Faculty of Electrical Technology and Engineering

DESIGN AND DEVELOPMENT OF A REMOTE-CONTROLLED SOLAR-POWERED CLEANING ROBOT FOR CANAL AREA APPLICATIONS

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Bachelor of Electrical Engineering Technology with Honours

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DESIGN AND DEVELOPMENT OF A REMOTE-CONTROLLED SOLAR-POWERED CLEANING ROBOT FOR CANAL AREA APPLICATIONS

NUR AQILAH ALIAH BINTI MOKHTA ZA'BAH

A project report submitted
in partial fulfillment of the requirements for the degree of
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I hereby declare that I have checked this project report and in my opinion, this project report is adequate in terms of scope and quality for the award of the degree of Bachelor of Electrical Engineering Technology with Honours.

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Date : 13/01/2024

DEDICATION

To my beloved mother, Raimah binti Rahmat,
And father, Mokhta Za'bah bin Ali,

ABSTRACT

It is impossible to separate technology use from daily life, and human resources must stay up with its development. As the population rises, so does the demand for raw materials and waste. Carelessly disposed of trash can harm the air, the soil, and the water, lowering the quality of the water in the rivers and raising the risk of illness. What if humans need to spend a lot of time and energy cleaning up the waste? The objective of this project is to create a boat that can clean water remotely. The water-cleaning boat is designed using a transmitter and receiver circuit. The boat has a DC motor that propels it forward and allows it to swivel right and left, as well as a net that serves as its major component and collects and holds trash underneath it. The goal of this prototype was to simplify, speed up, and lower the risks associated with river transportation in the process of remotely moving garbage. The net serves as a rubbish collector and keeper, and the boat's design permits unrestricted movement on the water's surface. The boat's weight without the load is two kg and the boat can endure load on it until three kg. The boat's speed is 2 m/s and the boat is suitable at medium flow water. Overall, the research presented in this thesis has succeeded in contributing to understanding the importance of effective and practical water-cleaning systems.

ABSTRAK

Dalam kehidupan seharian manusia tidak terlepas dari penggunaan teknologi, perkembangan teknologi ini perlu diikuti oleh sumber manusia. Semakin ramai orang, semakin banyak keperluan bahan mentah dan semakin banyak bahan buangan. Pembuangan sampah sembarangan boleh mencemarkan udara, tanah dan air, akibatnya kualiti air di sungai akan menurun dan boleh menyebabkan penyakit. Bagaimana pula jika pembersihan sampah yang dilakukan oleh manusia memerlukan banyak masa dan tenaga untuk membersihkan sampah tersebut. Tujuan penyelidikan ini adalah untuk mereka bentuk dan membangunkan bot pembersihan air yang dikawal oleh alat kawalan jauh. Bot pembersihan air direka menggunakan litar pemancar dan penerima. Terdapat jaring yang berfungsi sebagai kompenen utama dalam bot yang berfungsi untuk mengumpul dan menyimpan sampah di bawah bot, dan terdapat motor DC yang menggerakkan bot untuk membelok ke kanan dan ke kiri, dan bergerak ke hadapan. Prototaip ini dibuat bagi memudahkan manusia mengangkut sampah dengan alat kawalan jauh dan mengurangkan kecekapan masa yang diperlukan serta bahaya yang wujud di sungai. Hasil yang diperoleh daripada reka bentuk ini adalah bot boleh bergerak bebas di permukaan air dan pukat sebagai pengumpul dan penjaga sampah. Berat bot tanpa muatan ialah dua kg dan bot itu boleh menahan beban di atasnya sehingga tiga kg. Kelajuan bot ialah 2 m/s dan bot sesuai pada aliran air sederhana. Secara keseluruhannya, kajian yang dibentangkan dalam tesis ini telah berjaya memberi sumbangan untuk memahami kepentingan sistem pembersihan air yang berkesan dan praktikal.

ACKNOWLEDGEMENTS

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I am also indebted to Universiti Teknikal Malaysia Melaka (UTeM) and the Faculty of Electrical Technology and Engineering for the financial support that enabled me to accomplish the project. Not forgetting my classmates, 3 BEEY for the willingness to share their thoughts and ideas regarding the project.

My highest appreciation goes to my parents and family members for their love and prayers during the period of my study. An honorable mention also goes to my lecturers for all their motivation and understanding.

Finally, I would like to thank all the staff at the Faculty of Electrical Technology and Engineering, colleagues and classmates, the Faculty members, as well as other individuals who are not listed here for being cooperative and helpful.

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δ	-	Voltage angle
Ω	-	Ohm
$^{\circ}$	-	Angle

LIST OF ABBREVIATIONS

V	-	Voltage
A	-	Ampere
mm	-	Millimeter
cm	-	Centimeter
m	-	Meter
IoT	-	Internet of Things
DC	-	Direct Current
ROS	-	Robot Operating System
NSGA	-	Non-Dominated Sorting Genetic Algorithm
RF	-	Radio frequency
FRED	-	Floating Robot for Eliminating Debris
LCD	-	A liquid-crystal display

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CHAPTER 1

INTRODUCTION

1.1 Background

For the survival of all living things and the health of the ecosystem, water is a very important resource. Unfortunately, pollution can be harmful to water sources like rivers, lakes, and seas. Waterbody pollution has grown to be a major issue on a global scale, with many negative effects including the spread of water-borne diseases, the extinction of aquatic life, and the degeneration of aquatic ecosystems. Environmental pollution can be attributed to the effects of human actions, which include factors such as pollution of water bodies, regulation of river flow, consumption of water, and climate changes [1]. Only 3% of the water on Earth's surface is pure enough for human consumption, making up roughly 70% of the planet's surface [2]. This finding highlights how important it is to investigate water pollution situations.

Many actions are made to reduce pollution, such as manual and automated cleaning that requires constant human supervision. The person may be put in danger if manual labor is required to remove garbage. Thus, it is essential to put appropriate and creative measures into place to control water contamination. Therefore, a robot that independently removes waste from the water could have a big impact on pollution reduction. This has prompted the development of numerous techniques for cleaning polluted water and preventing additional pollution. Numerous authors have highlighted their efforts to develop cleaning-focused robots for local contexts as the range of uses for robots increases. Naturally, water-cleaning robots should be the subject of research and development. In order to collect plastic pollution, semi-manual refuse-removal vessels are currently being employed. Ships designed specifically for collecting and transporting solid waste, such as trash and other types of garbage, are known as refuse removal vessels.

These vessels typically have large storage areas or compactors for holding the waste, as well as equipment for loading and unloading the waste at different ports or facilities. Refuse removal vessels are often used in coastal areas or on large bodies of water where land-based waste management facilities are not available or are insufficient to handle the volume of waste generated.

The refuse removal vessel is big, making it only suitable for rivers with significant areas of waste that have accumulated over time. In this situation, using a refuse-removal vessel to clean small, low-density garbage in small waters is not practical. Notably, this approach is unable to distinguish between floating objects that should be removed and those that shouldn't. In addition, secondary pollution could be brought on by the vessel's emissions.

A composite robotic system comprising a vision module, motion control module, and grasping module, the intelligent water surface cleaner robot in particular, can sequentially perform three tasks: cruising and detecting, tracking and steering, and grabbing and collection. In the first challenge, the robot navigates a predetermined path along the water's surface while looking for debris using its vision module. As soon as an item is chosen for removal, the second job begins. The vision module tracks the target and determines the robot's position in reference to the target. To seamlessly rectify the yaw angle error and guarantee a perfect target-approach angle, the motion control module uses the position data from the vision module.

1.2 Addressing Water Pollution Through Water-cleaning Project

Water pollution is a major environmental issue that is having a significant impact on the planet. More than 50 kinds of diseases are caused by poor drinking water quality, and 80% of diseases and 50% of child deaths are related to poor drinking water quality in the world [3]. To address this issue, it is important to understand the changes in water quality parameters such as pH, temperature, dissolved oxygen, and conductivity and to track the levels of water pollution. This is where a water-cleaning project can be a critical intervention. The prototype can be designed with a cleaning mechanism that can collect and remove debris and pollutants from the water, such as plastics, chemicals, and other contaminants. This can help to reduce pollutants and improve the quality of the water.

Then, the mechanism can be programmed to target specific areas of the water that are known to be polluted. This can help make the cleaning efforts more efficient and effective. By removing pollutants and debris from the water, the robot can help prevent future pollution. For example, removing plastics from the water can prevent them from breaking down into microplastics that can harm aquatic life. Manual cleaning efforts can be dangerous for human divers and can cause damage to the ecosystem. The use of a water-cleaning robot can reduce the need for manual cleaning efforts, making it safer and more environmentally friendly [4].

Additionally, sensors monitor water quality parameters such as pH, temperature, dissolved oxygen, and conductivity. This can help identify areas of the water that are polluted and in need of cleaning. It can also provide data on the effectiveness of the cleaning efforts. Overall, a water-cleaning robot can have a positive impact on water pollution by reducing water pollution. Manual cleaning efforts. It can also provide valuable data on water quality and make cleaning efforts more targeted and efficient.

1.3 Problem Statement

The increasing pollution of rivers worldwide poses a significant threat to both the environment and human health. Traditional methods of cleaning rivers are often costly, time-consuming, and limited in their effectiveness. Therefore, there is a need to develop innovative solutions for river cleaning robots to remove pollutants efficiently and effectively from water bodies while minimizing the negative impact on the ecosystem.

For these purposes, these robots are frequently equipped with specialized equipment including nets, vacuums, and filtering systems. Some models might run on their own, while others might be managed remotely by people. The efficiency and effectiveness of water-cleaning activities can be greatly increased by these robots, contributing to the protection of marine ecosystems and animals.

However, rivers are large and constantly flowing, with water volume and speed influenced by precipitation, land use, and topography [18]. This makes it difficult to locate, access, and effectively remove pollutants from the water. Water receives various types of pollutants from different sources. Hence, a cleaning solution that works for one pollutant may not be effective for another. Water has complex ecological and hydrological systems with varying depths, currents, and temperatures, which influence the way pollutants travel within the water [18]. Cleaning water can be expensive in terms of personnel, equipment, and other resources like energy and time. Human cleanup efforts may require shutting down sections of the river, causing inconvenience to various stakeholder groups. In developing countries and low-income communities, where much water is polluted, there may be limited resources and capacity to undertake significant water-cleaning efforts.

Therefore, addressing these challenges is critical to improving the efficiency, reliability, and sustainability of water-cleaning robots, and solving water pollution aligns with achieving sustainable development goals to ensure the availability of clean, affordable, and safe water sources for all people, now and in the future.

1.4 Project Objective

The main aim of this project is to propose a systematic and effective methodology to estimate the development of a remote-controlled solar-powered cleaning robot for canal area applications with reasonable accuracy. Specifically, the objectives are as follows:

a) To design a remotely operated control of river cleaning robot.

b) To develop a prototype for the solar-powered cleaning robot.

c) To analyze the performance of the developed prototype under various testing conditions.

1.5 Scope of Project

The scope of this project is as follows:

a) Design and construction of the robot which selecting the appropriate materials, motors, sensors, and other components required for the robot. The robot is designed to operate in water.

b) The robot is designed with a cleaning mechanism such as a net to collect and remove debris from the water.

c) The robot is remotely controlled by a human operator, who can monitor the robot's progress and adjust its trajectory as needed.

d) The robot is tested in various situations on water quality and cleaning performance. This data can be used to improve the robot's performance and make informed decisions on future cleaning efforts.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

A water-cleaning robot was developed to help in the cleaning of bodies of water like lakes, rivers, and oceans. This literature review aims to explore the existing literature on water-cleaning robots and their applications. Besides, the literature review helps to provide appropriate research methods while avoiding duplication of existing research. The design, usability, and efficiency of water-cleaning robots will be the main topics of the literature review. The goal is to give a thorough overview of water-cleaning robots' latest developments and how they might be used to deal with the problems caused by water pollution. The review will include an analysis of existing studies, research papers, and reports on the subject, and will highlight the key findings, limitations, and future research directions. In the end, this literature review aims to provide an informed and educational discussion on the function of water-cleaning robots in environmental conservation and management.

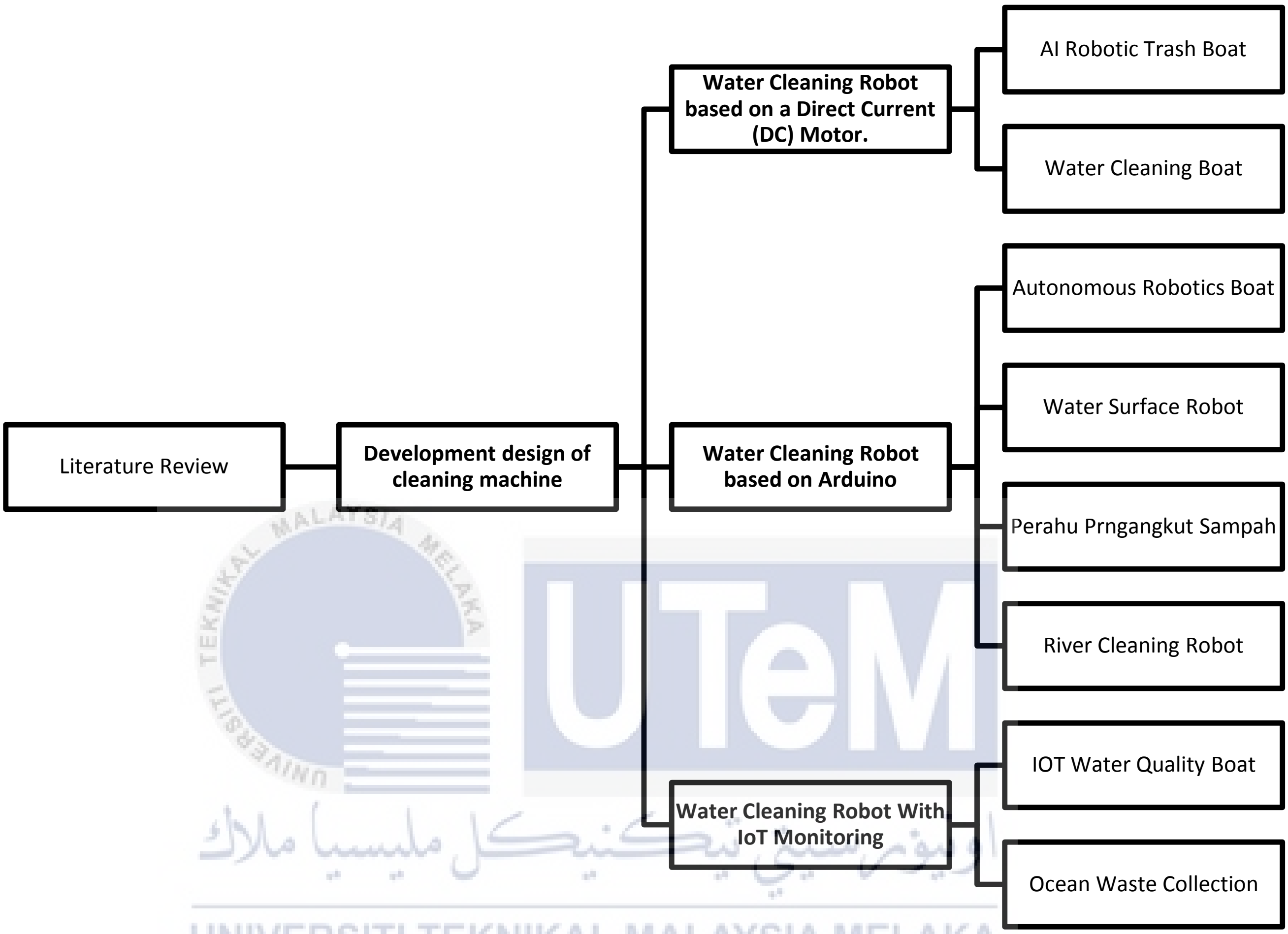


Figure 2.1 Recent development in the design of cleaning machine

2.2 Understanding Water Pollution in the Literature

Through a review of the literature on water pollution, this section will explore how cleaning robots can contribute to our understanding of water pollution and inform strategies for mitigating its impacts. Water pollution is one of the main problems humanity is experiencing in the twenty-first century, and it needs to be tackled in order to improve water quality and decrease its detrimental impacts on both human and ecological health. Industrialization, climate change, and the expansion of metropolitan areas all contribute to the contamination of water in various ways. Surface water is more susceptible to contamination by human activities like the expansion of urban and suburban areas, businesses, cities, and agriculture.

