusnya. Akhir sekali, kajian ini juga dijalankan di tasik sekitar kawasan kampus UTM Johor Bahru.

.

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LIST OF ABBREVIATIONS

3D	Three-Dimensional
ADC	Analog-to-Digital Converter
ASV	Autonomous Surface Vehicle
BNC	Bayonet Nut Coupling
CG	Centre of Gravity
CO_2	Carbon Dioxide
CO DM	Chromophoric Dissolved Organic Matter
COB	Centre of Buoyancy
CO G	Centre of Gravity
CTD	Conductivity, Temperature and Depth
DO	Dissolve Oxygen
ECS	Electronic Speed Controller
DO C	Dissolve Organic Carbon
FS	Full Scale
GNS S	Global Navigation Satellite System
GPS	Global Positioning System
H_2S	Hydrogen Sulphide
LiPo	Lithium Polymer
NH_3	Ammonia
NTU	Nephelometric Turbidity Unit
pCO_2	- Potential of Hydrogen
pH	Polylactic Acid
PLA	Radio Control
RC	Secure digital
SD	Potential of Hydrogen
UT M	Universiti Teknologi Malaysia
UV	Ultraviolet

LIST OF SYMBOLS

%	-	Percentage
°C	-	Degree Celcius
µS/cm	-	microSiemens per centimeter
mg/L	-	Milligram per litre
ppm	-	Parts per million
V	-	Voltage

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background Study

This undergraduate project specifically studies on an autonomous drone boat which is catamaran type with a single propulsion system used. This project is carried out by analysis involving experimental and development to help to solve the problem in development of autonomous RC catamaran for surveillance.

Unmanned Surface Vessel (USV) or Autonomous Surface Vehicle (ASV) lately getting more intention from many researchers around the world as the alternative of drone that being used on the surface of water. USV or ASV development generally used as surveillance or patrolling mission getting more favours due to its cheap cost development and maintenance. Water quality monitoring also one of the pushing factors of the development these kinds of technologies. Conventional method of collecting data consumed energy and cost can be reduced by the involvement of drone with its continuous data recording monitoring capabilities.

The study about the development of the autonomous RC catamaran for surveillance will surely improving the current method of water quality monitoring as well as surveillance on the certain water reservoir or any water sources. By doing the analysis on this development, we will be able to find out the benefits and advantages by implementation of USV in water monitoring as well as improving any problems facing during the development.

1.2 Problem Statement

Environmental issues are not the new topic need to be discussed nowadays especially related to the water pollution around the world especially in Malaysia. Water pollution is one of serious issues because as a human being, water is important source of our body, any pollution to the water source will affecting our water supply and hence effects our health.

In Malaysia, water polluted water source increase from year to year and the clean water keep on decreasing and it rise awareness among the citizens because of health concerns. The existing water quality monitoring is lack in efficiency, this is because some of the method used to monitor the water quality is not covering the whole area and only limit at the certain area of water source. Some part of the water might be indicated as clean by the sensor; however, if the other area where there is no sensor installed and the water is not clean, it will become problematic to the consumer who consume the water from that area.

Moreover, the lacking on autonomous technology for water quality monitoring system which is not widely use in Malaysia as an alternative for water quality assessment. Therefore, in this undergraduate project, a development of new method of monitoring that will be able to obtain the data from various location across the water source is needed

1.3 Problem Question

a) How bad is water pollution in Malaysia?
b) What are the existing methods used nowadays for water quality monitoring?
c) What are the parameters to be considered when doing the water quality monitoring?
d) What are the sensors used to measure the parameters involved?
e) What is the type of hulls available?

f) How to control and navigate a boat or ship?

1.4 Research Objectives

This undergraduate project is involving in numerical, analytical, and empirical research on the development of autonomous RC catamaran. Catamaran is a type of multihull watercraft that use two parallel hulls with equal size. The main purpose of the project is to develop an autonomous RC catamaran used for surveillance and patrolling in water reservoir. An analysis on its single propulsion system, communication system as well as it controls system, and a catamaran type hull is chosen in this project.

The first objective of the project is to fabricate a physical boat in order to store the components and sensors that will be used. Second, to simulate the performance of autopilot for autonomous navigation system. The autonomous RC Catamaran was able to navigate autonomously without any human interruption and can be controlled in manual mode. Not only that, but it will also include with a system that can monitor the water quality during the patrolling. The parameters such as pH, temperature, specific conductance, and turbidity can be measured and recorded for further analysis of the water quality monitoring.

1.5 Scope of Study

The undergraduate study is time limited that already be set by the faculty leads to some constraint and limit so that it can be finished in the time given. The first scope will be covered in this study is the catamaran developed must use an airboat propeller as a single propulsion system.

The second scope covers in the development is it using Pixhawk autopilot for autonomous navigation. The autonomous RC catamaran must be operated without any human intervention; hence a communication system is needed to control, navigate, and collect the data for further analysis.

The last scope is the catamaran, and all the equipment must be powered by using a 6 cells 5200mAh Lithium Polymer battery. It is importance that the source of power to make the catamaran and the equipment can be used repeatedly and rechargeable so that a minimum cost needed during operation of the catamaran.

1.6 Significant of Study

From the study carried from the project, any problems or challenges can be identified so that any improvement can be made to improve and tackle the problems. This type of Unmanned Surface Vessel has a big potential to be used in future in various kind of mission used either in water reservoir or in ocean itself. The small development might be becoming big in the industry because the future technologies will be able to deliver new kind of USV to market. Not only that, from water monitoring or surveillance, USV also have it potential in military where it could be used as a stealth mission or defends mission from any incoming attack throughout sea border.

1.7 Project Schedule

Tasl/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Title Proposal															
Collecting Information															
Thesis Writing (Chapter 1 and 2)															
Catamaran Model Solidwork															
Water Quality system Circuit Mapping															
Autopilot Circuit Mappings															
Methodology Writing															
UGP 1 Presentation															

CHAPTER 2

LITERATURE REVIEW

1.8 Water Pollution

According to Schweitzer and Noblet (2018), water pollution is any presence of physical, biological components, chemical or any factors that cause in reduction of any benefits of a given water source. Schweitzer and Noblet (2018) also stated that any level of contamination and is based on its type of uses either it is bad or unbeneficial at all. A single source of water that is considered unsafe to drink by human may be suitable for other types of uses such as for wild habitat, recreation, or plantation. However, in this project, we would like to focus more into the way to monitor water pollution in a reservoir or any kind of water sources that are safe for human being to take advantages from it.

According to a study done by Alforz et al. (2014), in 2008 in Malaysia, there were more than 17,633 water pollution point sources were found which are from sewage treatment plant (54.1%), manufacturing industries (38.7 %), animal farm (4.48%) and agro-based industries (2.78%). It was estimate that more than 50 countries of the world with a wide area of 20 million hectares are treated with polluted or partially polluted water (Ashraf et al., 2010 as cited in Afroz et al., 2014). It is clearly shown that most of the country having a bad management in water quality measurement and monitoring system. Not only that, most of the poor countries, more than 80% of polluted water was use for watering for agriculture or other means of irrigation meanwhile 70% - 80% used for food and living security in industrial urban and semi-urban area (Mara and Cairncross, 1989 as cited in Afroz et al., 2014).

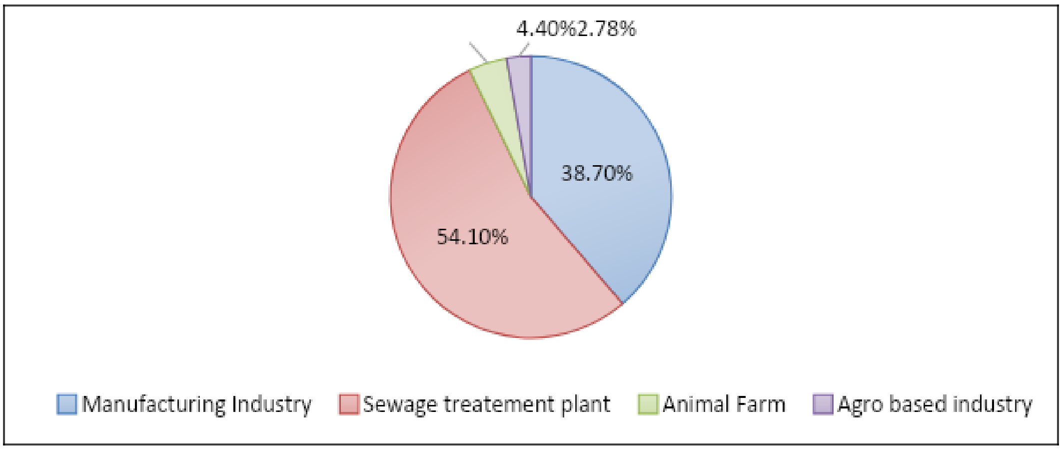


Figure 2.1 Water pollution point source

In Malaysia, from 473 rivers monitored, it was found that only 53% (244) were clean, 39% (186) were partially contaminated, and 9% (43) were infected (Afroz and Rahman, 2017). According to Department of the Environment (2014) as cited in Afroz and Rahman (2017), 3 states in Malaysia were found that have most of the river were severely contaminated which are Selangor, Johor and Perak. From the analysis on data about river pollution from 2007-2012, it was found that river pollution gas a high correlation with increase in gross domestic product for several years (Wahab, 2015 as cited in Afroz and Rahman, 2017). It is clearly shown that the 3 states with high number of industries involved will increase the contamination to water source. The same study also done by Lee (2020), from 477 river monitored in 2017, only 46% (219) were found clean, 43% (207) were partially clean and 11% (51) were contaminated. From comparison between Afroz and Rahman (2017) and Lee (2020), the number of clean rivers were decrease and the number of infected and contaminated rivers were increase based on Figure 2.2. Therefore, an action needs to be taken to reduce the number of polluted river and maintaining the current clean river with the most effective way.

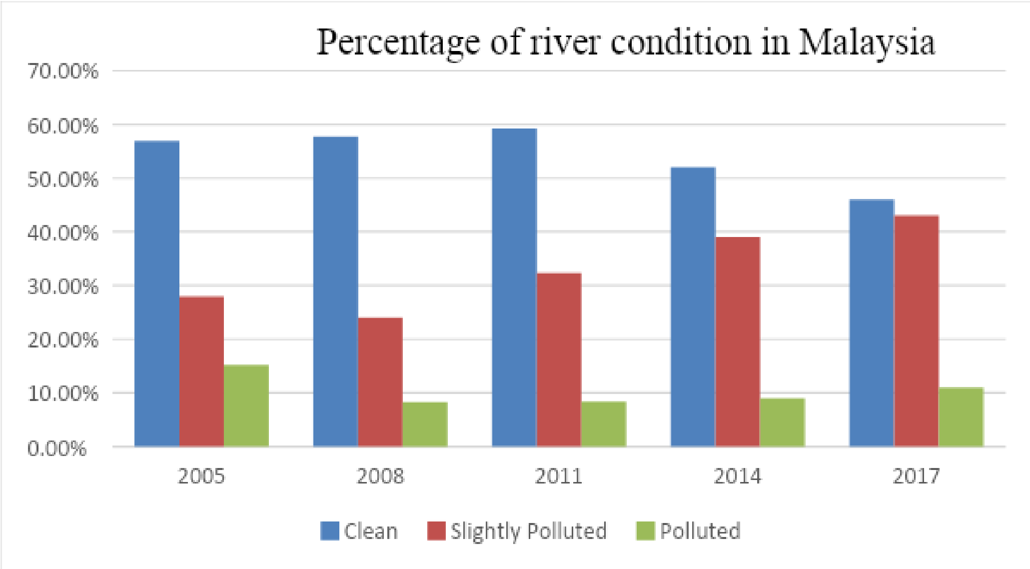


Figure 2.2 Percentage of river condition in Malaysia

1.9 Current method used to observe water quality

Water quality monitoring method always been updated in every decade and the system keep improving to give data to the scientist or observer. From station-based monitoring system into networking monitoring system already successfully implemented in order to gather data from various type of sensors involved. There are several types of station-based monitoring system that already set as a guideline and networking type of monitoring system already in used in the water quality assessment.

1.9.1 Flow-through Monitoring system

Flow-through monitoring system channel water from water source by using pump to a tank inside a shelter which as housing for all the sensor to analyse the water quality (Wagner et al., 2000). Wagner et al. (2000) also stated that the pump usually requires up to 120-volt alternating current and it can deliver 10 gallons of water per minute. There are several advantages and disadvantages from using flow-through monitoring system.

Table 2.1 Advantages and Disadvantage of Flow-through monitoring System

Advantages	Disadvantages
Expensive sensor system secured in vandal-proof shelter	Higher installation cost
Calibration can be done inside the shelter	Required electricity to pump the water
	Pump may be exposed to corrosion and clog with algae or sediment load

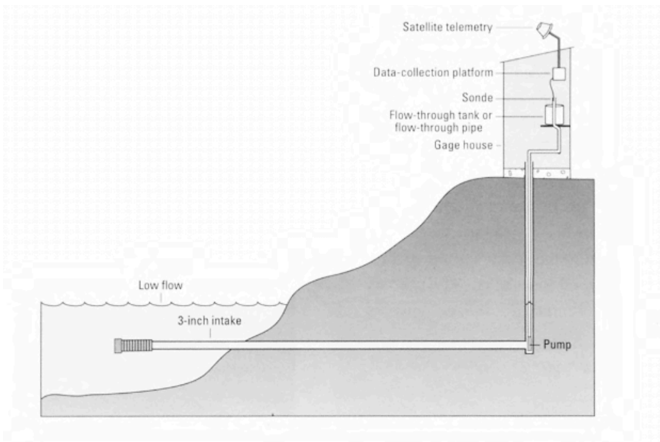


Figure 2.3 Flow-through monitoring system

1.9.2 In-Situ Monitoring System

In-situ system usually placed at the measuring point in the water source. The sensor and put inside the water source and the data transfer into recording equipment inside the nearby shelter (Wagner et al., 2000). What makes In-situ system more reliable than flow-through system is because it does need any pump to operate, hence, no excessive power required. Several advantages and disadvantages as Table 2.2 below according to (Wagner et al., 2000).

Table 2.2 Advantages and Disadvantage of In-Situ monitoring System

Advantages	Disadvantages
Required no pump water	Servicing sensors are difficult during flood

Smaller shelter	Water flow cannot be treated to reduce fouling
Low maintenance and installation cost	Sensor are exposed to debris or high flow
Reduced electrical hazard	Shifting of the channel cause the movement of the equipment

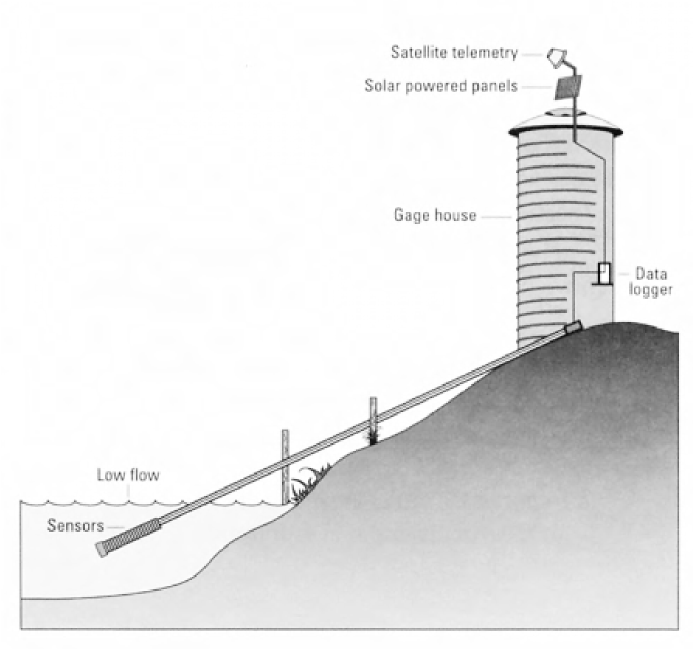


Figure 2.4 In-Situ monitoring system

1.9.3 Combined sensor and recording sonde

A self-contained, with no power requirement and does not expose to vandalism. Power supplies using batteries and all the sensor stored within the sonde on non-volatile, flash-memory and recording devices. The advantages and disadvantages as shown in Table 2.3 Advantages and Disadvantage of Combined sensor and recording Sonde below:

Table 2.3 Advantages and Disadvantage of Combined sensor and recording Sonde

Advantages	Disadvantages
Flexible location	Data only can be access during site visit
The system well protected from vandalism	Difficult in equipment maintenance
	Data lost when batteries die

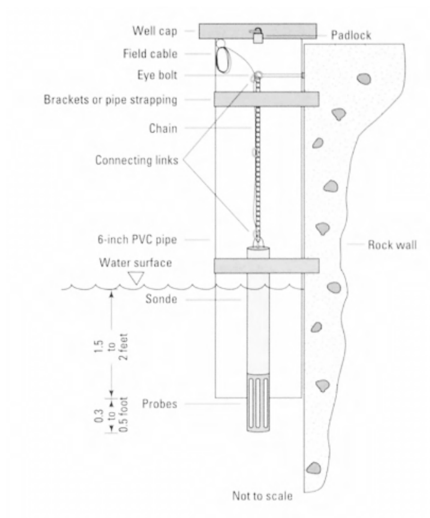


Figure 2.5 Combined Sensor and Recording Sonde

1.9.4 Wireless sensor network

Using WSN network which consists of two main components (nodes and base-station). Pule et al., (2017) stated that this simple network allowed monitoring process to be conducted remotely, real time with minimum human intervention. Node device that equipped with sensing, processing and communication capabilities and responding for measuring parameter like pH, temperature, conductivity, turbidity, and chlorine. According to the Zennaro et al. (2009), Amruta and Satish (2013), and Faustine et al. (2014) as cited in Pule et al., (2017), the WSN used their water monitoring application was powered by the battery and solar panel. Hence, it was unstated about the exact location of the sonde nodes, however from the power source mentioned earlier might state that the sonde nodes were floating on the water stream.

The main advantages from using wireless sensor network are real-time monitoring and low cost on installation and maintenance.

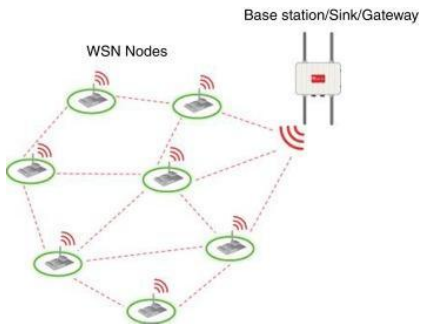


Figure 2.6 Wireless Sensor Network

1.9.5 Unmanned Surface Vessel

The usage of Unmanned Surface Vessel becoming an attention to the researcher who are trying to develop to kind of method to monitoring the water quality monitoring and sampling (Chang et al., 2021). There are many kinds of Autonomous Surface Vehicle (ASV) or Unmanned Surface Vessel (USV) that were equipped with various kind of sensor in order to obtain related data for further investigation on water quality. The real monitoring capabilities is a big advantage with new system of navigation that allowed it to move and navigate itself without any interruption by human. Since it offers low initial investment and maintenance cost, it can be used by anyone in many kinds of sector (Tuna et al., 2013).

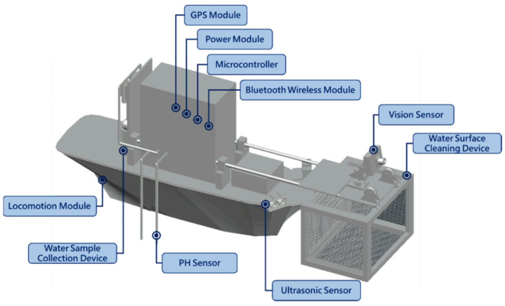
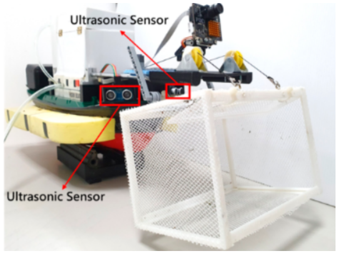
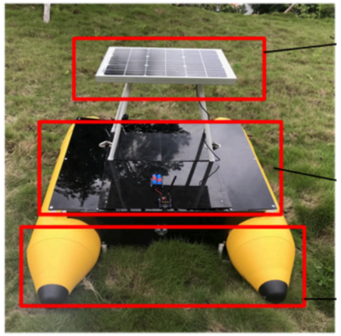


Figure 2.7 Unmanned Surface Vessel

Below is the list of the USV/ASV that already being proposed by several researcher used for water quality monitoring:

Table 2.4 Example of USV development

Author	USV model proposed	Mission	Navigation and data recording Mode	Sensor	Boat specification	Module/System
Chang et. al (2021)	 Figure 2.8 Multi-Function Unmanned Surface Vehicle (MF-USV)	Water Quality Monitoring, Water Surface Cleaning, Obstacle avoidance	Remote Navigation and Real-Time data transfer	Ultrasonic sensors, pH sensors, and vision sensors	Deep-Vee Hull, underwater Ducted Propeller,	Locomotion module, Positioning Module, Obstacle avoidance module, Power module, Communication module, Remote Human- Machine Interface, Water Quality Monitoring system, and Water surface cleaning system

W. Jo et. al (2019)	 Figure 2.9 SMARTBoat 3	Water Quality Monitoring	Autonomous and Remote Navigation, Real-Time data transfer	pH sensor, Turbidity Sensor, Temperature sensor	Hovercraft-type hull, Underwater ducted propeller	Water Quality Monitoring system, Communication System
Cao et al. (2020)	 Figure 2.10 Automatic cruise intelligent unmanned surface vehicle (USV)	Water Quality Monitoring	Autonomous Navigation, Memory data storage	pH sensor, TDS sensor, turbidity sensor	Catamaran	Wireless Communication Transmission module, Water Quality Monitoring Module

Cryer et. al (2020)	 Figure 2.11 The C-Worker 4 (CW4)	Water Quality Monitoring	Pre-planned Autonomous and Remote-Control, Real-time data storing	CTD, DO, pH, pCO2, nitrate, chlorophyll fluorescence, CDOM, turbidity, DOC sensors	Deep-Vee Hull,	Navigation system, Water Quality monitoring system

1.10 Parameter Involved in Water Quality Monitoring

Water quality measurement is a crucial aspect that need to be considered to estimate the level of contamination to the water sources from river or dam. There several parameters need to be considered such as temperature, specific conductance, pH value, dissolve oxygen (DO) level, chromophoric dissolved organic matter (CODM), chlorophyll fluorescence, and total suspended solid (turbidity). In order to measure all the parameters involved, several dedicated sensors are chosen and suitable to use for water quality surveillance with their own specification will be discussed.

1.10.1 Temperature

Temperature of the water is an importance parameter need to be measure because it is influence on the density of water, solubility, pH value, specific conductance, the rate of chemical reaction and biological activity (Radtke, Kurklin, and Wilde, 1998 as cited in Wagner et al., 2000). The increasing temperature of water in reduce the pH value and the saturation of dissolve oxygen also decrease. Not only that, but higher temperature could also dissolve more minerals from surrounding therefore will have higher electrical conductivity. According to Radtke et al. 2004) as cited in Wagner et al. (2006) stated that a suitable temperature range for water should be between 0°C to 40°C.

1.10.2 Specific Conductance

According to Wagner et al. (2000) specific conductance is a measurement of the capacity of water to conduct electrical current. It has no linear relation between total dissolved solids; however, it is a good indicator of specific conductance. If the concentration of dissolve ion increase, specific conductance will increase (Wagner et al., 2000). The suitable range for the specific conductance is between 200µS/cm to 1000 µS/cm or microSiemens per centimeter.