Surface water sources are the most common places for the discharge of wastewater, which may contain bacteria, pharmaceutical waste, heavy metals, and harmful chemicals. In the current scenario, our oceans, rivers, and other inland waters are being "squeezed" by human activities so their quality is reduced. The proof is tons of trash in our rivers and creeks, making them look and smell like a dumpsite by which the quality of water is going too poor effect of which animals, as well as humans, are getting affected by the new types of fevers and diseases.

The flow of used water from residences, businesses, commercial enterprises, institutions, etc. is referred to as wastewater. The project can also be employed in locations where waste debris in the water body needs to be eliminated. This will lessen aquatic animal deaths that are unpredictable and water contamination.

2.3 Development Design Of Cleaning Machine

Over the years, there has been significant development in the design of water-cleaning robots. Initially, early designs of water-cleaning robots were simple and rudimentary, consisting of a simple hull, propellers, and a net or filter. However, with advancements in technology, modern water-cleaning robots have become more sophisticated, incorporating advanced sensing, control, and navigation systems. Current designs of water-cleaning robots vary in size, shape, and functionality, depending on their specific application. For instance, some are small and lightweight, while others are larger and more robust, designed for cleaning larger water bodies. Some robots operate on the water's surface, while others operate underwater or can perform both functions. Additionally, some robots are designed to collect and dispose of debris, while others are equipped with specialized sensors that can detect and monitor water quality parameters such as temperature, pH, dissolved oxygen, and conductivity.

The development of water-cleaning robot design has also seen an increase in the use of renewable energy sources such as solar power and wind energy [11]. This has enabled the design of eco-friendly robots that can operate for longer periods without the need for frequent battery replacements. Overall, the development of water-cleaning robot design has been driven by the need for efficient and effective solutions to address the challenges of water pollution. As technology continues to evolve, it is expected that future designs of water-cleaning robots will become even more advanced and capable of performing complex tasks in challenging environments.

2.3.1 Water-cleaning Robot based on a Direct Current (DC) Motor.

Several studies in the literature have reported the development of a cleaning robot based on a DC motor. For instance, a cleaning robot was developed to drive and harvest floating trash. It was integrated with artificial intelligence mode in which a rotating conveyor belt is positioned in between the catamaran hulls along the center line [2]. For a productive trash collection system, a revolving conveyor is attached at the front of the boat and inclined at a specific degree. To operate as the primary trap to collect and capture the floating solids and transport them to the storage container or dustbin that is situated at the back of the garbage collecting boat, a few wire mesh are attached to the conveyor system. To drain any water that may have become caught in the waste, the dustbin is composed of a wire mesh web.

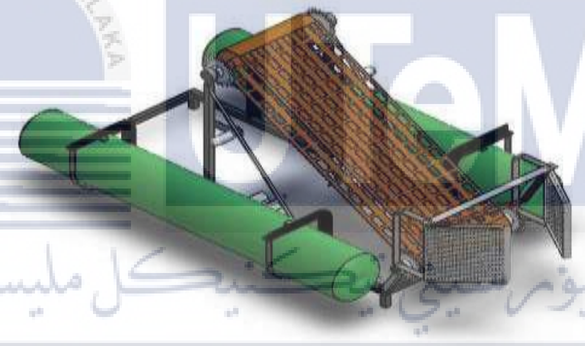


Figure 2.2 Artificial Intelligence Enabled Robotic Trash Boat to Drive and Harvest Floating Trash from Urban Drain [2]

2.3.2 Water-cleaning Robot based on Arduino

Several projects are using Arduino as their main component. For the project “Autonomous Robotics for Identification and Management of Invasive Aquatic Plant Species” a small fleet of fully autonomous boats capable of subsurface hydroacoustic imaging (to scan aquatic vegetation), machine learning (for automated weed identification), and herbicide deployment (for vegetation control). With the use of these tools, physical labor will be minimized while weed control will be safer (staff will be exposed to fewer chemicals). Three different aquatic plant species (Hydrilla, Kabamba, and Coontail) had their geotagged hydroacoustic imagery gathered and used to build a software pipeline for subsurface aquatic weed classification and distribution mapping.

The project's goal is to create and demonstrate a small fleet of completely autonomous boats with the ability to apply herbicides to control vegetation, automate weed detection using machine learning, and scan aquatic vegetation using subsurface hydroacoustic imaging. With the use of these tools, physical labor will be minimized while weed control will be safer (staff will be exposed to fewer chemicals). The herbicide producer who sponsored this research advised a 15-gallon (56.8 L) herbicide tank for the detailed applications, which involve electric propulsion, as well as battery-based energy storage.

Figure 2.3 Autonomous Robotics for Identification and Management of Invasive Aquatic Plant Species [3].

Other than that, the project " A Water Surface Cleaning Robot" is also using Arduino. The trash can obstruct the flow of water, making it unclean and odorous to the point that it frequently overflows and creates calamities, including flooding. By creating robotics technology that can function in water locations, this project seeks to offer an alternate solution to the issue of garbage in water areas. The suggested applied research is anticipated to represent a different approach to catastrophe prevention, particularly flood prevention.

The development of eco-robots, which have the primary duty of collecting trash, is an example of robotics technology. The robot is made to be manually operated with a remote control. ADDIE is mentioned in the research's development methodology. This process entails analyzing the robotic cleaning system, creating and constructing the robot, putting the robot to work cleaning waste in small water areas and assessing the robot's efficacy in cleaning up waste for larger areas. Through the use of the aqua robot, this work seeks to create a system that is more flexible and effective.

This robot has a fantastic chance to develop its capabilities in the future. It is intended for such conducting tasks as clearing out algae, leaves, and twigs, applying chemicals when needed, testing the water quality, and deploying cargo to be carried out autonomously. These features could reduce human effort significantly and offer a long-term fix for the persistent issue. Numerous well-designed algorithms have previously been created for single robotic systems as well as for swarms for navigation and rubbish collection on the ground. However, these methods cannot be employed directly on aquatic surfaces because of the difference in the dynamic environment, the propulsion system, and the challenge of precisely estimating the present position based on relative velocity and acceleration.

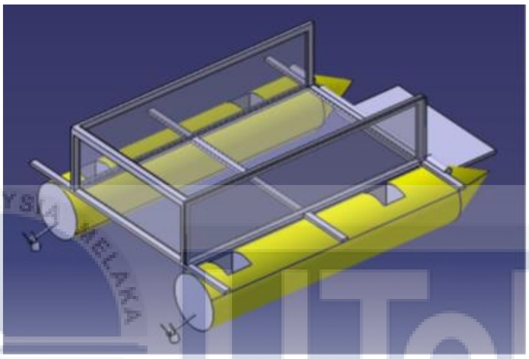


Figure 2.4 A Water Surface Cleaning Robot [4]

While project “Perahu Pengangkut Sampah Berbasis Arduino” also uses Arduino as a main component. It is impossible to separate technology use from daily life, and human resources must stay up with its development. As the population rises, so does the demand for raw materials and waste. Carelessly disposed of trash can harm the air, the soil, and the water, lowering the quality of the water in the rivers and raising the risk of illness. What if humans need to spend a lot of time and energy cleaning up waste? The objective of this project is to build a remote-control trash carrier.

The microprocessor that manages the garbage boat is an Arduino Uno R3. Both a servo motor and a DC motor are used to propel the boat's arm, which is used to load garbage onto the vessel, and to propel the vessel forward and in either direction. This prototype was created to make it simpler for people to move waste using microcontroller control, save the amount of time required, and eliminate any potential risks in the river. The outcome of this design is that the boat may travel freely on the water's surface and that the servo motor serves as the arm drive for moving trash.

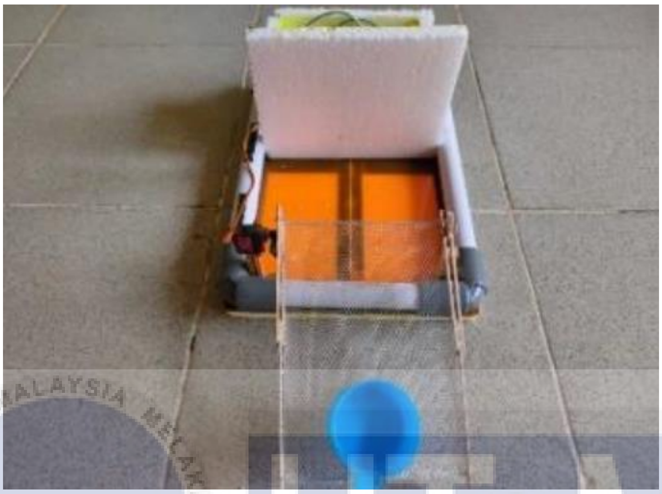


Figure 2.5 Prototype Perahu Pengangkut Sampah Berbasis Arduino [8]

Likewise, because of the remisseness of people and the upkeep of water bodies, a huge number of plastics and other drifting squanders are unloaded into the water consistently. Mostly, when required, the water bodies are cleaned physically with human work which requires a much of time and cost. To address this, the proposed work in this article focuses on the plan and advancement of a water surface junk cleaning semi-independent bot controlled by Arduino-Uno.

The most interesting thing about this robot is that it not only cleans the water surface but also the ground floor. Hence, it is very effective in cleaning things like farm ponds, lakes, beaches, and public places like hospitals, roads, and railway stations. This robot has two front working parts namely- The robotic arm and the Loading Bucket. These two things can be replaced with one another very easily according to requirements and conditions. This will help in keeping neatness of the water and places around us with minimal expense and least human exertion.

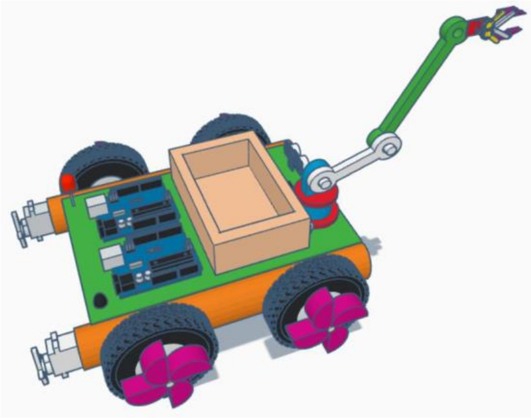


Figure 2.6 A Water Surface and Floor Cleaning Robot [5]

2.3.3 Water-cleaning Robot With IoT Monitoring

Water quality is impacted by both point and nonpoint sources of pollution, including sewage discharge, industrial discharge, runoff from agricultural areas, and urban runoff. Floods and droughts are additional sources of water contamination since customers are uninformed and uneducated about these issues. Users must cooperate in maintaining water quality and take other elements like hygiene, environmental cleanliness, storage, and disposal into account in order to sustain the quality of water resources. The system is divided into two parts: the remote, which has an LCD, a Wi-Fi module, and an Android phone, and the boat, which contains sensors and a wireless Wi-Fi camera. The two are connected using wireless RF modules. All sensor readings will be received by the remote, which will then show them on an LCD attached to the device. The boat can be propelled by two DC motors attached to the back, which are managed by switches on the remote.

Figure 2.7 IOT-Based Water Quality Monitoring System Using RC Boat[6]

The "Ocean Waste Collection Technology" project includes an aerial drone that will be mounted to the boat and operate underwater. The device will be able to differentiate between waste and other objects on the seafloor, such as critters and algae, thanks to artificial intelligence. A large collection of images of various objects, including plastic bottles and fish, will be used to train an algorithm to recognize them and detect garbage.

They came up with the technology of FRED for cleaning surface water garbage. It is a solar-powered Floating Robot for eliminating debris. FRED is ascendable for bays, rivers, and oceans. Materials used by FRED are Pontoon Hulls, Conveyer Belts, Remote control, auto-navigation, Solar panels, battery system, embedded sensors, and data communication. The two FRED prototypes are the 6-foot FRED prototype and the 16-foot FRED junior prototype.

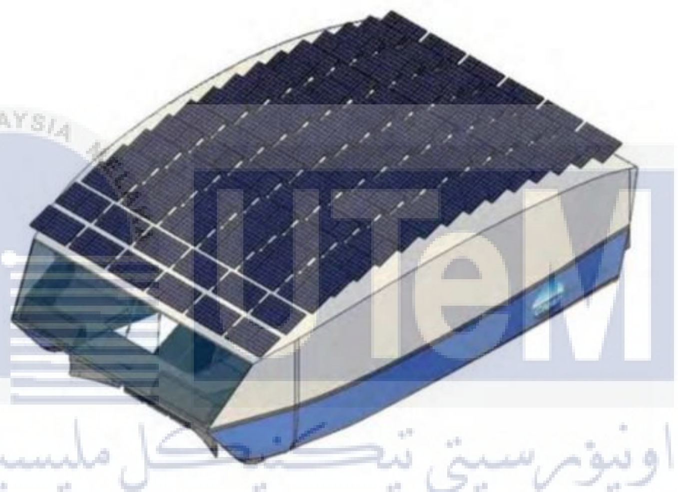
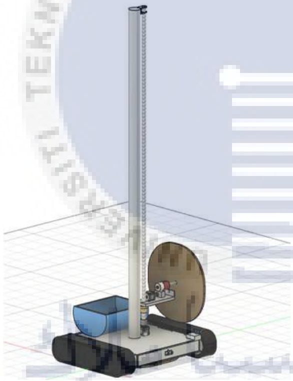
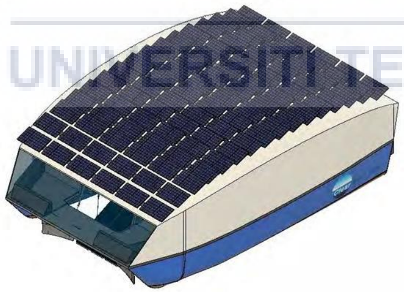
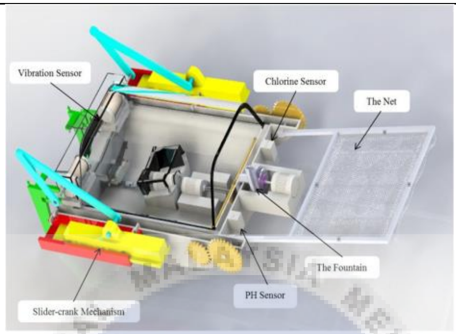
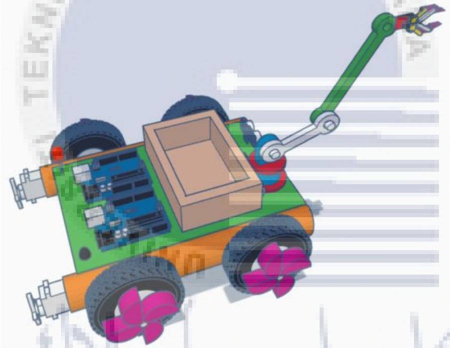


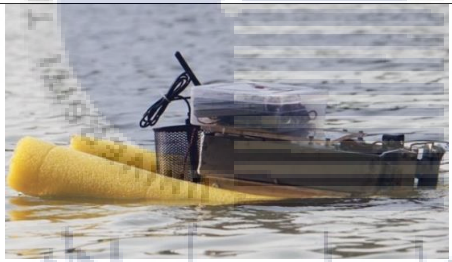
Figure 2.8 Ocean Waste Collection Technology [7]

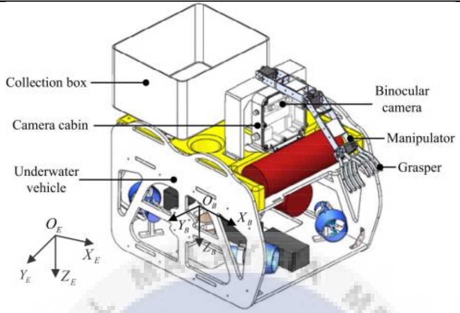
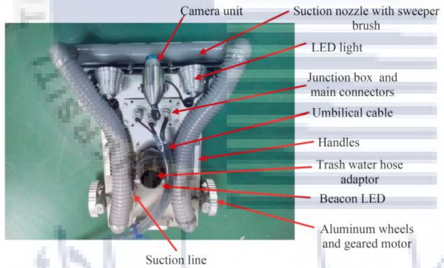
2.4 Summary of Literature Review

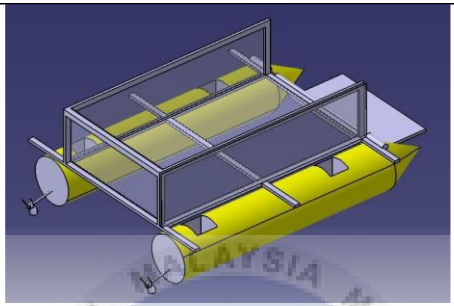
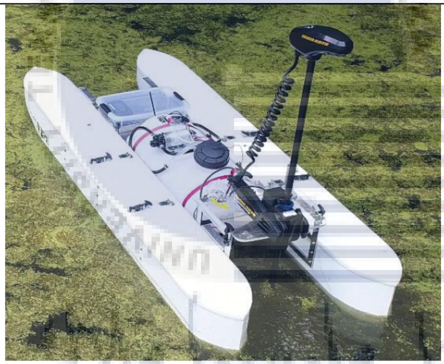
Table 2.1 Recent development of water-cleaning robot

Author(s)	Year	Experimental setup	Methodology	Findings
[14]	2023		n/a	• The robot is created using Fusion 360, is simulated using Gazebo, and has been programmed using a Robot Operating System (ROS).
[13]	2023		n/a	• recognizing trash should be prepared thoroughly • The size of the robot should be upward scaled for genuine water bodies

[15]	2022		Arduino UNO R3	• A message on the LCD displays the remote • an Android mobile application was developed • It can act as a pool security guard's helper.
[16]	2022		Arduino UNO R3	• It called an amphibian robot. • Can reduces the quality of water nor disturbs or harms aquatic life. • It is programmed to work according to the signals of sensors and signals from the remote.
[4]	2022		Sensor RGB camera, Wave radar, GNSS, IMU	• SMURF, is a fully autonomous water surface cleaner. • human-free, high-efficiency water surface cleaning

[10]	2022		Arduino UNO	• Design by EasyEDA software • Main controller -Arduino Uno R3 with supporting components such as servo motors, Bluetooth, L298N Motor Driver, DC motors, and jumper cables to connect everything, and batteries as a source.
[17]	2022		Wireless RF modules	• The second component of a boat with sensors and a wireless Wi-Fi camera is a remote control with an LCD, a Wi-Fi module, and an Android smartphone. • The boat is connected via wireless RF modules

[18]	2021		TCP/IP, USB video class (UVC), and Bluetooth	• The robot navigates the predetermined path on the water's surface. • Can detects trash using its vision module. • Can calculates the robot's position in relation to the target.
[19]	2020		Wireless control pendant	• An improved sequential route is discovered using the Non-Dominated Sorting Genetic Algorithm with Reference Point Based (NSGA-III). • NSGA-II and MOPSO are inferior to NSGA-III, which reduces cleaning time by 11.11 and 5.12 percent, respectively.

[20]	2019		Arduino UNO	• The robots have a strong thrust and can turn 360 degrees instantaneously. • They can be manually operated from a distance using Xbee Pro wireless modules. • A maximum of 16 kilograms of trash per load.
[21]	2019		Wireless control	• The hydroacoustic images of three aquatic plant species (Hydrilla, Cabomba, and Coontail) were geotagged. • To transfer the hydroacoustic data to the main computer, a wireless module (Navigo Marine Electronics, Egersund, Norway), a Wi-Fi-enabled SD card, or hydroacoustic wireless technology (such as the "Navigo go free wifi1") may be utilized.

2.5 Summary

The development of water-cleaning robots has involved a range of technologies, including sensors, GPS, cameras, and artificial intelligence, to allow the robots to navigate through waterways, detect and identify pollutants, and collect and dispose of debris. As the demand for sustainable and efficient water management solutions continues to grow, the development of water-cleaning robots is likely to gain more attention and funding in the years to come.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This section outlines the research methods and techniques used to conduct the study. It provides a detailed description of the approach taken to achieve the research objectives.

It includes a detailed explanation of the research design in a process flow chart.

3.2 Selecting and Evaluating Tools for a Sustainable Development

In designing and implementing a water-cleaning project with a focus on sustainability, it is important to carefully select and evaluate the tools and technologies that will be used to collect and analyze data. This involves a range of methodological considerations, such as assessing the accuracy and reliability of sensors, evaluating the compatibility of different tools and software, and considering the environmental impacts of the project. Additionally, it is important to consider the social and economic implications of the project, such as ensuring that the data is accessible and understandable to diverse stakeholders and considering the costs and benefits of different tool selections. To support these methodological considerations, there is a range of approaches that can be used, such as conducting field tests to evaluate projects, using open-source software to promote transparency and accessibility, and conducting life cycle assessments to evaluate the environmental impacts of the project. By carefully selecting and evaluating tools for a water-cleaning project, can ensure that these projects are effective, sustainable, and impactful.

3.3 Methodology

All experimental and descriptive techniques used in the project were outlined and recorded in detail. The flow of the project is represented by using a flow chart with a clear explanation. All the process or progress of this project is recorded and explained. The equipment that had been used in this project is listed in detail. The method (design) is experimental, which utilizes empirical modeling and a statistical approach. Subsequently, Figure 3.1, Figure 3.2, and Figure 3.3 shows the flowchart for each objective of this project.

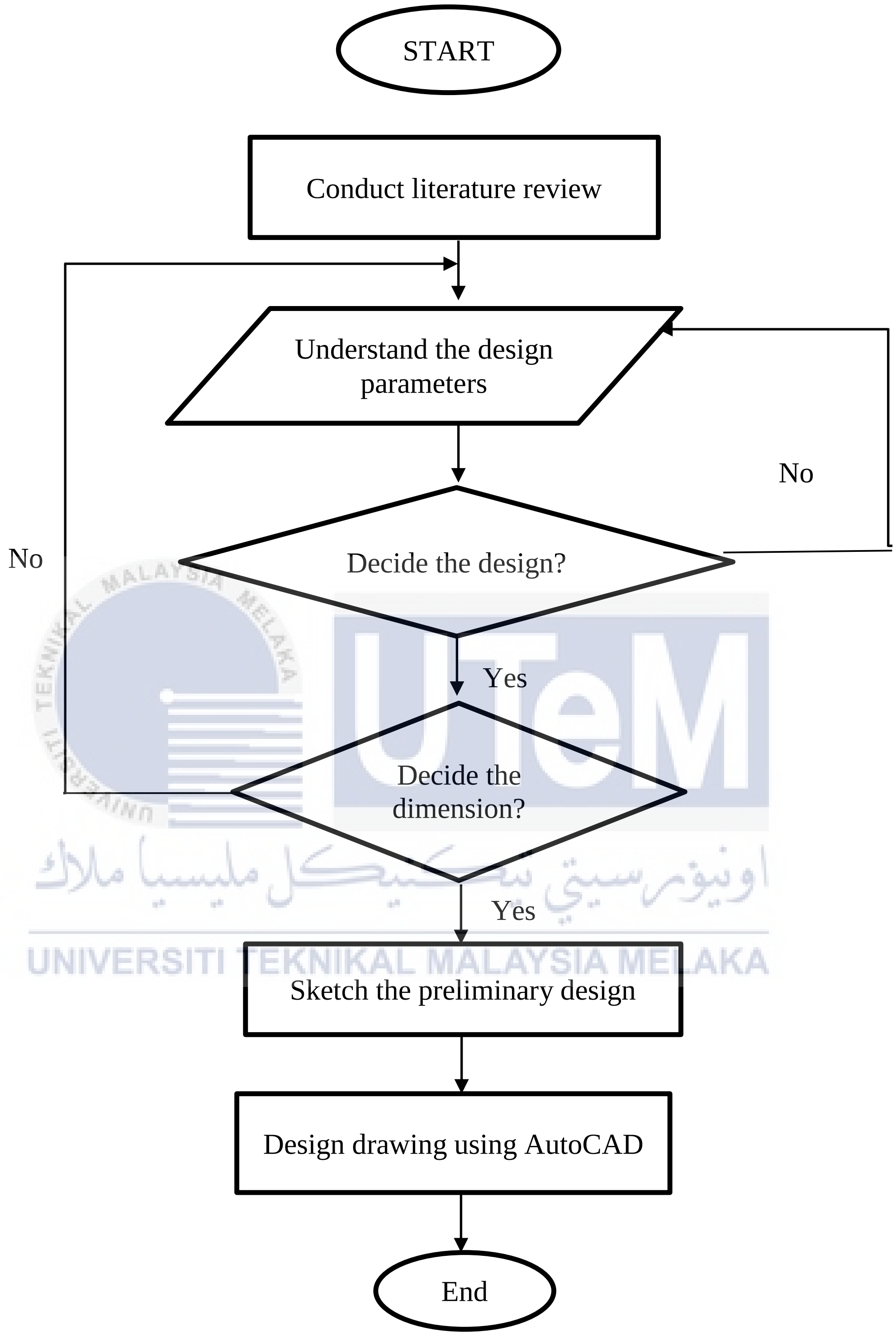


Figure 3.1 Flowchart for Objective 1.

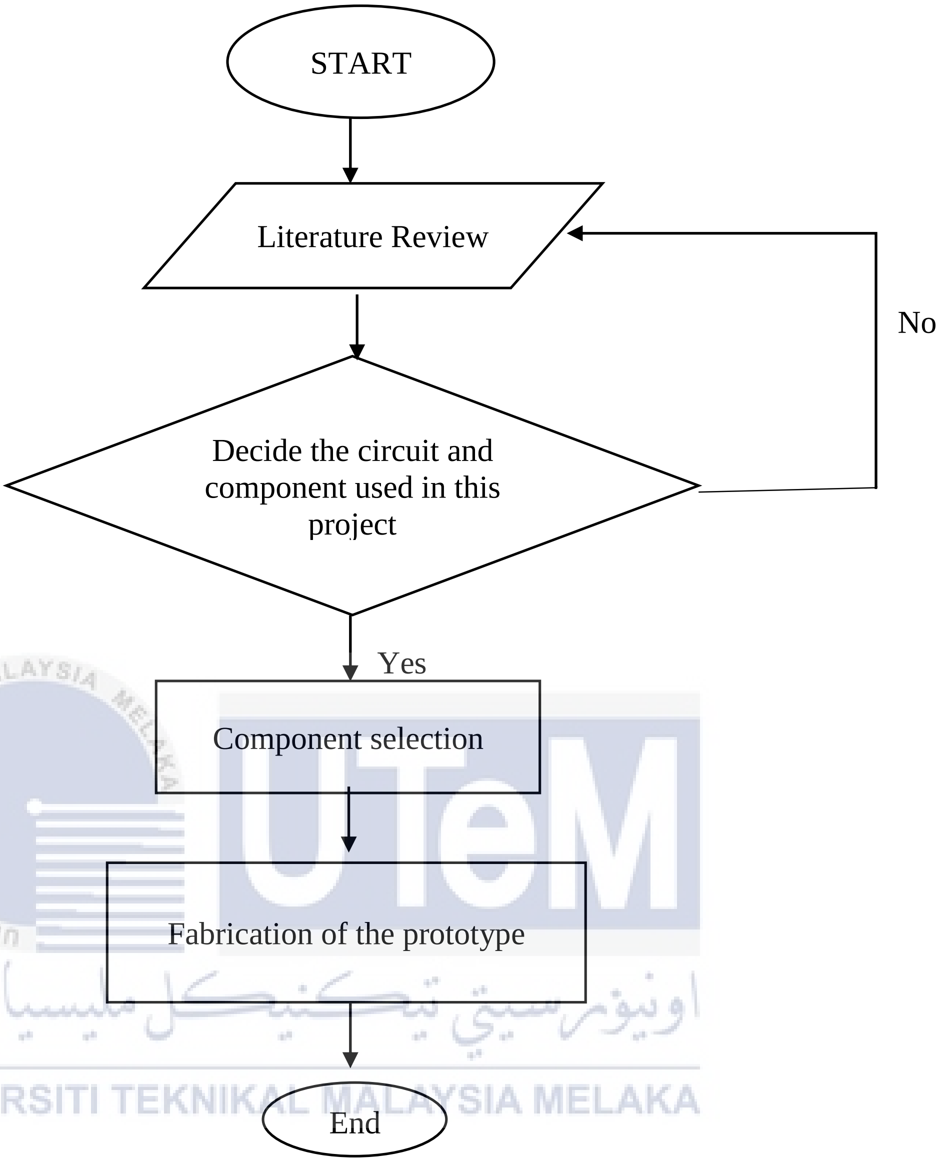


Figure 3.2 Flowchart for Objective 2.