1.10.3 pH value

pH value is the most importance parameter to consider during water quality monitoring. It measures the effective hydrogen ion concentration (Wagner et al., 2000). The pH value above 7 can be considered basic or alkaline, 7 is neutral and below 7 is acidic which is sometime dangerous to the aquatic habitant. The effect of dissolve gases like CO_2, H_2S, and NH_3 will affect the pH value (Wagner et al., 2000).

1.10.4 Dissolve Oxygen (DO) Level

DO level in surface water usually related to photosynthesis and reaeration or supply of oxygen to aquatic plant or habitat (Lewis,2005 as cited in Wagner et al., 2006). It is one of the most important factors for survival of aquatic organisms and for chemical reaction in water which usually in range from 2 to 10 mg/L (Wagner et al., 2006). Dissolve oxygen (DO) level is basically a measurement of the amount of oxygen available. According to Vizcaíno et al. (2018), the DO level that is considered acceptable for aquatic habitat is around 5mg/L to 8mg/L, meanwhile if it below than 5mg/L, it would be dangerous for aquatic organisms.

1.10.5 Turbidity or Total Suspended Solid

According to Voichick et al., (2017) as cited in Lee et al., (2020), turbidity is a measurement of water clarity where the dissolved solids and suspended particle in water absorb light, decrease the amount of sunlight penetration to the water where the visibility of water will be reduced also it need to be less than 1 NTU (Nephelometric Turbidity Unit).

1.11 Sensors Used to Measure Water Quality

1.11.1 DS18B20 Temperature sensor

A temperature sensor usually using thermistor which is a semiconductor material that use resistance that is change varies to the temperature (Wagner et al., 2000). As proposed by (Koestoer et al, 2019), a waterproof sensor that is suitable to be used to measure underwater temperature is DS18B20 as in Figure 2.12 DS18B20 Sensor below. According to Koestoer et al. (2019), DS18B20 sensor comes with selective bits number that can be calibrated by the user and it varies from 9-bits to 12-bits. The higher the bits resolution number shown that the more accuracy of the temperature can be read. Bit resolution is an Analog-to-digital converter (ADC) which used to convert signal in voltage to digital signal that can be read by the microcontroller. 9-bits to 12-bits resolution in DS18B20 sensor show that the analogue value which power of 2 for example 2^9 (9-bits) and 2^{12} (12-bits) (Koestoer et al. 2006). Below the Figure 2.12 DS18B20 Sensor of DS18B20 is a Table 2.5 DS18B20 Sensor Specification of specification for the sensor.

Figure 2.12 DS18B20 Sensor

Table 2.5 DS18B20 Sensor Specification

Power Supply	3V to 5.5V
Current consumption	1mA
Accuracy	+- 0.5˚C
Resolution	9-12 bits
Conversion time	<750 ms

1.11.2 Specific Conductance using TDS sensor

J E Suseno et al (2020) proposed that in order to measure the organic compound dissolved by using TDS sensor. TDS sensor or Total Dissolve Solid senso in Figure 2.13 below can indicate how many soluble solid that are dissolved in the water. The higher the TDS value, the more the soluble solid dissolved. It has 2 electrodes that is equally space apart which will be inserted into water and used to measure charge. If there is no soluble solid dissolve, it will not conduct any electricity.

Figure 2.13 TDS Sensor

Table 2.6 TDS Sensor Specification

Input Voltage	3.3V – 5.5V
Output Voltage	0 - 2.3V
Working Current	3 – 6 mA
TDS Measurement range	0 – 1000ppm
Accuracy	+- 10% FS (25˚C)
Number of needles	2

1.11.3 pH with Analog pH meter

According to Caraballo, (2015) the suitable sensor used is analog pH meter from Dfrobot. pH sensor measures the voltage produced by the water acidity with the voltage of it known solution by using the difference in voltage between them to deduce the difference in pH value. Figure 2.14 and Table 2.7 below show the analog pH meter from Dfrobot and its specification

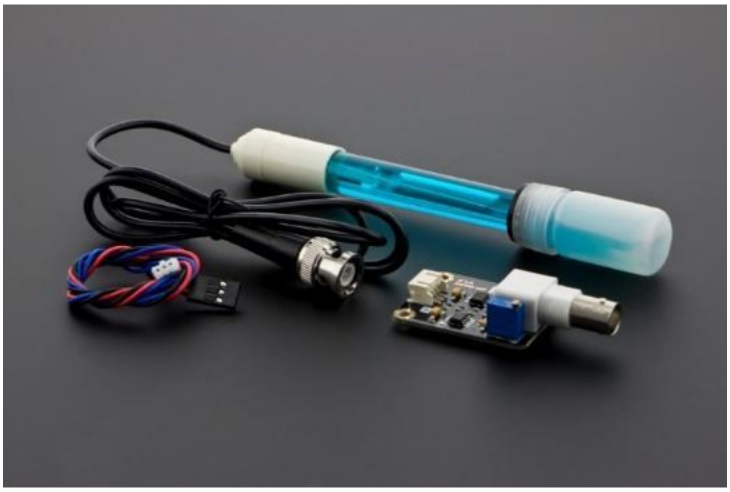


Figure 2.14 Analog pH Sensor

Table 2.7 Analog pH Sensor Specification

Voltage	5 V
Size	43mm x 32mm
Range	0 - 14 pH
Measuring temperature	0 - 60˚C
Accuracy	+- 0.1 pH
Response time	<1 min
Connector	BNC connector
PH2.0 interface	3 Foot patch

1.11.4 Dissolve Oxygen with Gravity Analog Dissolve Oxygen sensor

The suitable sensor used for DO level measurement is Gravity Analog Dissolved Oxygen sensor from Dfrobot.

Figure 2.15 Gravity Analog Dissolved Oxygen Sensor

Table 2.8 Gravity Analog Dissolved Oxygen Sensor Specification

Working Voltage	3.3V – 5.5V
Output Voltage	Analog 0-3.0V
Sensor Type	Galvanic Probe
Range	0 – 20mg/L
Response Time	90 seconds (up to 98% full response)

The function of this sensor is to measure the amount of oxygen dissolve in an aqueous solution by using Galvanic Type probe. Galvanic probe uses 2 types of polarized electrodes which is anode and cathode in an electrolyte solution which separated with thin, semi-permeable membrane in Figure 2.16below. When the measurement taken, the dissolved oxygen diffuses across the membrane then reduced and consumed at the cathode (Vizcaíno et al., 2018). The chemical reaction produces an electric current which carried by the ion in the electrolyte and run from cathode to anode. The output measurement increases when the dissolved oxygen increase (Vizcaíno et al., 2018).

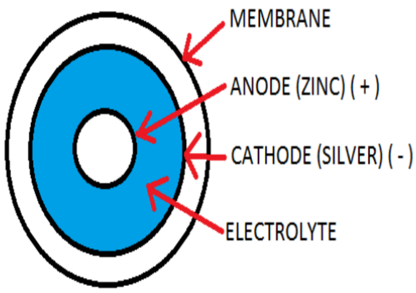


Figure 2.16 Galvanic Probe

1.11.5 Turbidity/ Total Suspended Solid with Turbidity sensor

The suitable sensor used to measure turbidity is turbidity sensor from Dfrobot. It measures the amount of light that scattered by the suspended solid in water. The water turbidity level or cloudiness increase as the total suspended solid in water increase.

Figure 2.17 Turbidity Sensor

Table 2.9 Turbidity Sensor Specification

Operating Voltage	5V DC
Operating Current	40 mA
Response time	<500 ms
Insulation resistance	100M
Output Method	Analog: 0-4.5 V Digital: High/Low level signal
Operating Temperature	5˚C - 90 ˚C

1.12 Types of hulls

A hull of a ship or boat is one of the most importance structures because it is a watertight enclosure that protect most of the component of a certain ship like cargo and machine, meanwhile for boat it is suitable to be place for the sailor or its passenger to be at. The shape of hull comes with various classification and categories such as *Planning Hull, Displacement Hull and Semi-Displacement Hull* (Khan, 2017). Each of the categories have their own function, advantage and shape that will be discussed.

1.12.1 Planning Hull

Planning Hull is type of hull where the weight of the boat or ship is supported by hydrodynamic pressure at high-speed in forward motion (Yousefi et al., 2013). The Planning Hull acting according to the Archimedes Principle which is stated as the buoyancy force that acting on a body is the same as the weight of the fluid displacement of the body. When at high-speed, the under sides of vessel create a lifting force that makes the hull lift vertically and change it trim angle as in Figure 2.18 below.

Figure 2.18 Planning Hull

1.12.1.1 Flat-Bottom Hull

Flat-Bottom hull is one of the hulls that typically found smaller, open boat and has shallow draft. It usually good use for fishing activities in small lakes, pond and slow-moving river. It stable in calm weather and sometime give a rough ride because of the flat bottom pounding on each wave (Dandabathula et al., 2021). The broad bow area can create rough ride which takes more power to move.

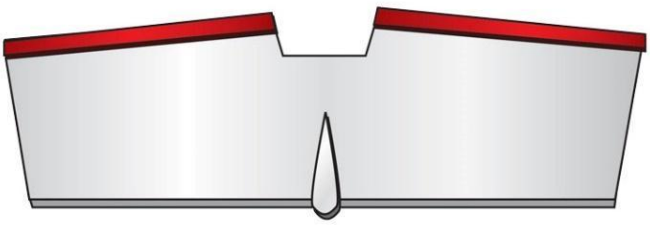


Figure 2.19 Flat-Bottom Hull

1.12.1.2 Deep Vee Hull

According to Riley (2020) as cited in Dandabathula et al. (2021), Deep Vee bottom tends to have sharper entry to the water which allowed to have a smoother ride in any type of water especially rough water. It is usually used to operate in rough wavy water or usually used to go farther offshore. Deep Vee Hull offers easy manoeuvrability at slow speed, stable in rough water, and has shallow draft. However, it used more power to move than the flat bottom at the same speed and may roll or bank during sharp turn.

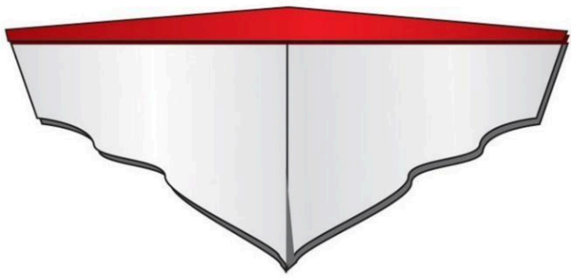


Figure 2.20 Deep Vee Hull

1.12.2 Displacement Hull

Displacement hull is a hull type that uses buoyancy to support its weight. As it follows the Archimedes principle even at rest or slow moving or at the high-speed moving boat. As the name, the weight of the water displacement is equal to the buoyancy force acting to the body. In order to make the boat not sink, the weight of the water displacement must be bigger or equal to the weight of the body or object. There 2 types of displacement hull which is Round-Bottom Hull and Multi-Hull.

1.12.2.1 Round-Bottom Hull

Round-Bottom Hull is type of hull that usually used as dinghies, tenders and some car-top boat. The advantage of the Round-Bottom Hull is it easily travel through water at lower speed. However, it is unstable and tend to roll unless has a deep keel or stabilizer.

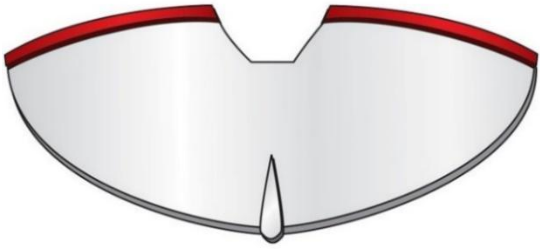


Figure 2.21 Round-Bottom Hull

1.12.2.2 Multi-Hull

Multihull is a type of hull that has more than one hull to use for displacement or planning such as Catamaran or Trimaran. This type of hulls is very popular because of their low wave resistance even at high speed with reduction of power and larger deck area (Nabila, 2017). Multihull has greater stability due to its wide beam and easy traveling through the water. However, Multihull needs larger area for turning.

Figure 2.22 Multihull

1.12.3 Semi-Displacement

It is a combination of planning hull and displacement hull. At low speed, it can displace water like the displacement hull while at high speed it can generates lift. It more stable than the planning hull and faster than displacement hull. However, it still moves slower than the planning hull.

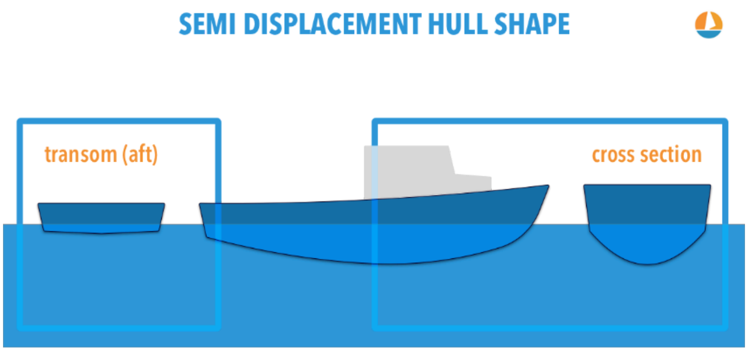


Figure 2.23 Semi-Displacement Hull

1.13 Mechanism to control and navigate a boat

Most of the ship nowadays use single propeller system, single rudder that designed to make sure the boat or ship getting from point to their destination economically as possible. In order to control and navigate a boat or ship, there are 2 mechanism or system that are widely used today which are:

- Propulsion system by using propeller
- Turning system using rudder

1.13.1 Propulsion system by using propeller

Propeller shaft creates a torque or energy required to turn the blade that powered by an engine or motor. The torque then produces thrust, with implication of Newton's Third Law, it then produces velocity (axial-induced velocity) to the opposite direction of the thrust (Hong et al., 2019). (Rawson & Tupper, 2001) The rotating propeller will create a low-pressure area in front of the propeller and high-pressure area at the back of the propeller will make the boat move forward according to the Bernoulli's Principle. According to the Carlton (2018), there are several types of the propeller used nowadays which are Fixed Pitch Propeller, Ducted Propeller, Tandem Propeller, Cycloidal Propeller, and more. However, in this development, only Fixed Pitch Propeller and Ducted Propeller will be discussed.

1.13.1.1 Fixed-Pitch Propeller

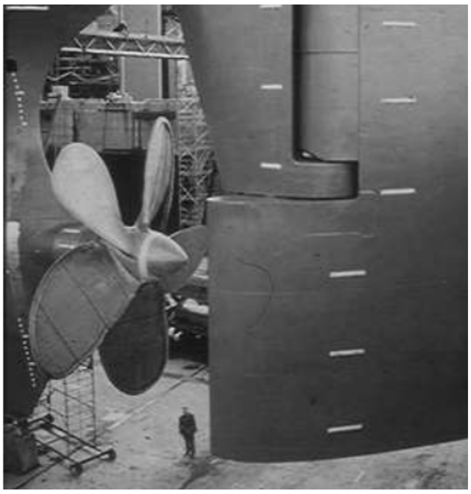


Figure 2.24 Fixed-Pitch Propeller

The fixed pitch is a type of propeller where the blades position and the position of the pitch is permanently fixed and cannot be change during operation

(Carlton, 2018). It is cost efficient and strong, but the pitch of the blade cannot be changed that limit in area of use when it comes to load, speed, and manoeuvrability.

1.13.1.2 Ducted Propeller

Figure 2.25 Ducted Propeller

Ducted Propeller comes with 2 components, which are annular duct with aerofoil shape and a propeller (Carlton, 2018). This type of propeller can produce a high thrust at low speed and usually used for towing and trawling. The contribution of the duct up to 50% of the propulsion total thrust at zero ship speed (Carlton, 2018). The output power from ducted propeller is higher than the fixed pitch propeller, better turning and steering characteristic at low speed. However, it reduces the efficiency at high speed.

1.13.1.3 Airboat Propeller

Figure 2.26 Airboat Propeller

According Kaizu et al. (2011), water surveillance on a shallow pools or lake with a lot of weeds, it is difficult by using conventional propeller for manoeuvrability; hence, an airboat propeller is needed. The advantage of using airboat propeller is the propeller is not entangled in any aquatic weeds and any mud at the bottom of the lake. However, the propulsion force is smaller in cruising speed than the propeller-driven boat with the same powered-engine used (Kaizu et al., 2011).

1.13.2 Turning System using Rudder

Rudder had become an importance tool that helps to turn a ship or boat since long ago, from Egypt era to Viking ages, many types of rudders and controlling tools invented to help manoeuvrability of ship or boat (Molland & Turnock, 2011). Rudder does not turn a ship while it turns at certain angle. For example, when rudder turn to starboard, the rudder force (sway force) is directed to the port that create a rudder moment about the CG of a ship/boat. The rudder moment must have enough to introduce drift angle and a small amount of surge velocity to the ship. On the other hand, during the hull turn toward the port it exerts a force to the water particles and in turn the water particle exerts an opposite force toward the hull. Force exerted toward the hull in 2 parts (stern and bow). Because of the inertia force exerted on the bow is higher than the stern. So, it produces the resultant moment toward the starboard.

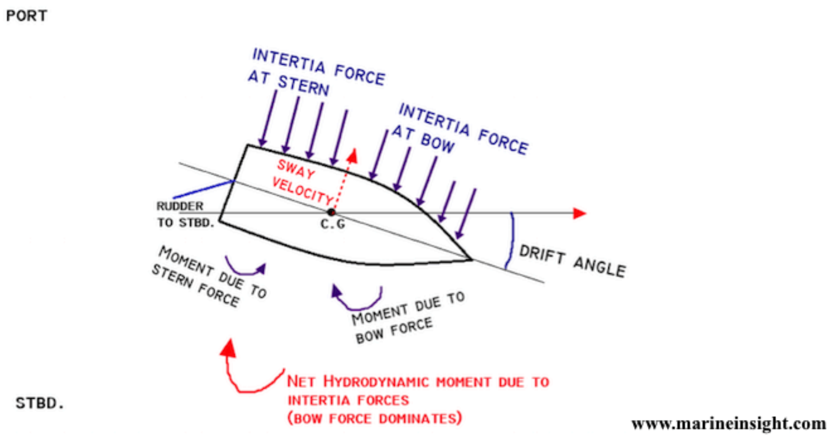
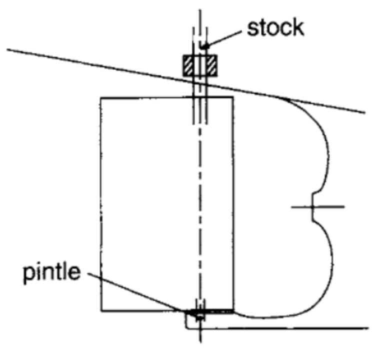
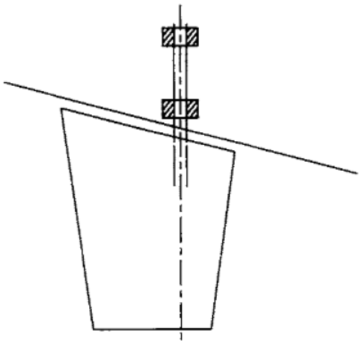
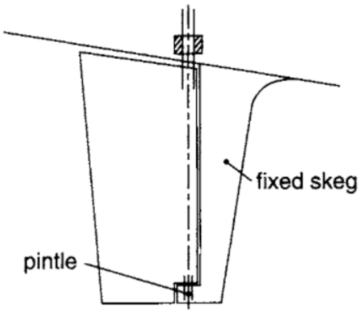
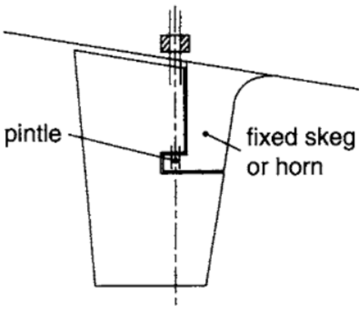
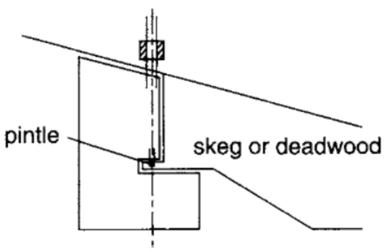


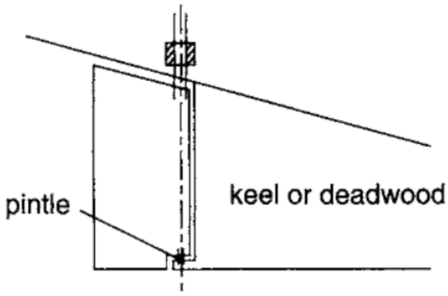
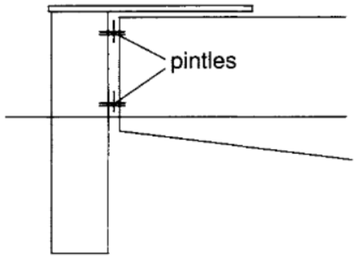
Figure 2.27 Boat Steering Mechanism

There are several types of rudders used in ship and boat nowadays. According to Molland & Turnock (2011), several factor effecting the choice of rudder such as ship or boat type, the size, shape of stern, size of rudder required, and the position of the propeller used. Table 2.10 below shows some type of rudder available as discussed by Molland & Turnock (2011).

Table 2.10 Rudder Type

Rudder Type	Description
a. Balanced Rudder 	- Open Stern frame with bottom pintle supported by pin or bolt with bearing - Used in tugs and trawlers for single-crew merchant ship - This model being replace with Semi-Balanced Skeg Rudder
b. Spade Rudder	- Balanced rudder with both bearing inside of the hull

	- Larger stock diameter and rudder thickness used to carry the bending moment and torque of the rudder - Used in single/twin-crew vessel, small power craft, ferries, yacht and some warship.
c. Full Skeg Rudder  (a)	- Unbalanced rudder supported by fixed skeg with pintle at the bottom. -Used in large sailing yacht, hydroplanes on underwater vehicles
d. Semi-Balanced Skeg Rudder  (b)	- Known as Horn rudder or Mariner Rudder - The rudder is supported by the fixed skeg with bottom pintle at the bottom of the skeg. - Used in bigger ship
e. Semi-Balanced, after of skeg or deadwood  (c)	- Used to twin-crew ship with single rudder - Model being replaced by spade rudder and semi balance d skeg rudder
f. After of keel or deadwood	- Unbalanced rudder - Used in older type of sailing craft

 (d)	
g. Pintle  (e)	- Unbalanced rudder - Used in small sailing craft

CHAPTER 3

RESEARCH METHODOLOGY

1.14 Introduction

objectives of the project will be elaborated all steps involved. The flow of the process from the fabrication of the physical boat to store the components and sensors, to simulate the performance of autopilot for autonomous navigation system and to obtain the necessary data for water quality monitoring will be explained in this chapter. The basic performance of the catamaran including thrust required and power required will be calculated in order to provide correct amount of thrust and power to move the catamaran.

The fabrication of catamaran from scratch by using 3D printing by using material Polylactic Acid (PLA) for some of the structure of the catamaran. The dimension and position of the hull and the container also will be explained. The location of the Centre of Gravity (CoG) and Centre of Buoyancy (CoB) will be determined in order to make sure the catamaran in the correct position and stable before it fabricated.

The wiring connection for the autopilot system by using Pixhawk and several other components such as GPS module with compass, Telemetry, Receiver and more will be shown the chapter. The specification and requirement of each component will also be listed in the chapter for further understanding.