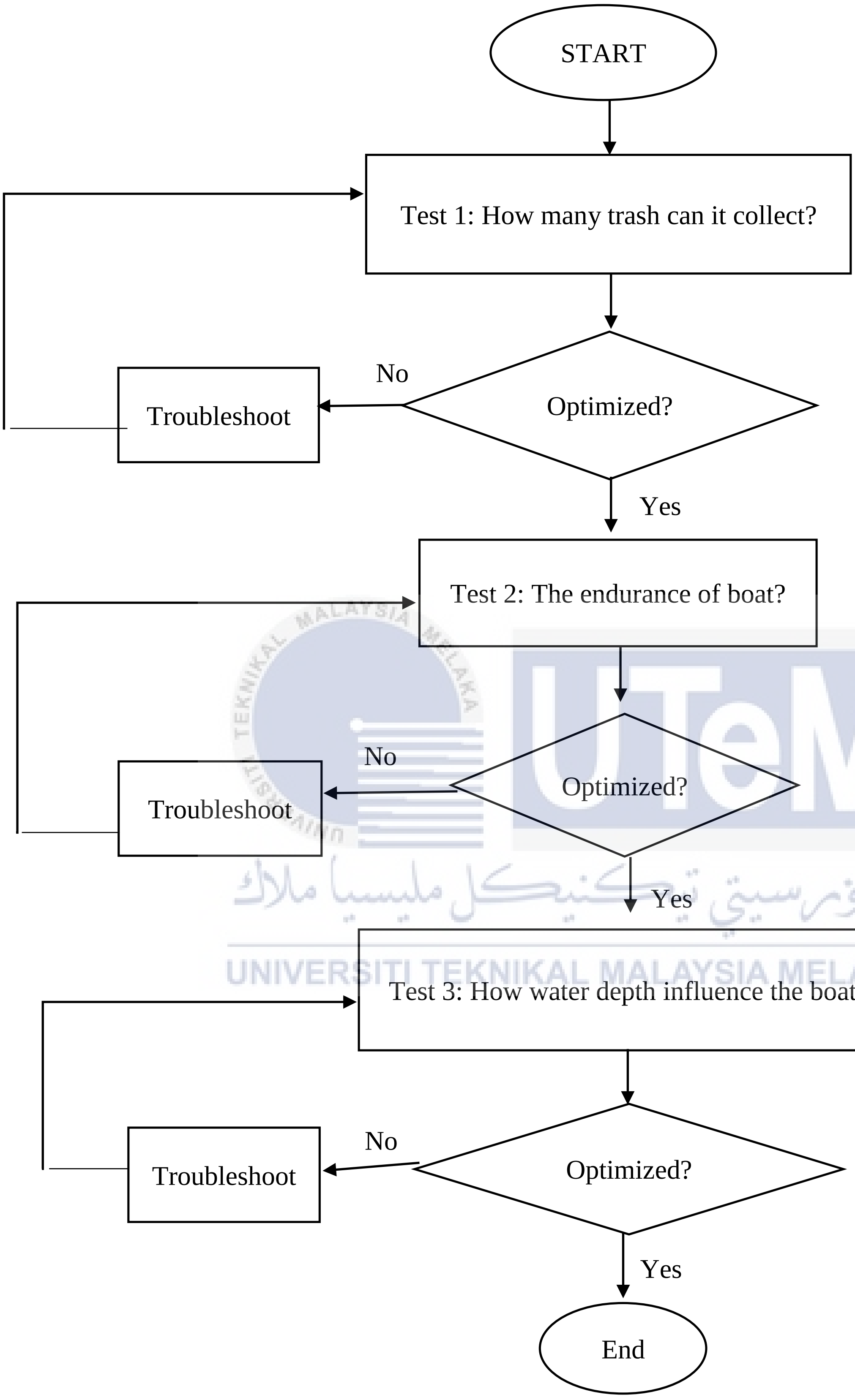


Figure 3.3 Flowchart for Objective 3.

3.3.1 Mechanical Design

This thesis presents a rough and detailed design of the water-cleaning robot which is a preliminary design, final design, and detailed design. The experimental method (design) makes use of statistical analysis and empirical modeling. Figure 3.1 then displays the thesis's research strategy.

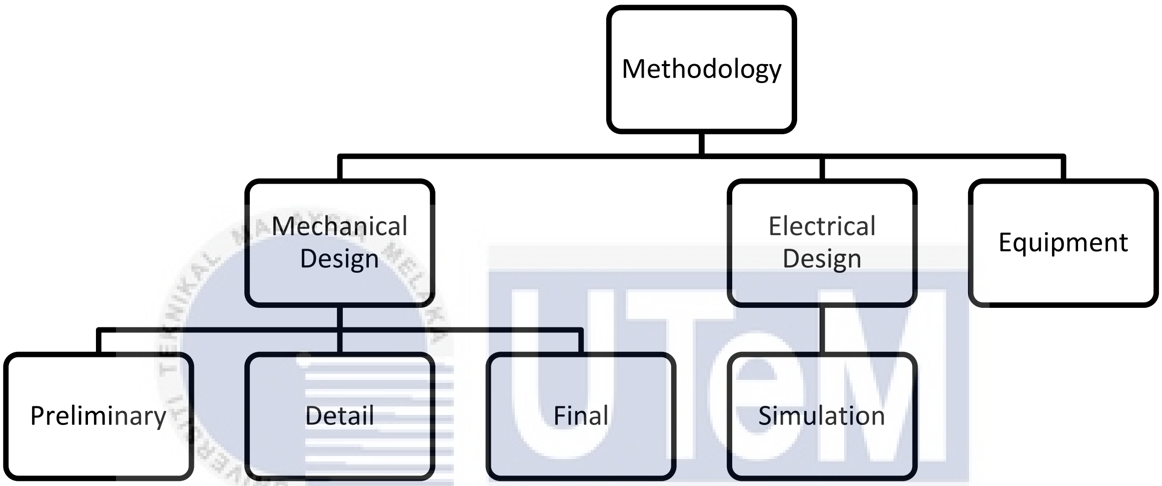


Figure 3.4 Summary of Methodology

a) Preliminary Stage

For the preliminary stage, there are two designs that are chosen according to the objective and problem statement that has been stated. This stage is still using rough design. The rough design begins with generating ideas and concepts for the product or system. This stage involves brainstorming, sketching, and exploring various possibilities to define the overall form, features, and functionality.

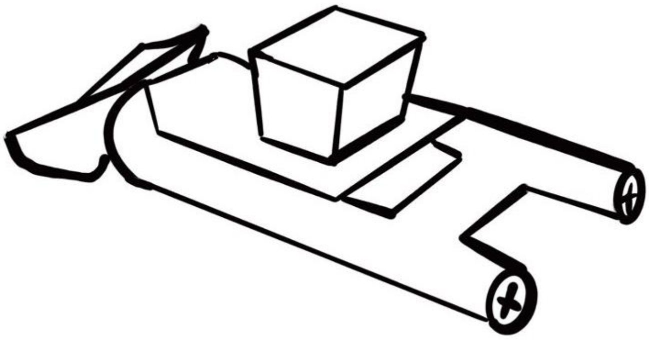


Figure 3.5 Design 1

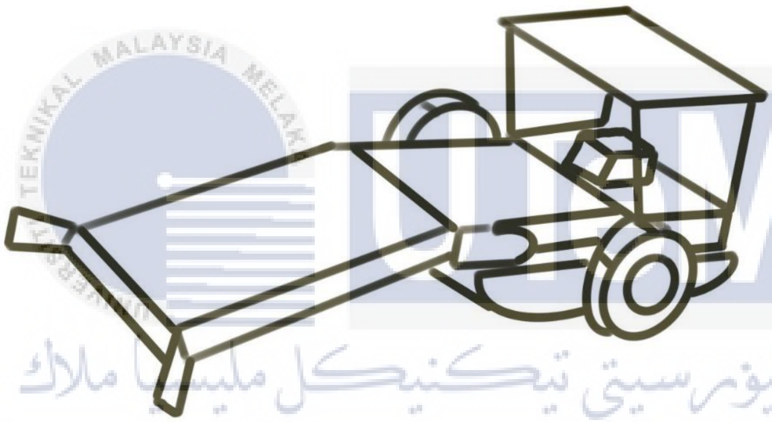


Figure 3.6 Design 2

b) Design Detail

At this stage, 3D design software is used to show the details of the overall design prototype. The preliminary design phase sets the foundation for the subsequent detailed design. It aids in defining the overall structure, layout, and key features, which will be further developed and specified in the detailed design process.

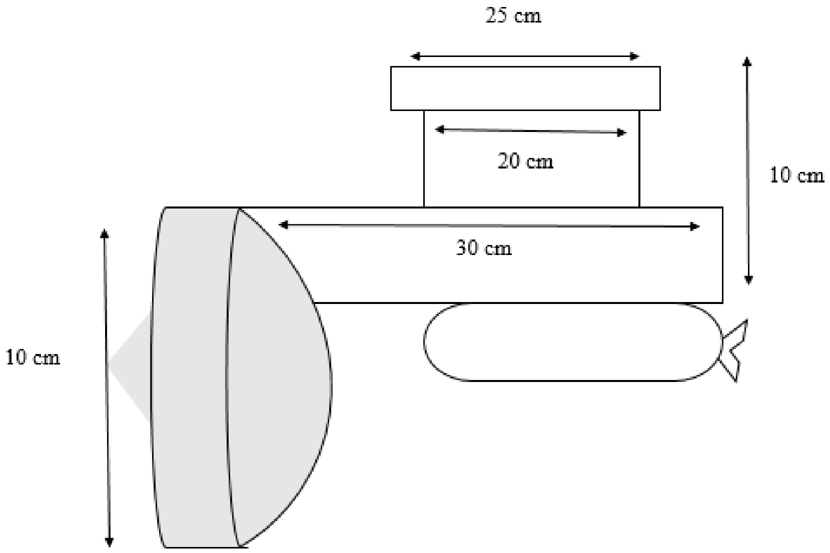
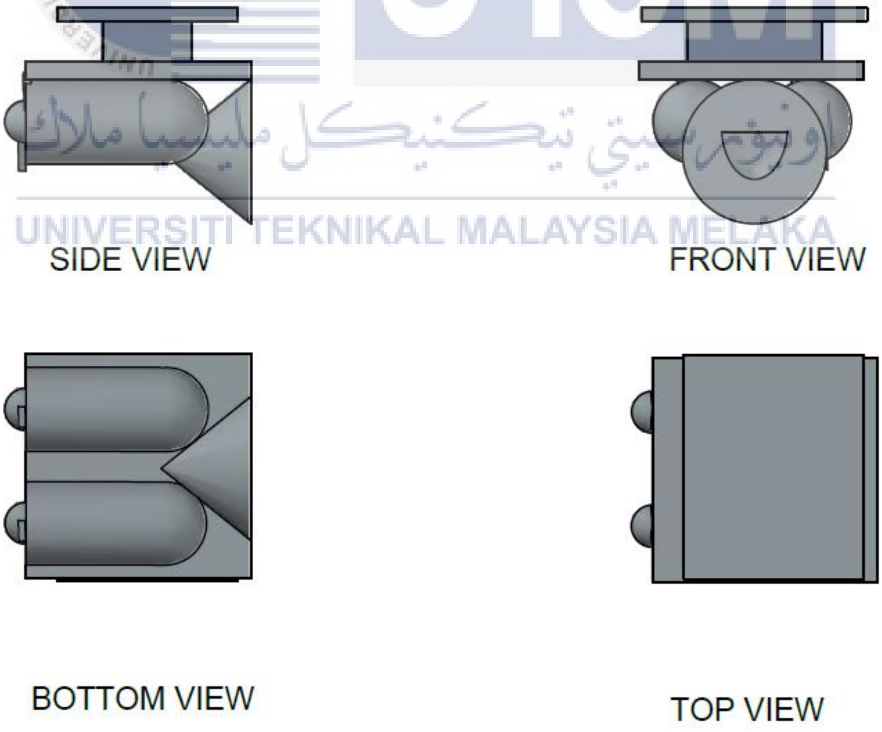