Next, the wiring connection for sensors used to assess water quality will be explained in the chapter. The selection of several sensors to obtain the data for further analysis will be controlled with the Arduino Uno R3 microcontroller and the data storage in the SD Card. All the sensors and equipment will be powered by 6 cells Lithium Polymer battery.

Last but not least, the planning to test the catamaran and the system used in it will be held around the UTM Lake. The waypoint, location coordinate, operation area, condition will be explained further in the chapter.

1.15 Flow Chart

Flow chart is a necessary method to illustrate the planning flow of the project to fulfil the objectives. The flowchart below shows three separate initial flow which is catamaran fabrication, water quality monitoring system, and autopilot navigation system.

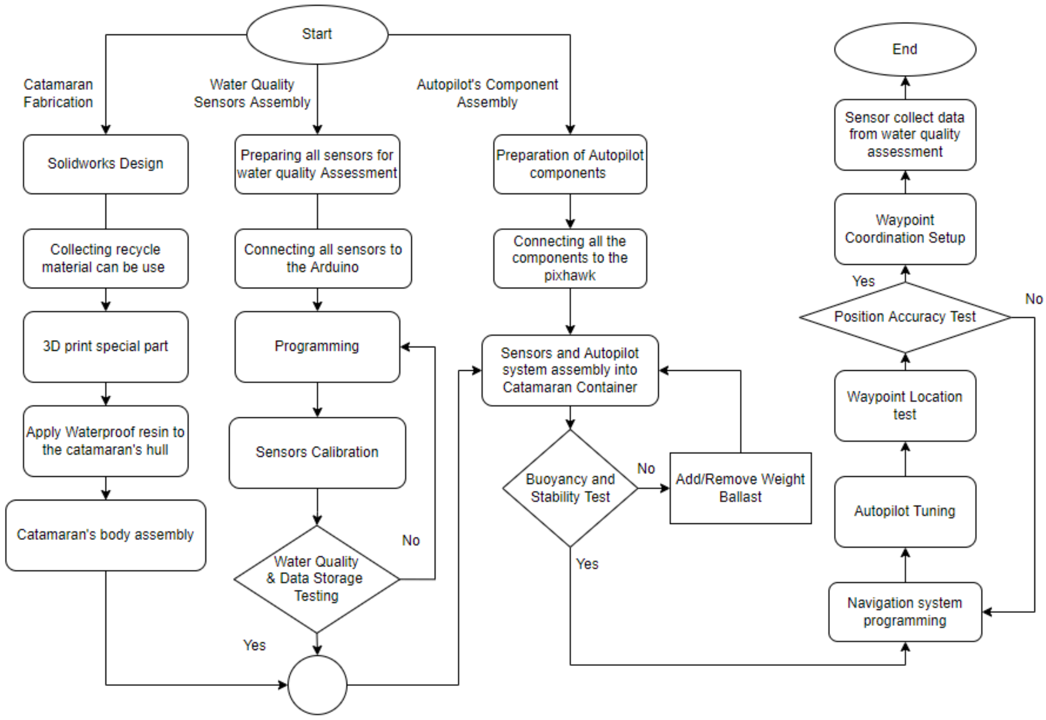


Figure 3.1 Methodology Flowchart

1.16 Boat proposed design

Boat is one of the most important mechanisms in this project because most of the components will be placed and stored inside of the boat. Not only that, but it also plays a big role in Archimedes' Principle where most of the buoyancy force acting on it depends on their design. The buoyancy force acting on the boat is equal to the weight of the volume of water displaced by it. Hence in this project, several types of structure being considered to make sure a higher buoyancy force can be produced with a good stability and manoeuvrability of the boat during operation.

Therefore, in this project, a multihull or catamaran design were chosen as its main hull. Catamaran is one of the types of multihulls in the displacement hull's category as discussed in Chapter 2 earlier. The main reason on choosing the Catamaran is because its offer a great stability with larger deck area to store component and necessary equipment. It also produces low resistance throughout wave water which is a good type of hull for this project. Below is the Isometric View of the Complete Catamaran boat that has been drawn using Solidworks software.

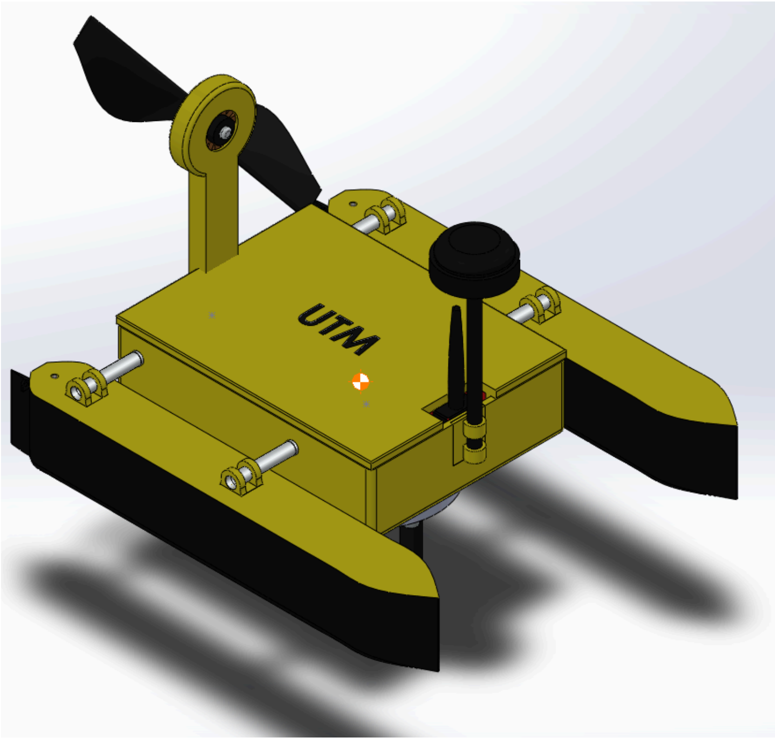


Figure 3.2 Isometric View of Catamaran

The catamaran's deck or middle container will be used to store sensors and equipment of all the system involved such as Water Quality Monitoring system and Autopilot Navigation system. The main material used for the container is a plastic Tupperware which is easily accessible and light. Not only it is easy to get and to modified, but this project also use other recycle material in order to reduce excessive waste and cutting the fabrication cost. However, some of part need to be custom made such as motor holder and the both hulls, need to be 3D-printed with Polylactic Acid (PLA) material.

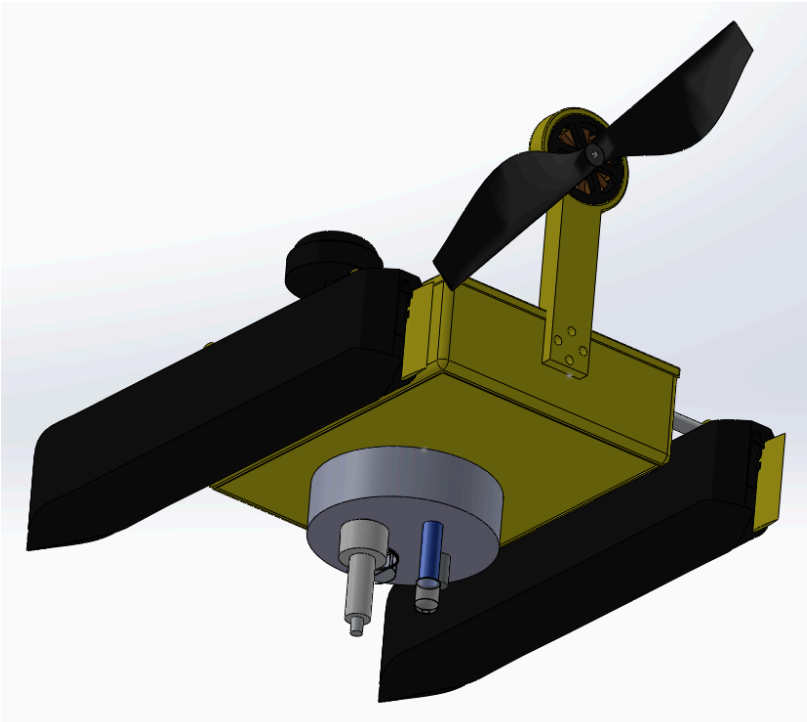


Figure 3.3 Isometric View of Catamaran from bottom

The catamaran will be powered by a single airboat propeller propulsion system because it is suitable to be used in this project. This is because, the movement and the manoeuvrability of the catamaran will be difficult if the conventional underwater propeller due to mud and weeds entangle into it. As being discussed earlier in Chapter 2, the propeller works to produce a thrust to move the boat forward by creating the pressure different between in front of the propeller and at the back of the propeller. When the propeller starts to rotate, a low-pressure area in front of it will be created and a high-pressure area at the back of the propeller will push the boat forward.

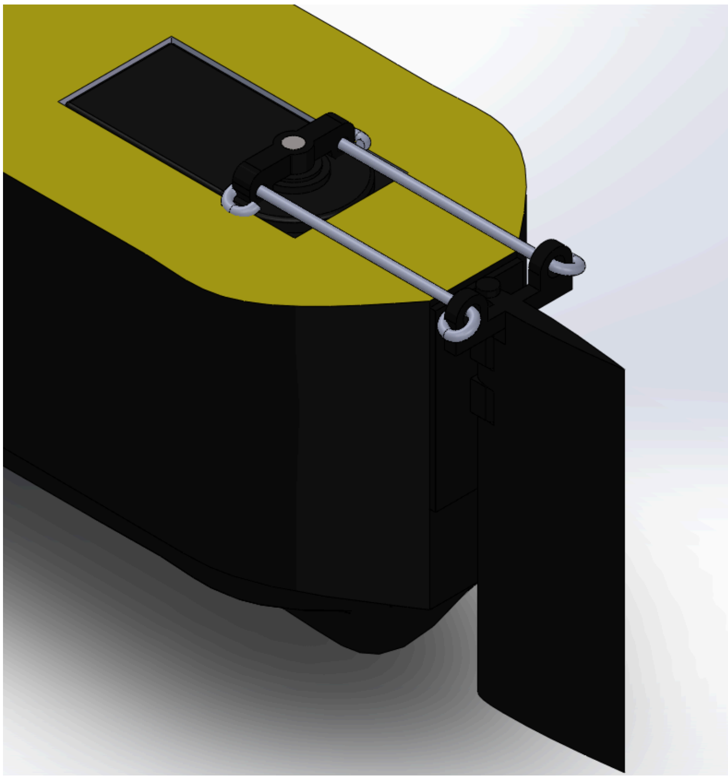


Figure 3.4 Connection of servo and the rudder

A pair of rudders will be used and attach at both hull's stern for a better manoeuvrability. Rudder will be controlled by servo inside of the hull. The reason for choosing rudder to be used at each hull is because of steering mechanism of boat itself. A boat turning due to rudder force was produced during turning of the rudder. Hence the force then induced a rudder moment about the CG of the boat then produce a drift angle and a surge velocity to the boat. During the turning, the hull exerted force to the water particle and the water particle exerted a reaction force toward the hull. Due to a large bow area than the stern is, the resultant reaction force by the water particle is larger at the bow rather than the stern, Hence the boat is turning. Therefore, by using two rudders at both sides, a larger amount of rudder force could be produce and making the boat easier to manoeuvre.

To complete the water quality monitoring, several sensors were used due to their accuracy at recording data. The chosen sensors are pH sensor, Turbidity sensor, TDS sensor, and temperature sensor. All the sensors will be connected with Arduino microcontroller which powered by 6 cells Lithium Polymer battery.

1.16.1 Catamaran Drawing

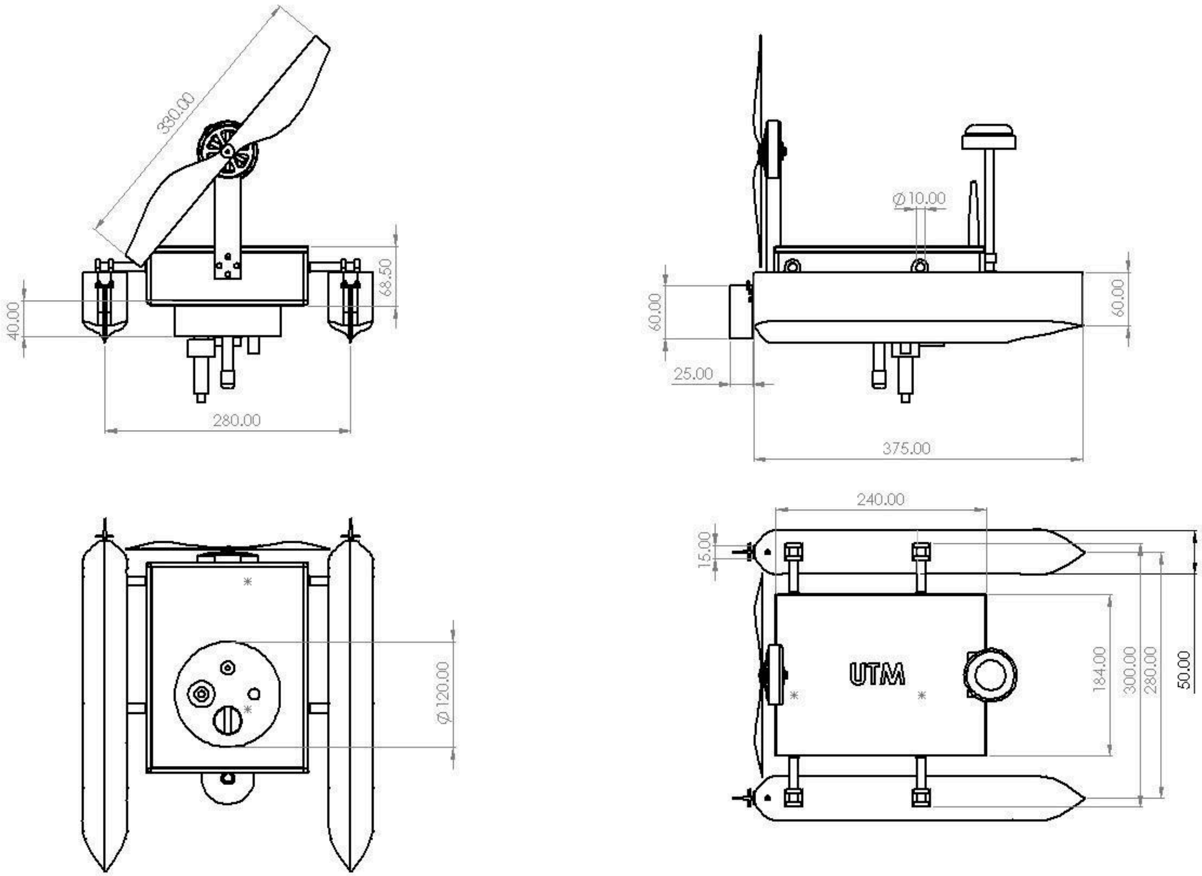


Figure 3.5 Catamaran Drawing (all dimensions in mm)

1.16.2 Centre of Gravity and Centre of Buoyancy estimation

Archimedes' principle state that the upthrust force is equal to the weight of the displaced fluid or liquid. In order to achieve equilibrium, the upthrust force or buoyancy force must be equal to the total weight of water displaced by the object. The location of the buoyancy force is at the centre of the submerged hull (Biran & Lopez, 2013). Stevin's Law states that the centre of gravity of a floating object must be vertically in line with the centre of buoyancy force where the centre of gravity at the top and the centre of buoyancy at the bottom (Biran & Lopez, 2013). Hence, in this section, the analysis on the Centre of Gravity (CoG) and Centre of Buoyancy (CoB) will be determined. Below is the table of all components inside the Catamaran with their respective position, because of the catamaran is symmetrical, only x-axis and y-axis will be involved in the calculation.

3.1.1.1 Centre of Gravity

Table 3.1 Component's Table

Component	**Weight(g)**	**x**	**y**	**Mx**	**My**
DS18B20 Sensor	40	201.29	-77	8051.6	-3080
TDS sensor	24	201.29	-95.26	4830.96	-2286.24
pH Sensor	60	231.29	-99.08	13877.4	-5944.8
Turbidity Sensor	30	213.36	1.94	6400.8	58.2
Left Servo	55	349.81	-19.45	19239.55	-1069.75
Right Servo	55	349.81	-19.45	19239.55	-1069.75
Receiver	16.6	123.86	9.22	2056.076	153.052
Pixhawk	38	283.83	-26	10785.54	-988
Motor	252	352.56	138	88845.12	34776
ECS + Power module	58	283.91	-0.8	16466.78	-46.4

GPS module with Compass	32	106.29	157	3401.28	5024
Telemetry	45	123.86	9.22	5573.7	414.9
Container	20	235.09	-17.35	4701.8	-347
Container Cover	10	234.19	26.14	2341.9	261.4
Port Hull	500	195.92	-32.87	97960	-16435
Starboard Hull	500	195.92	-32.87	97960	-16435
Arm 1	2.7	185	6	499.5	16.2
Arm 2	2.7	330.29	6	891.783	16.2
Propeller	150	368.44	138	55266	20700
Battery	757	138.86	-7	105117	-5299
Arduino Set (Uno R3/Voltage Regulator/SD Card Module)	42	197.06	-21	8276.52	-882
Motor Holder	150	351.2	78.42	52680	11763
GPS Holder	13	106.29	115.61	1381.77	1502.93
Sonde Set	65	201.13	-51.14	13073.45	-3324.1
TOTAL	**2918**			**638918.1**	**17478.84**

Centre of Gravity at *x-axis*

$$x = \frac{\Sigma Mx}{\Sigma M} = \frac{638918.1}{2918} = 218.96$$

Centre of Gravity at *y – axis*

$$y = \frac{\Sigma My}{\Sigma M} = \frac{17478.84}{2918} = 5.99$$

Hence the centre of gravity of the catamaran is at (218.96,5.99)

3.1.1.2 Centre of Buoyancy

Archimedes states that any the buoyancy force acting on a body is equal to the weight of the water displaced by the object and the buoyancy force formula is,

$$F_B = \rho_w V g$$

In order to make sure the Catamaran Floating on the surface of the water, The weight of the Catamaran must be equal to the Buoyancy Force, F_B. Hence,

$$W = F_B = \rho_w V g$$

Where,
W = weight of catamaran
F_B = Buoyancy Force exerted to the Catamaran
ρ_w = Density of water
V = Volume of water displaced by the Catamaran
g = Gravity

$$W = 2.918\,(9.81) = (997)V(9.81)$$

$$V = 0.00293\, m^3$$

Thus, the total volume of Catamaran must be at least, V = 0.00293 m^3

By using Solidwork drawing, the estimated waterline (blue line) where the Catamaran submerged as below,

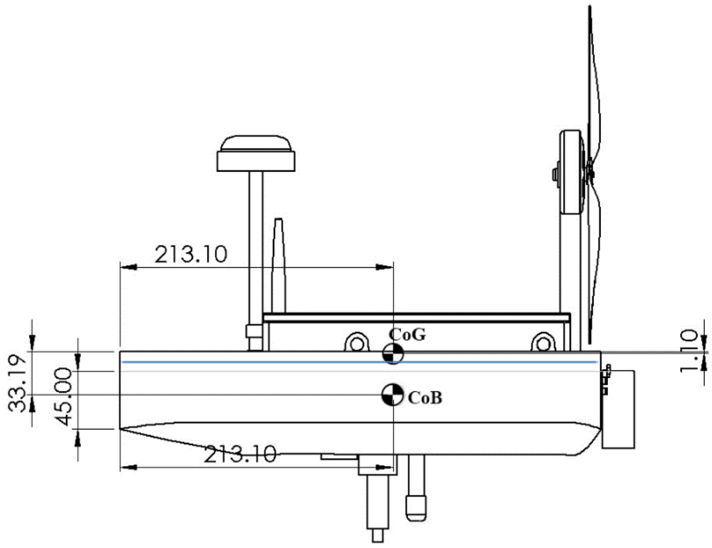


Figure 3.6 Centre of Gravity and Centre of Buoyancy

1.17 Autopilot and Navigation System

The development of Autonomous RC Catamaran for surveillance needs to achieve its second objective which is to simulate the performance of autopilot navigation system. An autopilot or autonomous system is a system use to control the path of the catamaran without intervention of in need of constant control by human operator. Various equipment and sensors communicating to each other to provide necessary data to make sure the autopilot system accuracy at the best condition. In the modernisation era, most of the vehicle manufacturers nowadays implemented autopilot or autonomous in their product or line-up. For example, Tesla's Autopilot system, not only able to navigate a car for a longer distance, but also help to avoid and reduce the accident from occur. Autopilot system was used widely in drone industry either it is a quadcopter drone or Unmanned Aerial Vehicle (UAV) or Unmanned Surface Vessel (USV) for various type of mission and purposes.

1.17.1 Components needed for Autopilot and Navigation System

1.17.1.1 Flight Controller using Pixhawk

Pixhawk is a flight controller that can control various equipment and sensor autonomously. It can control any vehicle, drones, UAV, and more in autopilot mode. It also an open-source hardware with connection prepared to be used with any brands of equipment such as servo, receiver, GPS, and more. It works by connecting necessary equipment and component to it and help them to communicate each other for an autonomous or autopilot navigation.

Table 3.2 Pixhawk 2.4.8 Specification

Dimension	82 x 16 x 50 (in mm)
Weight	32 g

RAM Memory	256 KB
Input Voltage	6-10 V, 10A max
Firmware	MissionPlanner

Figure 3.7 Pixhawk 2.4.8 Flight Controller

1.17.1.2 Receiver FrSky X8R

Receiver is a device that receive signal and information from the Transmitter that was given some input in real time. The information or data obtained by the receiver then passes it on to the flight controller to move based on the desired input. It contains several channels that can be set and programmed earlier. It can be used to control servo and motor at the same time.

Table 3.3 FrSky X8R Receiver Specification

Dimension	46.25 x 26.6 x 14.2 (in mm)
Weight	16.6g
Operating Voltage/Current	4-10V/100mA@5V
Range	>1.5 Km
Channel	16 Channels

Figure 3.8 FrSky X86 receiver

1.17.1.3 MG996R Servo

Servo motor is an electronic device that push and rotate any parts of a machine into certain angle with precision. It is a rotary or linear actuator that control any angular or linear position of an object. For this project, the servo motor will be used to control the rudder of catamaran. It will be connected with the rudder at each hull for a better manoeuvrability.

Table 3.4 MG996R Servo Specification

Dimension	40.7 x 19.7 x 42.9.2 (in mm)
Weight	55g
Operating Voltage	4.8-6.6V
Range	0-55deg
Operating Speed	0.19s/60deg (4.8V) or 0.15/60deg (6.6V)
Stall torque	9.4kg/cm (4.8V) or 11kg/cm (6.6V)

Figure 3.9 MG996R Servo

1.17.1.4 SUNNYSKY X3525 520KV Brushless Motor

Brushless motor will be used in this project and paired it with a single propeller. It is a direct current (DC) that operate without any mechanical brushes or traditional brushes. It offers more economical friendly in a long run which can reduce operational and maintenance cost.

Table 3.5 SUNNYSKY X3525 520KV Specification

Diameter	42.5mm
Weight	252g
Max Li-Po Cells	5S-6S
Max Continuous Current/Power	60A/15s and 1332W
Thrust produced with 13" prop	825g @22.2V,5.2mA

Figure 3.10 SUNNYSKY X3525 520KV Brushless Motor

1.17.1.5 Tahmazo Pro.C Max 6019-3S Electronic Speed Controller (ECS)

Electronic Speed Controller (ECS) is an electrical device that controls and regulates the speed of any electrical control. This project only uses a single brushless motor that will paired together with ECS. Tahmazo Pro.C Max 6019-3S ECS comes with Battery Eliminator Circuit (BEC) which is voltage regulator that been designed to reduce the amount of voltage from the power supply to the motor so that it does not damage the motor from excessive voltage supply.