Figure 3.7 Design Detail



c) Final Design

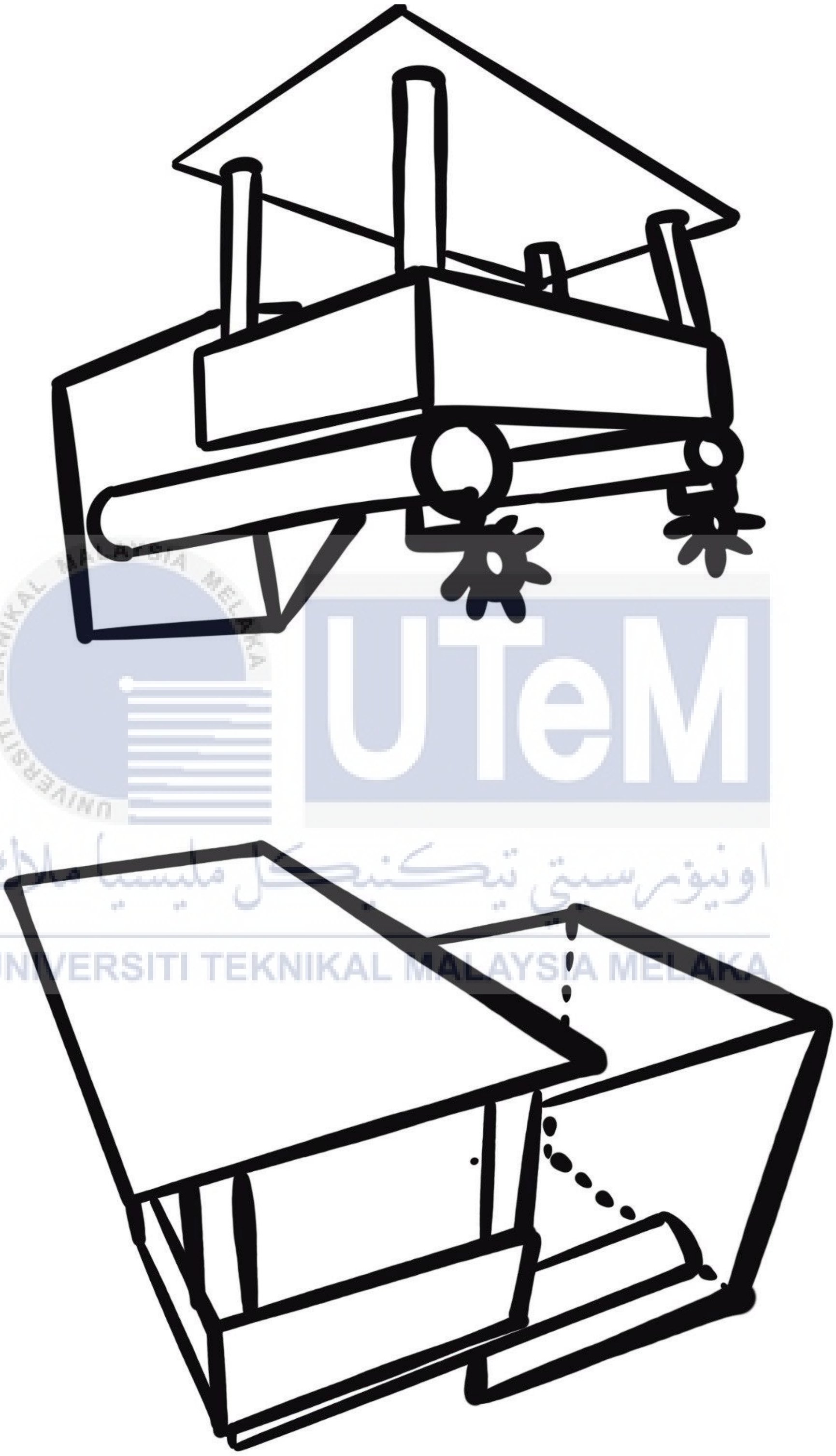


Figure 3.8 Final Design

Figure 3.9 View of Finished Prototype

3.3.1.1 Electrical Design

For electrical design, it was designed in the software Proteus. Proteus, a piece of software for electronic design, can be created using the simulation and PCB layout tools from Lab Centre Electronics. Previous to their implementation, it can offer full design and testing for those contexts. The newest version is 8.15 of Proteus.

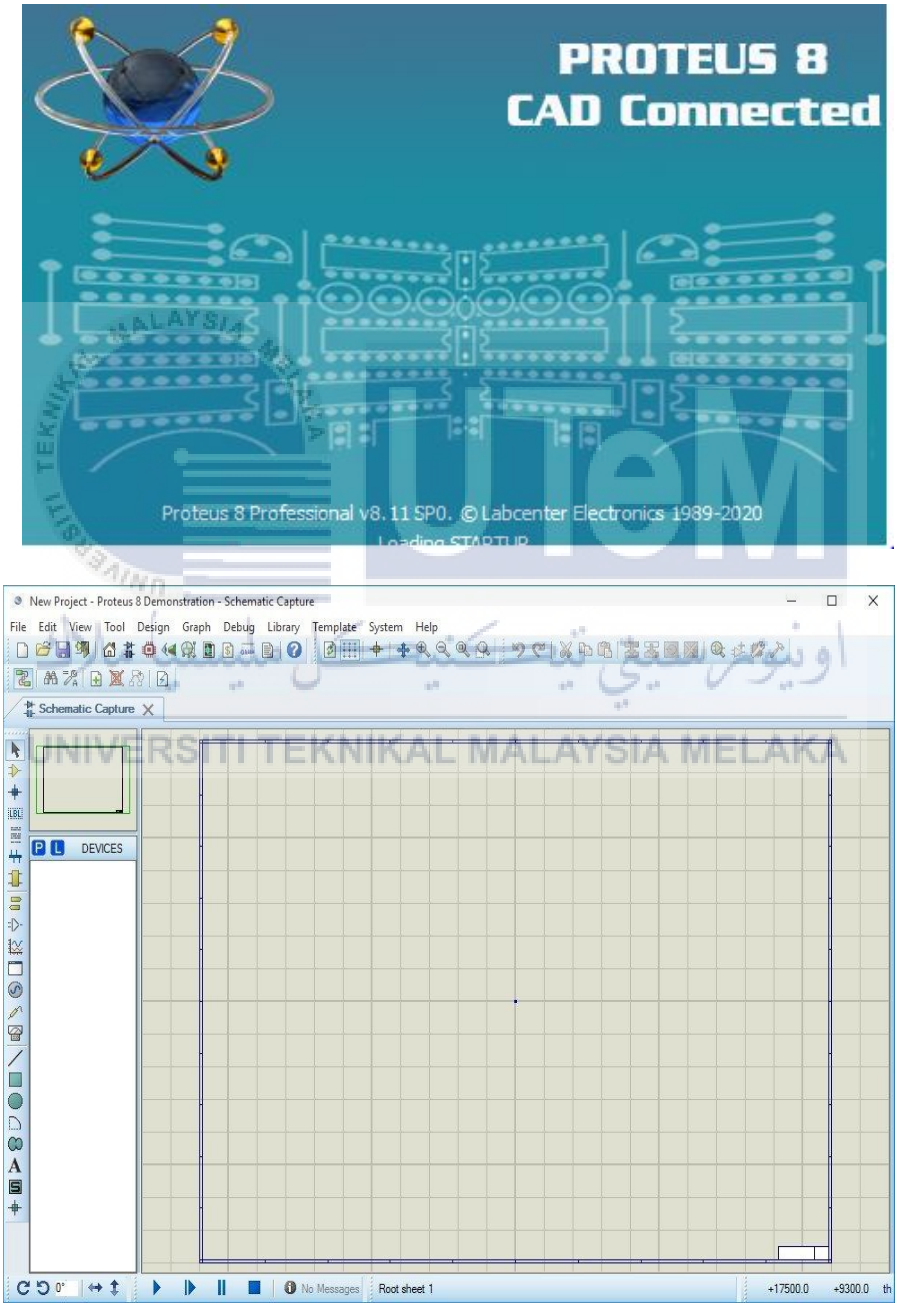


Figure 3.10 Software Proteus

a) Transmitter circuit

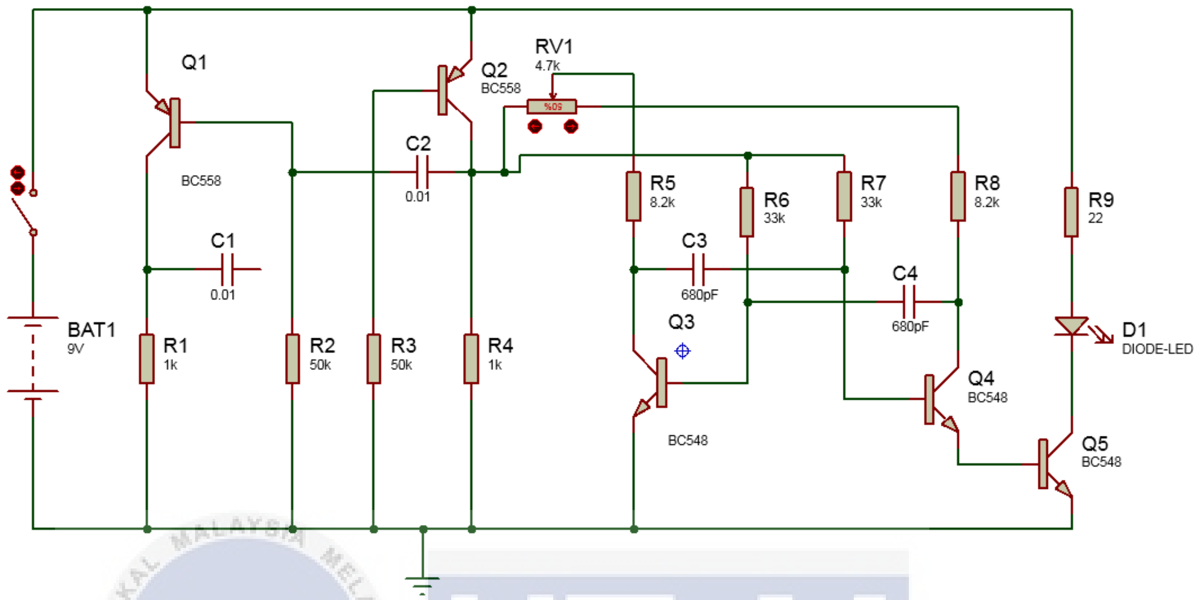


Figure 3.11 Transmitter circuit

b) Receiver circuit

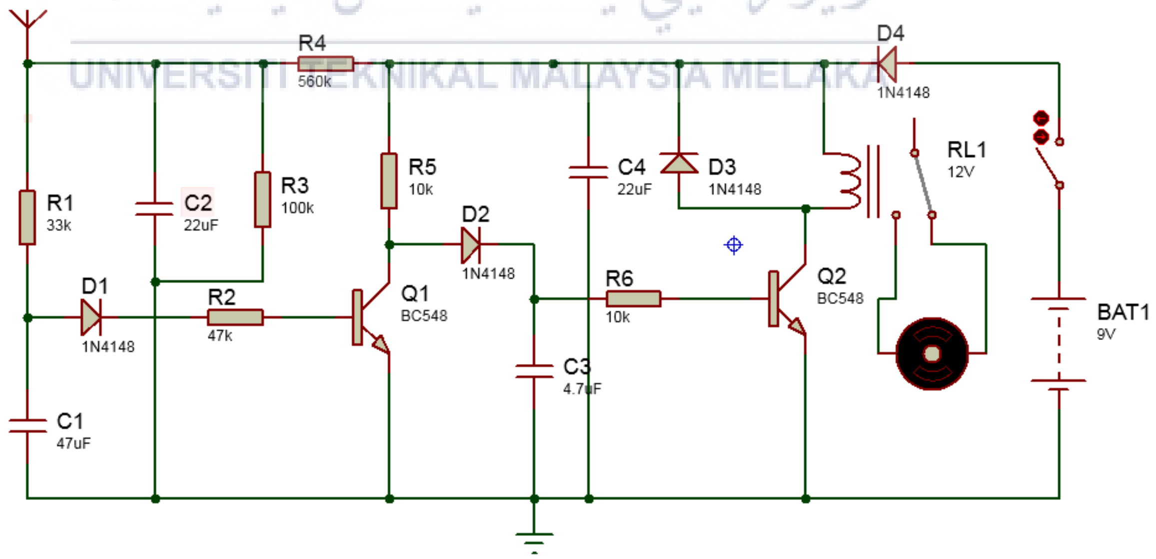


Figure 3.12 Receiver circuit

3.3.1.2 Costing

Table 3.1 List of costing project

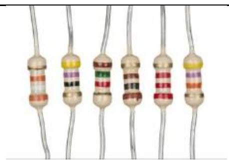
BIL	DESKRIPSI	NO RESIT/INVOIS	HARGA		
			TANPA GST (RM)	GST (RM)	JUMLAH (RM)
1	DC MOTOR	CS00045566	10.00	10.00	10.00
2	CONNECTOR	CS00045566	3.60	3.60	3.60
3	SWITCH	CS00045566	2.00	2.00	2.00
4	BATTERY HOLDER 9V	CS00045566	3.00	3.00	3.00
5	BATTERY HOLDER AA	CS00045566	3.00	3.00	3.00
6	CABLE	CS00045566	4.00	4.00	4.00
7	9V BATTERY	CS00045566	5.00	5.00	5.00
8	BATTERY AA	CS00045566	7.00	7.00	7.00
9	SPRAY PAINT	R000364039	10.50	10.50	10.50
10	INSULATION TAPE	R000364039	2.20	2.20	2.20
11	SCREW	R000364039	2.90	2.90	2.90
12	MARKER	R000364039	5.30	5.30	5.30
13	GLUE	13702311041113	2.40	2.40	2.40
14	BASE	13702311041113	2.40	2.40	2.40
15	JUMPER	231030A9EDSQ	1.80	1.80	1.80

16	METAL ROD	231030A9EDSQ	1.30	1.30	1.30
17	USB	231030A9EDSQ	2.90	2.90	2.90
18	PROPELLER	231030A9EDSQ	3.00	3.00	3.00
19	RECHARGEABLE BATTERY	231030A9EDSQ	6.50	6.50	6.50
20	CHARGE CONTROLLER	231030A9EDSQ	15.00	15.00	15.00
21	REMOTE CONTROL	231030A9EDSQ	20.41	20.41	20.41
22	SOLAR PANEL	231030A9EDSQ	15.00	15.00	15.00
23	MOSQUITO NET	231030A9EDSQ	26.22	26.22	26.22
24	CORRUGATED BOARD	671-597829	16.60	16.60	16.60
25	CLOTH TAPE	BIL73866	3.50	3.50	3.50
26	GREEN MOSS NET	BIL73866	7.50	7.50	7.50
27	UPVC BENT	BIL73866	1.80	1.80	1.80
28	UPVC END CAP	BIL73866	2.00	2.00	2.00
29	UPVC PIPE	BIL73866	5.00	5.00	5.00
JUMLAH TUNTUTAN (RM)					191.83

3.3.1.3 Materials and Equipment

Equipment is being selected and has been listed. The circuit for the hardware component must also be completed before parts are purchased or the hardware is produced. The Bachelor's Degree Project II (BDP II) can then be completed by finishing the report and delivering the final presentation.