Table 3.6 Tahmazo Pro.C Max 6019-3S ECS Specification

Dimension	66x25x10 (mm)
Weight	49 g
Continuous/Maximum (15s) current	60A/70A
Internal resistance	0.86 ohm

Figure 3.11 Tahmazo Pro.C Max 6019-3S ECS

1.17.1.6 6 Cells Lithium Polymer Battery

Lithium Polymer battery is a rechargeable battery with lithium-ion technology by using polymer as its electrolyte. It is a suitable power supply because it can be used multiple times. Lithium polymer battery also lightweight, has larger capacity with high discharge rate makes it suitable to be use in any kind of drone.

Figure 3.12 6 cells Li-Po battery

1.17.1.7 GPS module with compass build in

GPS module can directly receive data sent by the satellite with certain frequency. The GPS module will be communicated with the flight controller about its current location and make the flight controller easier to control. It is the one of the most importance components for autopilot that act as ‘eye’ for the system.

Table 3.7 GPS module with Compass specification

Dimension	4.5 x 3.7 x 0.5 inches
Weight	1.6 oz @ 45.34 g
Supply Voltage	1.65-3.6V
Concurrent GNSS	Up to 10 Hz
Nav. Update rate 1 Single GNSS	Up to 18 Hz

Figure 3.13 GPS module with Compass

1.17.1.8 Telemetry Radio

Telemetry radio use for Pixhawk Autopilot uses a radio signal to communicate and sharing data between Pixhawk Autopilot and any compatible transmitter (radio controller), mobile devices or computer at the ground control. It could be used to share data like speed, altitude, battery voltage and more.

Table 3.8 Telemetry Radio for Pixhawk Specification

Weight	15 g
Band	433MHz
Output Power	100mW
Sensitivity	-117dBm
Antenna Connectors	RP-SMA Connector

Figure 3.14 Telemetry Radio for Pixhawk

1.17.2 Circuit connection and wiring for Autopilot and Navigation System

Figure 3.15 shows the wiring connection for the Autopilot and navigation system for catamaran. All the components and equipment mentioned earlier will be connected into single Pixhawk flight control that will be powered by 6 cells of Lithium Polymer battery. A power module will be used to reduce the voltage that is compatible with the motor usually 5V and it can measure the battery voltage and capacity. 2 servos use at both hull each will be connected to the receiver and the receiver will be connected to the Pixhawk through channel RC. The GPS module with build in compass will be connected to its dedicated pin in the Pixhawk.

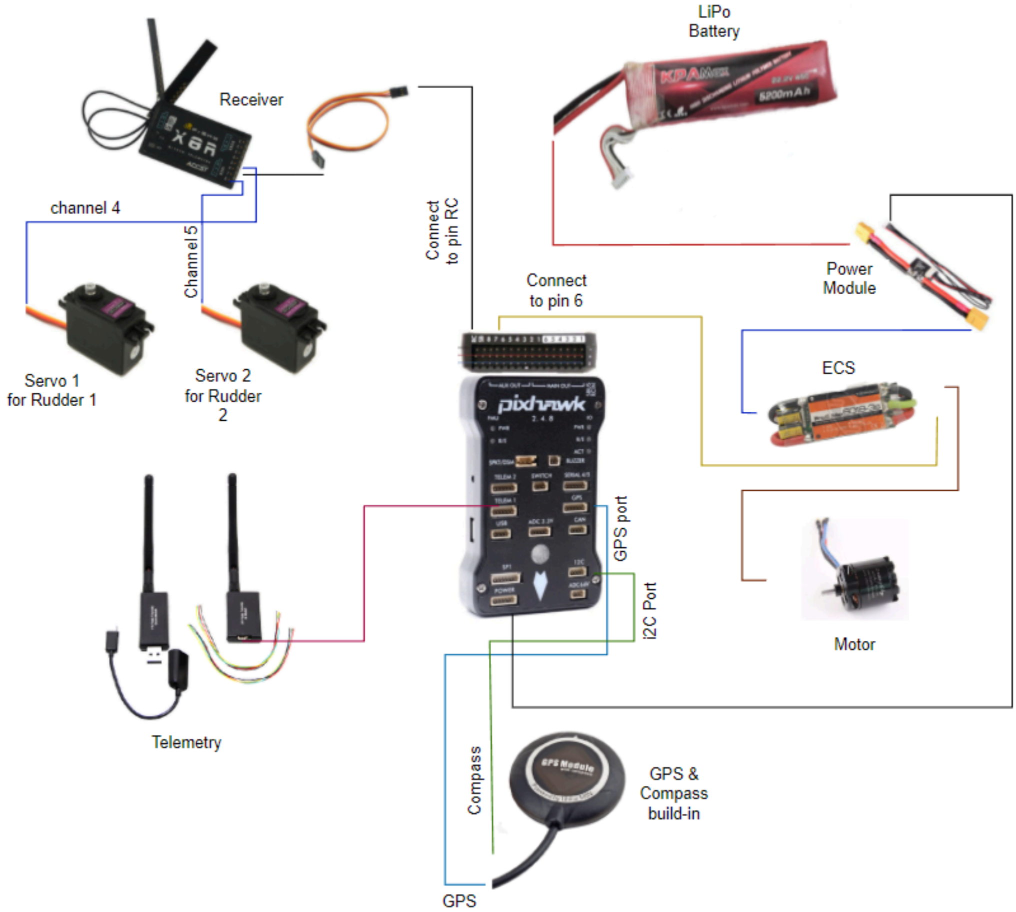


Figure 3.15 Wiring connection set for Autopilot navigation system

1.18 Water Quality Monitoring System

Water quality monitoring is the third objective in this project where a necessary data needs to be collected from the survey, hence, a water quality monitoring system is needed. From the discussion earlier in Chapter 2, the monitoring system consists of various kind of method from flow through, in-situ monitoring system, combined sensor and recording sonde, wireless sensor network, and using Unmanned Surface Vessel to collect the data of water. However, in this project method that is efficient and low cost will be used by using USV catamaran. The sensor sets and components will be put inside catamaran which will be sailed autonomously around the water source location at the same time the system will read and record the data from the water source. The data including temperature, pH, turbidity, and total suspended solid will be recorded. The dissolve oxygen level data will not be taken due to unavailable and expensive sensor set. List of components needed for water quality monitoring system will be listed together with the specification except for the sensor set because all the specification already explained in Chapter.

1.18.1 Components needed for Water Quality Monitoring System

1.18.1.1 Sensor needed to monitor water quality

Sensors that will be used in this project will be *DS18B20 Temperature Sensor, Analog pH Sensor, Turbidity Sensor,* and *TDS Sensor*. The Analog Gravity Dissolve Oxygen Sensor will be not included in this project due to expensive sensor to purchase. All the sensor working principle already being explained in Chapter 2 together with the specification. Therefore, the detail of the sensor will be not explained further.

1.18.1.2 Arduino Uno R3

Arduino Uno is a microcontroller board based on ATmega328 AVR Microcontroller consists of 20 output/input pin which 6 pin can be used for PWM output and 6 pin for analog input. The sensor set will be connected into Arduino analog input pin and the data will be stored in the SD card via SD Card Module.

Table 3.9 Arduino Uno R3 Specification

Weight	25 g
Operating Voltage	5V
Digital I/O pin	14
Analog I/O pin	6
DC Current for I/O pin	20mA

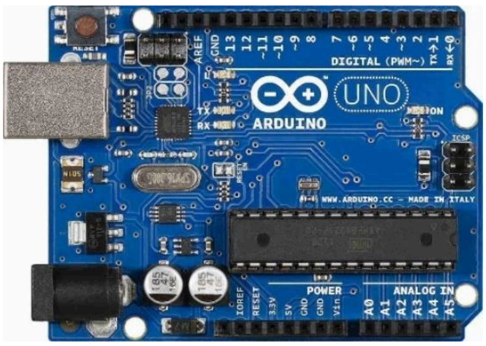


Figure 3.16 Arduino Uno R3

1.18.1.3 SD Card Module

SD card module is an electronic device used to read and write data from the SD card. SD card module will be connected into Arduino in order to collect and store the data obtained from the sensor set so that the operator will be able to obtain the data for further analysis.

Table 3.10 SD Card Module Specification

Operating Voltage	5V
Weight	5 g
Voltage regulator	3.3V

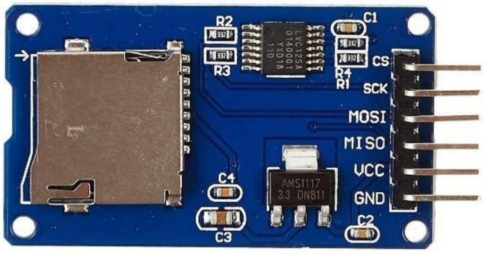


Figure 3.17 SD Card Module

1.18.1.4 LM2596 Voltage Regulator

Voltage regular is an electrical device used to reduce and maintain from certain voltage of a power source into a voltage that is acceptable for the electrical component to be used. In order to power up the Arduino, a constant 5V power supply is needed, and it is usually supply by the computer via USB port, however, the Arduino will be not connected to the computer during operation makes it lost it power source. Thus, a primary power source available is 6 cells Lithium Polymer battery used in Autopilot system with 22.2V. Therefore, by connecting the power supply from the Autopilot system to power up the Arduino, a voltage regulator is needed to reduce the voltage from power supply which is 22.2V into 5V for the Arduino Uno R3.

Table 3.11 LM2596 Voltage Regulator specification

Adjustable output Voltage	1.25V to 35VDC
Wide range input Voltage	3.2V to 40VDC
Output current	Continuous(2A), Peak (3A)
Efficiency	92% max

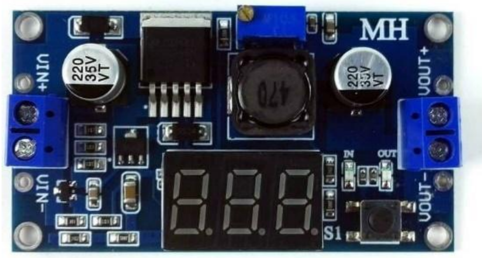


Figure 3.18 LM2596 Voltage Regulator

Table 3.12 List of material and costing

No	Component List	Availability in lab	Price (RM)	Purchase link
1	DS18B20 Temperature Sensor	No	9.88	t.ly/qJd0
2	Analog pH Sensor	No	95.73	t.ly/ghIz
3	Turbidity Sensor	No	109.9	t.ly/9bDu
4	TDS Sensor	No	54.52	t.ly/TFal
5	Arduino Uno R3	Yes	-	-
6	LM2596 Voltage Regulator	Yes	-	-
7	SD Card Module	No	12.48	t.ly/YSLl
		Total	282.51	

1.18.2 Circuit connection and wiring for Water Quality Monitoring System

Figure 3.19 shows the circuit connection and wiring for all the sensors and equipment needed to make sure the water quality monitoring system working together. All the sensor such as analog pH sensor, DS18B20 temperature sensor, TDS sensor, and Turbidity sensor is an analog sensor should be connected to analog input pin A0, A4, A2, and A3 respectively. The data recorded by the sensor will be send to the Arduino than later will be stored in SD card. The SD card only can be read by using SD Card Module (LM2596) which connected to several digital output pin as drawn in Figure 3.19 below. The power supply used is the same power supply that powered up Autopilot and Navigation system which is 22.2V Lithium Polymer battery. The excessive voltage can be reduced by using Voltage regulator to step down the voltage from 22.2V to 5V which is an operating voltage for Arduino and all the sensors.