Table 3.2 List of components

Equipment	Figure
Solar Panel (2Wp)	
Battery	
DC Motor	
BC558 transistors	
BC548 transistors	
Resistor	
Capacitor	

3.4 Limitation of the proposed methodology

The proposed methodology involves developing the design of a water-cleaning mechanism and comparing the performance of prototype in the several experiments. One potential limitation of this proposed methodology is the limited area of study. Since the study only involves the canal area, there may be various confounding factors that could influence the results. For instance, this project is only for the canal or lake area. It is not suitable for the sea and others. Additionally, the sample size in this proposed methodology is limited to small-scale trash. Thus, in this proposed methodology the size of the prototype or water-cleaning mechanism is in a small size. This is because this methodology, it is focusing on collecting small-scale trash in the canal area. In summary, the limitations of the proposed methodology include the lack of study in various areas and the size of the project.

3.5 Summary

This chapter outlines the suggested methodology for creating a fresh, efficient, and comprehensive strategy for creating the water-cleaning robot for the canal area. The proposed methodology's main goal is to create a straightforward, less meticulous, and efficient design that produces the best outcome and works effectively. The method's primary goals are efficiency, simplicity in usage and manipulation, and the viability of developing a water-cleaning robot for canal areas. These goals take precedence over obtaining the highest degree of accuracy.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents the results and analysis of the development of a prototype of a water-cleaning robot. In this chapter, results, and analysis of a preliminary prototype are presented. To showcase the practicality of the initial stage of the designed prototype, several case studies were conducted. Three aspects were examined including the following:

(i) Quantifying the maximum amount of trash that the water-cleaning robot is capable of collecting.

(ii) Evaluating the range of control for the water-cleaning robot, specifically determining the maximum distance it can control.

(iii) Observing how the condition of water affects the result of the performance of the water-cleaning robot.

(iv) Studying the characteristics of the solar panel that are suitable and can be used for the water-cleaning robot.

(v) Developing the suitable sizing and weight of water-cleaning robot for canal area application that gives the best performance.

4.2 Results and Analysis for PSM 1

In this stage, a mini prototype has been developed and is illustrated in Figure 4.1. The prototype consists of a boat equipped with two motor underwater motors, to facilitate the movement. The prototype is designed with two levels. The lower level is designed to house the circuit while the upper level is to be integrated with the solar module.

The prototype has demonstrated effective functionality in collecting waste from the water surface of up to 1 kg. The net attached at the rear side of the boat can gather and retain the trash.

The boat can be controlled by using an antenna remote control, allowing for movement within a range of 90 m to 100m further from the boat. For a more comprehensive understanding of the initial design, a video demonstration of the preliminary prototype is available: https://youtube.com/shorts/4DPjuArIKIc?feature=share

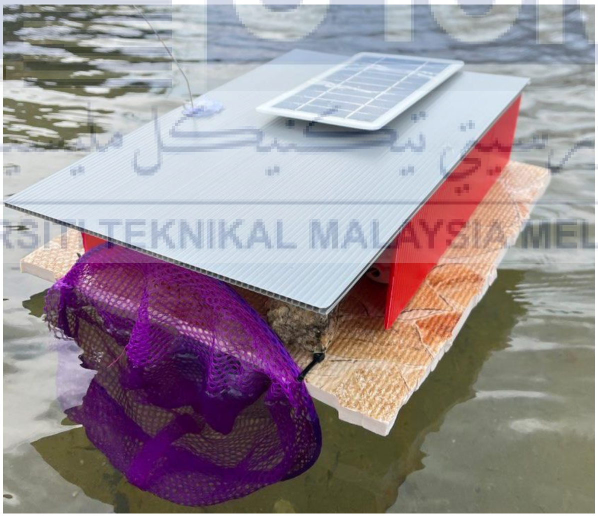


Figure 4.1 Preliminary Prototype of Water-cleaning Robot.

For this project, three case studies were observed. The results of case studies that are done are being observed and recorded:

Table 4.1 Table Performance of Mini Prototype

Performance Of Developed Prototype	
Case Studies	Result
Speed	1.5 m/s
Maximum Load	The boat can endure the load until 1 kilogram.
Maximum Distance Control	The boat can be controlled from 30 to 40 meters away.
Condition Water	• Strong waves and wind – The boat is hard to control and the speed is decreasing. • Weak wave – The boat is easy to control.

The mini prototype is being floated on water surfaces while the motor is underwater at the bottom of the boat. When the switch is on while the boat is still so, when the remote control is being moved forward the boat will start moving following the remote control. The boat can be controlled when the remote control is 30 to 40 meters away.

The boat's weight without the load is 1.2 kg and the boat can endure load on it until one kg. The mini prototype will be moved towards the trash on the river and then the net will collect the trash and keep the trash. The boat's speed is just 1.5 m/s because it is heavy and the speed is just average. When the load on it exceeds the maximum, the water-cleaning robot stays still and does not move even when you move the remote control.

The turning angle of the boat is 30 to 45 degrees and it takes time to make a turning. The boat can be smoothly navigated by making left or right turns, as well as reversing its direction. This functionality offers great convenience to the user, as it allows the boat to effortlessly maneuver.

4.3 Results and Analysis for PSM 2

In this stage, a mini prototype has been developed and is illustrated in Figure 4.2. The prototype consists of a boat equipped with two motor underwater motors, to facilitate the movement. The prototype is designed with two levels. The lower level is designed to house the circuit while the upper level is to be integrated with the solar module.

The prototype has demonstrated effective functionality in collecting waste from the water surface of up to 3 kg. The net attached to the front of the boat can gather and retain the trash.

The boat can be controlled by using an antenna remote control, allowing for movement within a range of 1 m to 20m further from the boat.

Figure 4.2 Prototype of Water-cleaning Robot.

For this project, there several case studies were observed. Firstly, the case studies boats in different types of flow of water which are in four situations which are medium flow, high flow, shallow water, and deep water.

a. Medium Flow

A condition in which a considerable yet moderate amount of water is moving steadily is referred to as "medium flow." This might happen in streams, rivers, or other bodies of water where the flow isn't too fast or too slow. The particulars of medium flow might change according to the situation, including the size and type of the water body.

b. High Flow

A high flow occurs when there is a significant and swift movement of water. This can happen in rivers, streams, or other waterways where there is a large volume of water moving quickly. Heavy rains or other sources that raise the volume of water in the system might cause high flow conditions.

c. Shallow water

An area of water with a comparatively shallow depth is referred to as shallow water. Deep water is the opposite of this. The amount of water between the surface and the bottom is constrained in shallow water. Ponds, lakes, rivers, and beaches with shallow water are common places to see this condition.

d. Deep Water

The difference in depth between the water's surface and its bottom is what defines deep water. Deep water conditions can be found in bodies of water like lakes and seas. Deep water has a depth that supports the existence of different water layers and can have an impact on a range of environmental physical and ecological traits.

The result of this case study is represented in Table 4.2. The results of case studies that are done are being observed and recorded:

Table 4.2 Performance of Different Situations

Situation	Observation
Medium flow	The water-cleaning boat moves with ease because of the powerful propellers and no obstacles.
High flow	In the battle against the river, propellers run the risk of losing control and drifting.
Shallow water	The boat clumsily crashed into the bottom and the boat was not suitable for shallow water.
Deep water	The boat moves smoothly with no obstacles.

The result from Table 4.2, the result, it can be concluded that the water-cleaning boat is well-suited for medium-flow and deep-water conditions due to its powerful propellers, which allow it to move with ease in these situations. However, in high-flow conditions, there is a risk of losing control and drifting, indicating potential limitations in managing strong currents. Additionally, the boat is not suitable for shallow water, as evidenced by its clumsy behavior and collisions with the bottom. Therefore, the boat's optimal performance is in medium-flow and deep-water environments where it can operate smoothly and effectively.

Secondly, the result for the performance of solar panels that have been used for this project is observed and recorded:

Table 4.3 Performance of Solar Panel

Time (h)	**Voltage (V)**	**Current (A)**	**Power (W)**
0600	3.08	0.01	0.0308
0700	3.52	0.054	0.19008
0800	3.76	0.089	0.33464
0900	4.34	0.089	0.38626
1000	5.76	0.123	0.70848
1100	5.96	0.284	1.69264
1200	6.86	0.297	2.03742
1300	6.75	0.278	1.8765
1400	6.43	0.198	1.27314
1500	6.57	0.191	1.25487
1600	6.48	0.172	1.11456
1700	6.39	0.105	0.67095
1800	5.13	0.058	0.29754
1900	3.73	0.05	0.1865
2000	0	0	0
2100	0	0	0
2200	0	0	0

The result of this case study is represented in the graph:

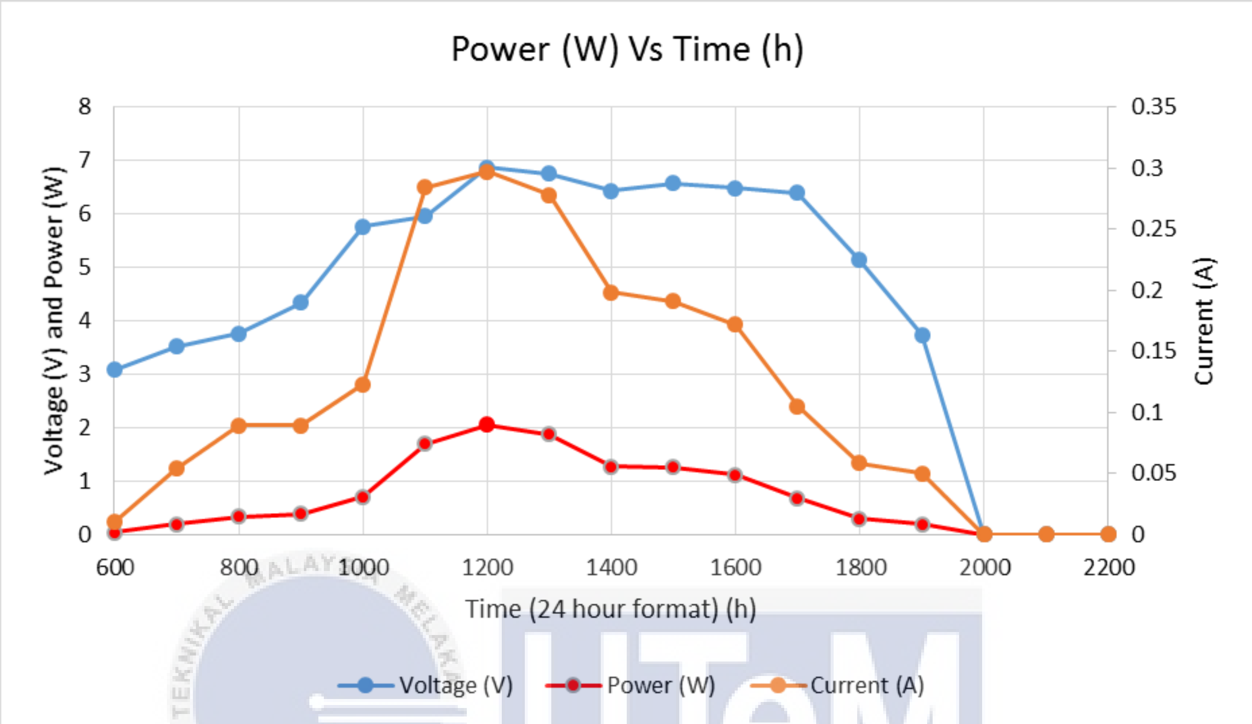


Figure 4.3 Power vs Time Solar Panel

From the result, there is a pattern of variation in the electrical characteristics throughout the day, based on the data provided on voltage, current, and power at various times. The voltage generally increases from 0600 to 1200 hours, reaching its highest value at 1200 hours (6.86 V). After 1200 hours, there is a significant drop in voltage, and it becomes zero at 2000 hours and remains zero thereafter. The voltage drop to zero at 2000 hours and subsequent hours suggests a complete loss of power.

Thirdly, the case studies for study the performance of remote-controlled boats by observing the how far distance of a boat that can be controlled by the remote. This study aims to observe how far the distance of a boat can be controlled and how the performance of a boat can be affected by the distance of the remote control.

The result of this case study is represented in Table 4.4. The results of case studies that are done are being observed and recorded:

Table 4.4 Distance vs Speed

Distance (m)	Speed (ms)
1	2
2	2
3	2
4	2
5	2
6	2
7	2
8	2
9	2
10	2
11	2
12	2
13	2
14	1.866666667
15	1.875
16	1.860465116
17	1.770833333
18	1.636363636
19	1.583333333
20	1.57480315

The result of this case study is represented in the graph:

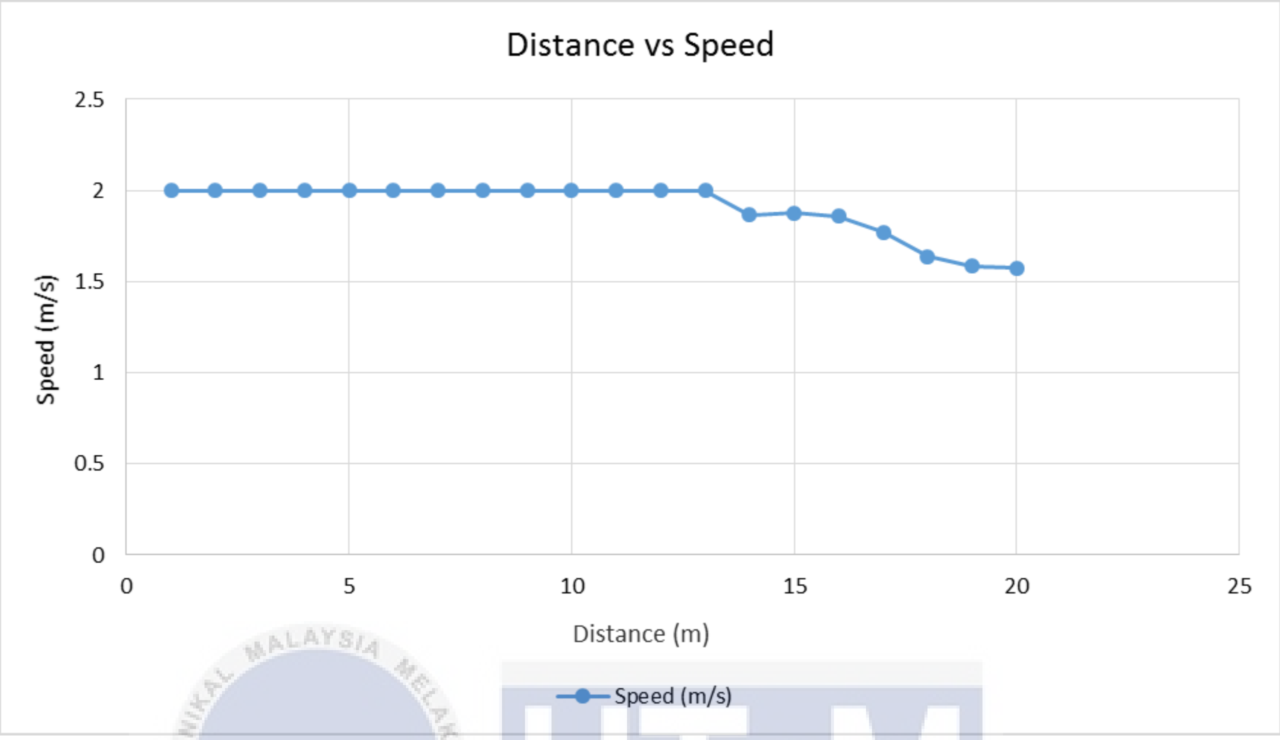


Figure 4.4 Distance vs Speed Boat.