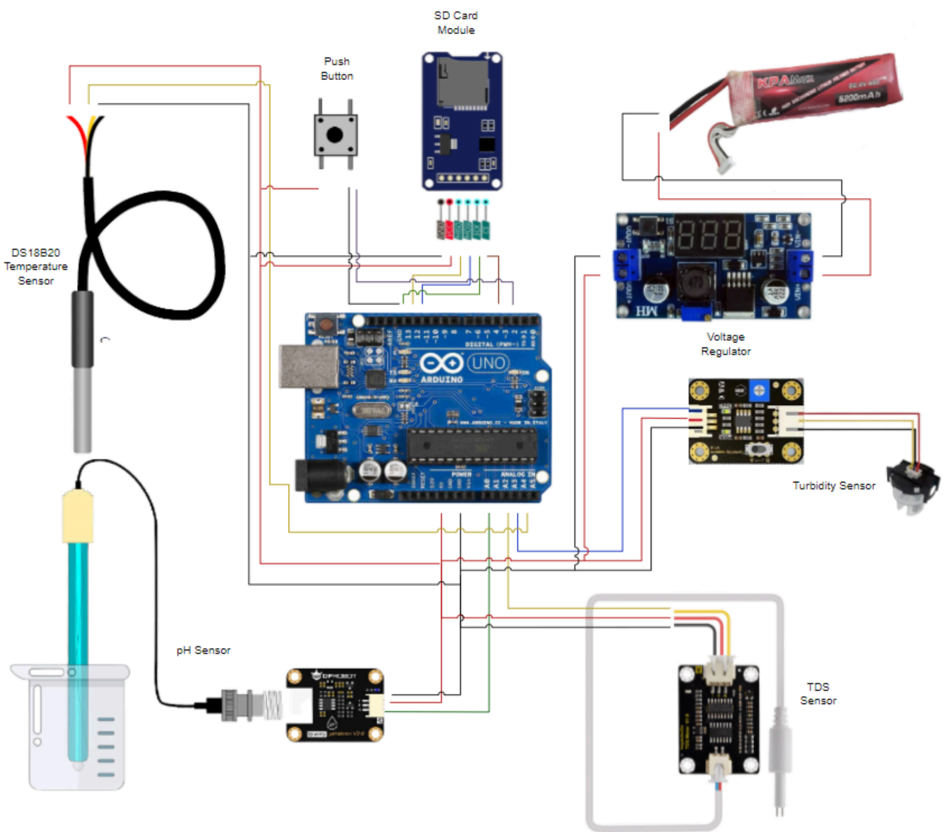


Figure 3.19 Wiring connection for Water Quality Monitoring System

1.18.3 Proposed Method

According to the Figure 3.1 Methodology Flowchart, the experiment will be divided into 3 stages which are Catamaran Fabrication, Water Quality Monitoring System assembly and programming, and Autopilot and Navigation System assembly and programming. These 3 stages or steps can be done separately without depending on each other until all the systems are install and assemble inside the Catamaran.

1.18.4 Fabrication of Catamaran

From the proposed catamaran design, the current available part are only the hull and the arm that connected between hull and the container as shown in Figure 3.20 below. The hulls were 3D Printed by using PLA material that makes it lightweight to support the buoyancy force. The other parts such as the container and its cover will be using a plastic Tupperware which is lightweight material that is available everywhere and affordable to help reduce cost.

Figure 3.20 Available Catamaran's Hull

The other customable part such as the motor holder will be 3D printed using the same material as hull which is a PLA material. The holder currently unavailable since it does not yet be fabricated. In order to make the hull stronger and can sustained long time in water, a resin will be applied to both hulls to make in waterproof and stronger. After the parts are available, the assembly will be taken place to make sure it follows as drawing in Figure 3.5 Catamaran Drawing (all dimensions in mm) .

1.18.5 Water Quality Data Collection

According to the flowchart, the water quality monitoring system will start with the sensor assembly as in Figure 3.21 followed by the programming of the sensor set according to the Figure 3.21 below by using Arduino software. The system will start with sensor calibration in order to make sure a more precise and accuracy of data recorded. Once the calibration pass, operator need to click a push button to indicate that the data process will start, and all the sensors will record the data and store it in SD Card. The speed of catamaran will be approximately 0.2m/s - 0.3 m/s and time loop for each data recorded will be 50s. Thus, the data will be recorded every 10m – 15m travel distance. When the catamaran finish it travel and back to home, the operator needs to push the button to stop the data from recording. All the data stored in SD Card will be accessible when connect it with computer.

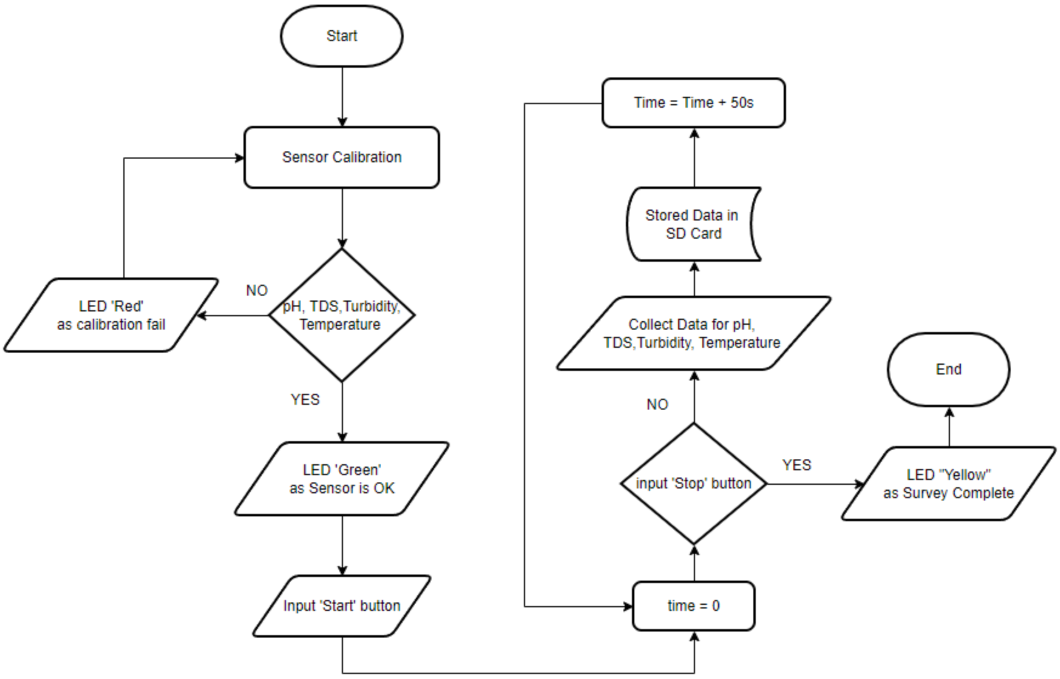


Figure 3.21 Sensor programming flowchart

1.18.6 Autopilot and Navigation

Below shows the specification of location that will become testing and operation location.

Location	: Tasik UTM
Operation Area	: 9340 m^2
Coordinate	: 1.555510,103.637515
Travel Distance	: 450m – 500m

Figure 3.22 Tasik UTM

Figure 3.23 Tasik UTM (Starting Point)

Figure 3.22 and Figure 3.23 shows the location that will become as testing ground. The catamaran will start at home point, refer Figure 3.23 and will travel approximately 450m – 500m from home point to the final checkpoint. Figure 3.24 show the waypoint that being planned by using the MissionPlanner software. MissionPlanner can be used to program the waypoint and it is a compatible with Pixhawk Ardupilot hardware. After the survey collecting data completed, the catamaran will come back to the home so that the operator can take the data for further analysis.

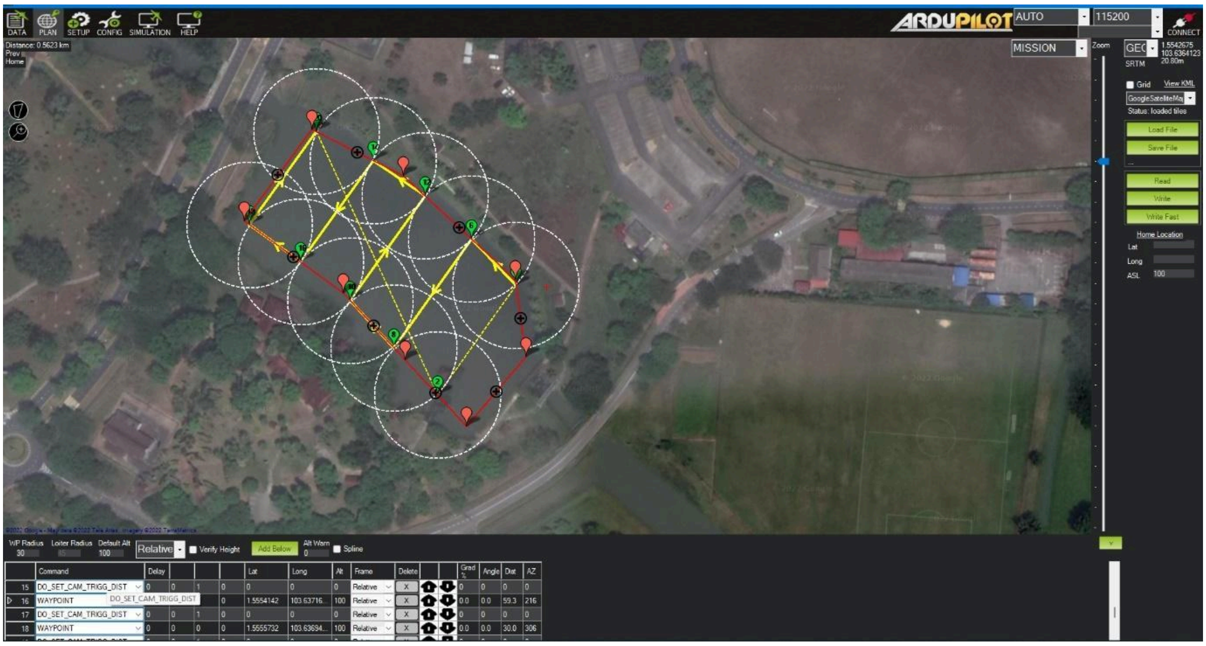


Figure 3.24 Waypoint using MissionPlanner

1.19 Chapter Summary

In this chapter, all the planning for the experiment to be conducted already explained. The usage of multihull boat catamaran for its stability and larger deck area were chosen in order to keep all the equipment and sensor safely. The wiring connection for the autopilot and navigation system and the water quality system being discussed need to be powered by same power source which is Lithium Polymer battery. A location test with area of 9340 m^2 which is Tasik UTM was chosen for the ground test for the catamaran that will travel about 450m to 500m distance.

CHAPTER 4

PROPOSED WORK

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

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Appendix A INTERIM NATIONAL WATER QUALITY STANDARD

Below is list of Parameter based on Interim National Water Quality Standards (INWQS) from Department of Environment (DOE) Malaysia.

Interim National Water Quality Standard

Parameters	Unit	Class					
		I	IIA	IIB	III	IV	V
Temperature	°C	-	Normal+2°C	-	Normal+2°C	-	-
Specific Conductance	µS/cm	1000	1000	-	-	6000	-
pH	-	6.5-8.5	6-9	6-9	5-9	5-9	-
DO level	Mg/l	7	5-7	5-7	3-5	<3	<1
Turbidity	NTU	5	50	50	-	-	-

Where,

Class I	Conservation of natural environment Can be used as water supply with no treatment necessary Contain very sensitive aquatic species
Class IIA	Can be used as water supply with conventional treatment required Contain sensitive aquatic species
Class IIB	Recreational use with body contact
Class III	Extensive treatment required for water supply Can be use as livestock drinking
Class IV	Irrigation
Class V	None of the above

Appendix B

Appendix C

LIST OF PUBLICATIONS