From the observation, it can be observed that there is a relationship between distance and speed, and there are variations in speed as the distance increases. For the first 14 metres, the object travels at a constant speed of 2 m/s. The object begins to slow down after 14 metres, and as the distance increases over that, its speed decreases. The speed starts to drop after 14 metres. There is a risk for the speed to decrease with increasing distance, and the speed measurements are no longer constant. As the distance grows from 14 to 20 metres, the speed numbers decrease from 2 m/s to 1.57480315 m/s, indicating a decrease in speed.

Lastly, the last case study is the weight of the trash vs the speed of the boat. This case study aims to study how the weight of the trash affects the performance of the boat. It also aims to know the limited weight of trash that the boat can endure. The results of the case study that are done are being observed and recorded:

Table 4.5 Load vs Speed

Load (kg)	Speed (ms)
0.2	2
0.4	2
0.6	2
0.8	1.785714286
1.0	1.666666667
1.2	1.388888889
1.4	1.25
1.6	1.25
1.8	1.162790698
2.0	1.162790698
2.2	1
2.4	1
2.6	0.833333333
2.8	0.833333333
3.0	0.714285714

The result of this case study is represented in the graph:

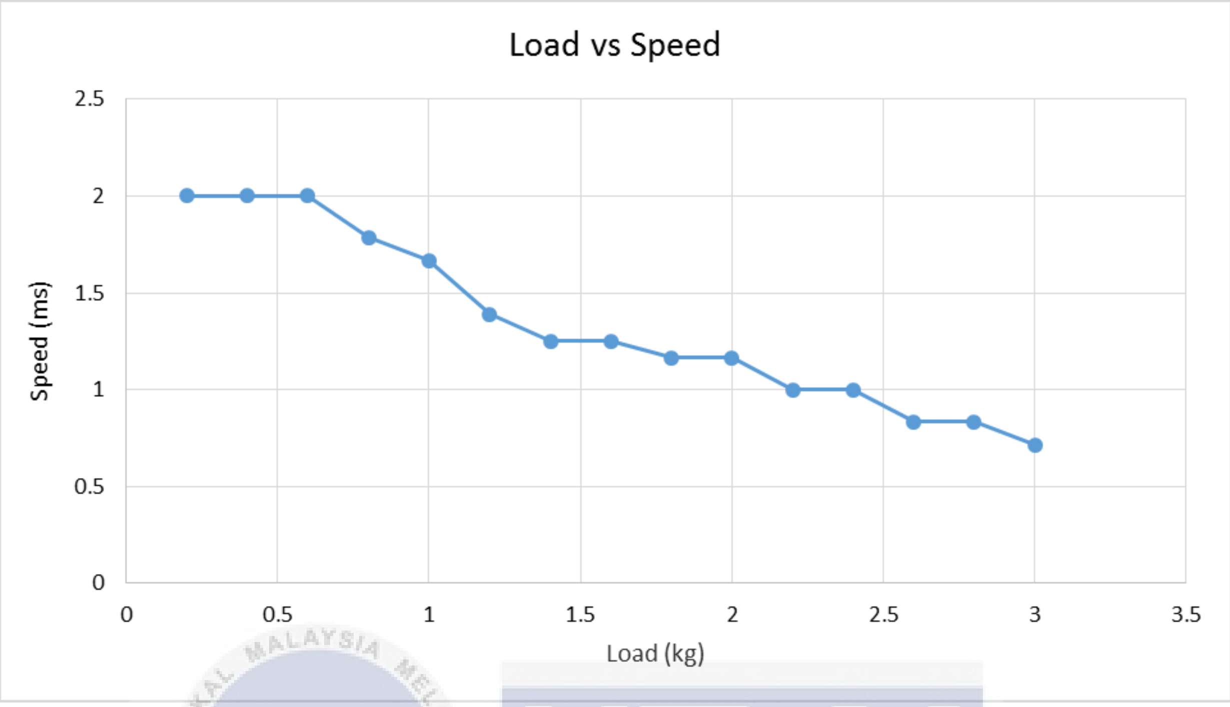


Figure 4.5 Load vs Speed Boat.

From the graph, the speed decreases with increasing load. This can be seen in the behaviour where the comparable speed values decrease as the load values increase. It indicates that load and speed have an inversely proportionate relationships. Below a certain load (around 2.2 kg), the speed remains constant at 1 m/s. This suggests that there might be a threshold load below which the water-cleaning boat can maintain a consistent speed.

4.4 Summary

This chapter presented case studies to demonstrate the applicability of the proposed water-cleaning system. The case study is based on three (3) conditions of water and trash. The three (3) case studies are being performed in a canal area, which is the maximum weight of the trash, the maximum distance the robot can be controlled, and the condition of water and trash. Using standard software, the water-cleaning system design (presented in Chapter 3) is designed to work in the canal area. In addition, water-cleaning robot results obtained based on the proposed approach show consistency with changes in the condition of water and yield reasonably accurate results.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This thesis presents a method for a new water-cleaning boat that can clean canal areas. The method suggested is efficient and reliable for getting good results using data from case studies and just reasonably correct data. The proposed analytical approach of using the water-cleaning robot is because there are many problems due to lack of cleanliness. The proposed project in this paper "Design and Development of a Remote-Controlled Solar-Powered Cleaning Robot for Canal Area Applications" is the solution to all these problems. The mechanism of the project is that it is programmed to work according to the signals of sensors and signals from the remote. The transmitter circuit will send a signal to the receiver circuit, so the water-cleaning robot can move according to the input from the remote control. This project neither reduces the quality of water nor disturbs or harms aquatic life. As a result, the project has proven very innovative and effective in promoting cleanliness drives.

Overall, the research described in this thesis has been successful in advancing knowledge about the significance of practical and efficient water-cleaning technologies. With the help of software, the proposed method creates a water-cleaning mechanism that may deliver results that are timely, reliable, representative, and to some extent correct. In addition, procedures that enable the testing and assessment of water-cleaning robots were developed as part of the work done. As a result, it establishes a foundation for the suggested additional research.

5.2 Potential for Commercialization

Water-cleaning projects have significant potential for commercialization, particularly as demand for cleaning trash and environmental cleaning continues to grow. There is a range of applications for water-cleaning technologies in various sectors, such as agriculture, river, pool, and sea. For example, water-cleaning usage can be used to optimize water cleanliness and support green planning and development. In addition to these applications, water-cleaning projects can also generate revenue through data licensing and partnerships with private sector organizations. However, it is important to balance the potential for commercialization with the need to ensure that water-cleaning usage is accessible and usable for diverse stakeholders, particularly in the context of addressing the global challenge of climate change. As such, water-cleaning projects with a focus on sustainability and equitable access have the potential to generate significant economic benefits while also promoting environmental and social well-being.

5.3 Future Works

For future improvements, the accuracy of the water-cleaning robot results could be enhanced as follows:

i) Add a conveyor so that the conveyor can separate the trash regarding the type of reuse, recycle, and reduce it so that consumers can separate it easily.

ii) Add more baskets and enlarge the base of the boat.

iii) Use an IR sensor, which means that the boat itself will detect movement toward the garbage floated.

iv) Can control the project using a phone without having to use a remote.

v) Adjust the boat's size to match its waste-gathering capability.

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APPENDICES

Appendix A Project Gantt Chart (PSM 1)

No	Week / Activities	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Meeting with supervisor														
2	Project Research														
3	Preparation Proposal														
4	Selection component														
5	Circuit designing using software														
6	Components Preparation & Developing the Product														
7	Circuit Construction & Troubleshooting														
8	Testing and operates														
9	Presentation														
10	Final Report														

Appendix B Milestone of the project

Description	Week	Cumulative project completion (in %)
Completion prepares the proposal	Week 4	20%
Completing discussion on the selection of hardware	Week 5	30%
Completion to buy the hardware	Week 7	45%
Completion of developing the project	Week 8	70%
Completion of running the project and troubleshooting	Week 12	90%
Completion of the project and final report	Week 14	100%

Appendix C Project Gantt Chart (PSM 2)

No	Project Activity		Week													
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Planning activities for project development	Plan														
		Actual														
2	Final year project briefing for PSM 2	Plan														
		Actual														
3	Starting to purchase the equipment for the project	Plan														
		Actual														
4	To achieve objective 1, starting to design the prototype using AutoCAD and Microsoft Word.	Plan														
		Actual														
5	Project start prototype.	Plan														
		Actual														
6	To achieve objective 2, the prototype being assemble and already ready to be testing.	Plan														
		Actual														
7	Update to supervisor: Progress Work 1	Plan														
		Actual														

8	Prototype testing under various condition to achieve objective 3	Plan														
		Actual														
9	Result and data collection for the prototype	Plan														
		Actual														
10	Report Draft Submission	Plan														
		Actual														
11	Update to supervisor:	Plan														
	Progress Work 2	Actual														
12	Submission report to panel	Plan														
		Actual														
13	PSM Presentation Evaluation	Plan														
		Actual														

Appendix D Datasheet Solar

Description

Description

Specification:

- Cell Type: Polycrystalline Solar Cell
- Maximum Power at STC*: 3 Watt
- Optimum Operating Voltage (Vmp): 6V
- Optimum OperatingCurrent (Imp): 500mA
- Open-Circuit voltage (Voc): 7.2 V
- Short-Circuit Current (Isc): 550 mA
- Power tolerance: -3/+3%
- Surface Coating :   Epoxy Resin
- Backplate: PCB (FR4)
- Size: 150×162 mm
- Thickness: 3 mm±0.2mm(Custom made)
- Net Weight： 11 g
- Cable Length& Connector: Custom Options
- Working temperature: -30℃~80℃
- Standard Test Condition(STC*): AM=1.5,E=1000W/M2 ,Tc=25°C

Appendix E Datasheet Solar Charge Controller

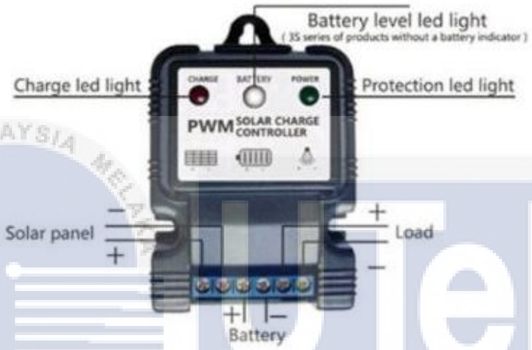
Install & Method of Using

1.Wiring Sequence

The preparation of the conducting wire: calculate the length of the wire, and then figure out the installation place.Before connecting the battery firstly, please pay attention to the anode and the cathode to avoid inverse connection. If reversed, the controller lights without any indication, will not damage Internal control components. If correctly connected, POWER indicator will light.

2.LED Lights Display Instruction

LED	STATE	FUNCTION
CHARGE	OFF	Didn't answer the solar panels or night
	LIGHE ON	Battery charging status
BATTERY	GREEN LIGHT ON	Battery power is normal
	RED LIGHT ON	Battery power is low
	BLINKING RED LAMP	Battery power shortage
POWER	OFF	The output protection or relating to state where the output
	LIGHE ON	The controller output is normal



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Technology Index

Charging mode	PWM			
Current system	3A/5A/10A			
Withstand voltage input	3S≤30V;5S≤50V			
Overload, short circuit protection	1.25 times the rated current delay 5 minutes off, Automatic recovery after 5 minutes; ≥3.0 times the rated current of short-circuit protection action			
System voltage	1.2V*S	3.2V*S	3.7V*S	6V*S
Overpressure protection voltage	1.6V*S	3.8V*S	4.3V*S	7.5V*S
Over-discharge protection voltage	1.0V*S	2.5V*S	3.2V*S	5.4V*S
Over-discharge recovery voltage	1.2V*S	3.2V*S	3.7V*S	6.0V*S
Charge cut-off Voltage	1.5V*S	3.7V*S	4.2V*S	6.9V*S
Enhance the charging voltage	System voltage < 6V , ->3.5V , > 6V , ->7.0V			
Do not set the voltage night	System voltage < 6V , ->1.5V , > 6V , ->3.0V			
Defense grade	IP30			
Size	53.4*68.6*22.0mm			
Install the line no.	AWG22 ~ 14/2mm²			
Weight	0.05kg			

Single section 1.2 V nimh battery 3 s ~ 24 s;Section 3.2 V single lithium iron phosphate battery 1 s ~ 7 s; Single section 3.7 V lithium battery 1 s ~ 7 s;Lead-acid battery 6 v / 12 v.

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Description

Specification:
Brand new
Material: Plastic
Color: As the Pictures shown
Size: As the Pictures shown
Quantity: 1 Pc
System Voltage: 6V, 12V
Output Current: 10A
Power Range: ≤60W(6V), ≤120W(12V)
Overload, Short Circuit Protection: Yes
No-load loss: ≤5mA
Charge Loop Drop: ≤0.2V
Disharge Loop Drop: ≤0.1V
Protection Degree: IP30
Working Temperature: -40℃~55℃
Install and Method of Using:
Firstly, determine the controller output mode , the device factory default setting is normally open mode .if you need to set for the pure light control mode or light control plus timing mode, you need to open the enclosure through set dip switch, changing the discharge mode
When the key set "on" is 1, the key set "off" is 0, normally open, pure light control
Connecting the battery first. if correctly connected, battery indicator will light
Connecting the wire of the solar panel second. if the connection is correct, the indicator light of “charge”will be on or flash 10 seconds later after laying outside under the sun. otherwise, please check the connection
Making sure the solar energy panel is laid outdoors under the sunshine
Connecting the load at the end. if inversely connected, the le
lamp may be damaged

Appendix F Datasheet Battery

S Series General Purpose Battery

S-650A (6V4.5AH) AGM Sealed Lead Acid

Specifications	
Nominal Voltage	6V
Nominal Capacity	4.5 AH/0.225A (20 hr. to 1.80V/cell @ 77°F/25°C) 4.2 AH/0.419A (10 hr. to 1.80V/cell @ 77°F/25°C) 4.1 AH/0.518A (8 hr. to 1.75V/cell @ 77°F/25°C)
Length **Width** **Total Height (with Terminal)**	2.76 in. (70±1mm) 1.85 in. (47±1mm) 4.17 in. (106±2mm)
Approx. Weight	Approx. 1.79 lb. (0.81 kg)
Tab Terminal	T1
Container Material	ABS
Max. Discharge Current	67.5A (5s)
Internal Resistance	Approx. 25mΩ
Operating Temp. Range	Discharge: 5° to 130°F (-15° to 55°C) Charge: 32° to 104°F (0° to 40°C) Storage: 5° to 104°F (-15° to 40°C)
Nominal Operating Temp.	77±5°F (25±3°C)
Cycle Use	Initial Charging Current less than 1.35A Voltage 7.2V to 7.5V at 77°F (25°C) Temp. Coefficient -15mV/°C
Stand by Use	Float Voltage: 6.75V at 77°F (25°C) Equalize Voltage: 7.05V at 77°F (25°C)
Capacity Affected by Temperature	104°F (40°C) 103% 77°F (25°C) 100% 32°F (0°C) 86%
Self Discharge	SBS S series batteries may be stored for up to 6 months at 77°F (25°C) and then a freshening charge is required. For higher temperatures the time interval will be shorter.

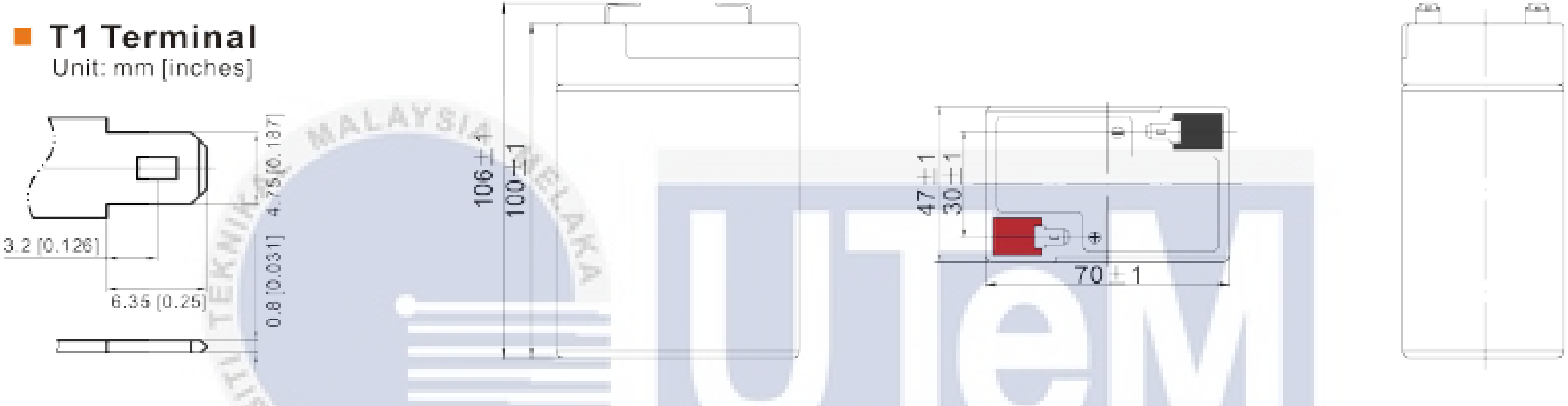
Constant Current Discharge (Amperes) at 77˚F (25˚C)															
F.V/Time	5 min	10 min	15 min	20 min	30 min	45 min	1 hr	2 hr	3 hr	4 hr	5 hr	6 hr	8 hr	10 hr	20 hr
1.85V/cell	8.64	6.02	4.97	4.31	3.46	2.66	2.17	1.33	1.01	0.831	0.706	0.611	0.483	0.404	0.223
1.80V/cell	10.6	7.19	5.76	4.87	3.83	2.90	2.34	1.41	1.06	0.874	0.736	0.638	0.504	0.419	0.225
1.75V/cell	12.6	8.13	6.35	5.31	4.09	3.08	2.46	1.47	1.10	0.901	0.756	0.654	0.518	0.427	0.227
1.70V/cell	14.3	8.96	6.88	5.70	4.29	3.20	2.57	1.53	1.14	0.924	0.775	0.670	0.525	0.434	0.231
1.65V/cell	15.7	9.64	7.27	5.98	4.47	3.32	2.67	1.58	1.17	0.943	0.792	0.683	0.534	0.440	0.234
1.60V/cell	16.5	10.0	7.58	6.17	4.60	3.40	2.73	1.63	1.19	0.966	0.808	0.696	0.545	0.447	0.236

Constant Power Discharge (Watts/cell) at 77˚F (25˚C)															
F.V/Time	5 min	10 min	15 min	20 min	30 min	45 min	1 hr	2 hr	3 hr	4 hr	5 hr	6 hr	8 hr	10 hr	20 hr
1.85V/cell	16.3	11.5	9.55	8.35	6.74	5.21	4.28	2.63	2.01	1.66	1.41	1.23	0.977	0.815	0.450
1.80V/cell	19.8	13.6	11.0	9.37	7.41	5.65	4.58	2.78	2.10	1.73	1.46	1.27	1.01	0.838	0.452
1.75V/cell	23.2	15.2	12.0	10.1	7.86	5.96	4.80	2.88	2.16	1.78	1.49	1.30	1.03	0.849	0.453
1.70V/cell	26.0	16.6	12.9	10.8	8.20	6.16	4.97	2.98	2.22	1.81	1.52	1.32	1.04	0.858	0.459
1.65V/cell	28.3	17.6	13.4	11.2	8.48	6.36	5.15	3.05	2.27	1.84	1.55	1.34	1.05	0.866	0.463
1.60V/cell	29.2	18.1	13.9	11.4	8.62	6.44	5.22	3.13	2.31	1.87	1.57	1.36	1.07	0.876	0.464

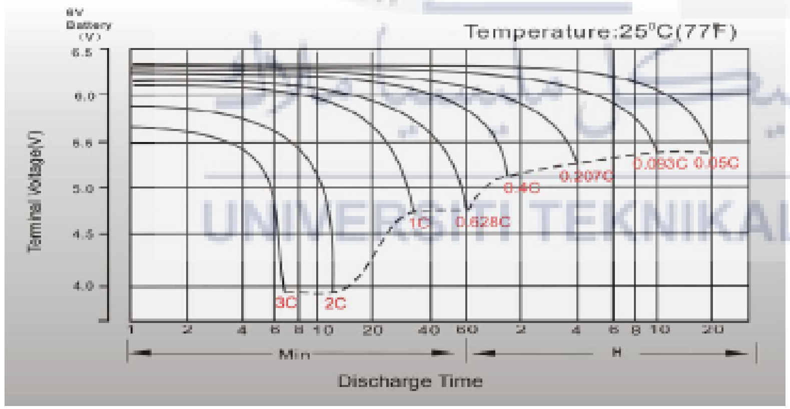
Dimensions

T1 Terminal

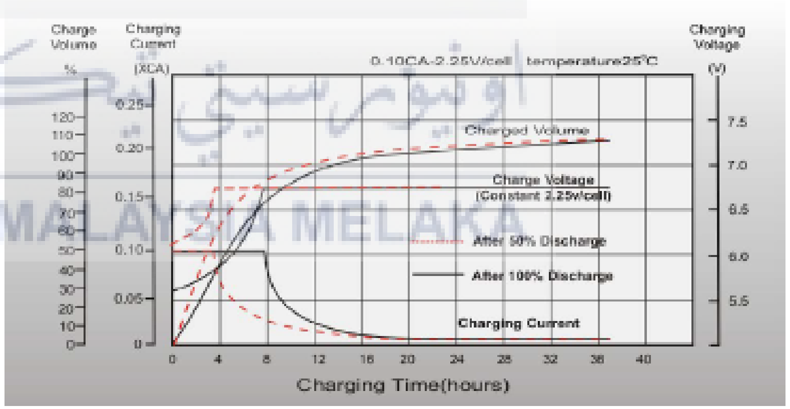
Unit: mm [inches]

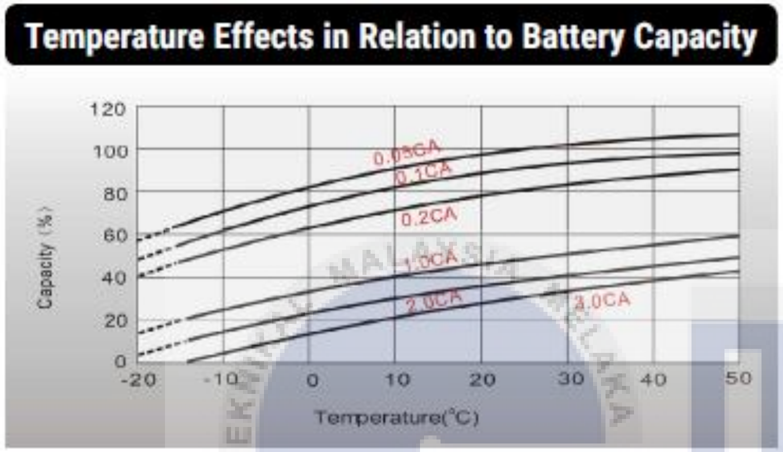


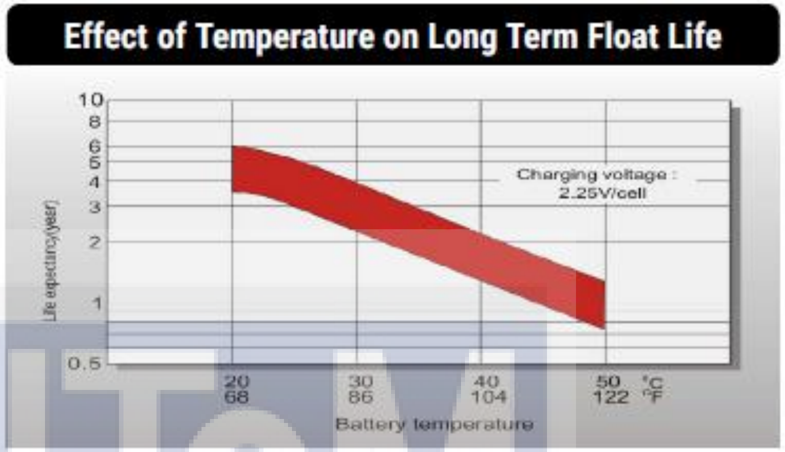
Discharge Characteristics

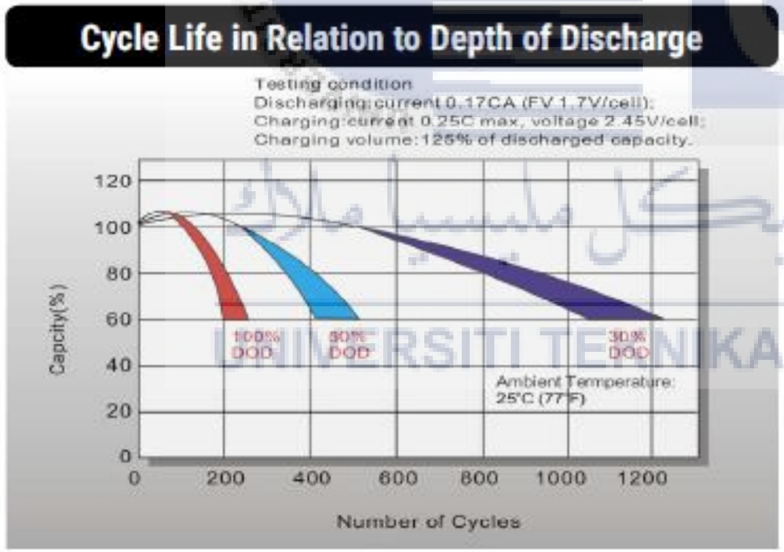


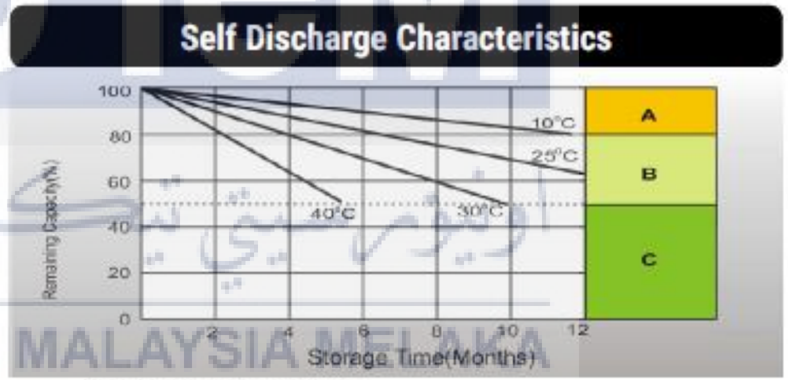
Float Charging Characteristics











A No supplementary charge required
(Carry out supplementary charge before use if 100% capacity is required.)

B Supplementary charge required before use. Optional charging way as below:
1.Charged for above 3 days at limted current 0.25CA and constant volatge 2.25V/cell.
2.Charged for above 20hours at limted current 0.25CA and constant volatge 2.45V/cell.
3.Charged for 8~10hours at limted current 0.05CA

C Supplementary charge may often fail to recover the capacity.
The battery should never be left standing till this is reached.

Appendix G Datasheet Motor

TECHNICAL DETAILS

- Rated Voltage: 3~6V
- Continuous No-Load Current: 150mA +/- 10%
- Min. Operating Speed (3V): 90+/- 10% RPM
- Min. Operating Speed (6V): 200+/- 10% RPM
- Torque: 0.15Nm ~0.60Nm
- Stall Torque (6V): 0.8kg.cm
- Gear Ratio: 1:48
- Body Dimensions: 70 x 22 x 18mm
- Wires Length: 200mm & 28 AWG
- Weight: 30.6g

Product Weight: 30.6g / 1.1oz