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Design and Development of Remotely Operated Small-Scale Waterways Cleaning Robot

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Abstract

Water pollution has become a pressing global concern, as water bodies continue to be contaminated with various forms of debris such as plastics, trash, and other solid waste. This project aimed to design and development a small-scale waterways cleaning robots that could collect floating debris on the waterways. The design works including proposing suitable structure, navigation, garbage collecting mechanism, and locomotion of the robot. This project utilized PS2 wireless controller, to control the robot's movements. Conduct a test to evaluate the buoyancy and debris collection performance of the waterways cleaning robot, ensuring it can effectively navigate and remove floating debris from the water's surface. The results show that the robot can float and move with stable. Analysis on debris collection shows that plastic, bottle cap and dry leaves can be collected. In conclusion, the design and development of this remotely operated waterways cleaning robot have successfully achieved its objectives, providing a promising solution for maintaining clean waterways.

1. Introduction

Waterways, such as rivers, lakes, and canals, are vital for transportation, recreation, and supporting aquatic ecosystems [1]. However, these water bodies are highly susceptible to pollution from various sources, including industrial waste, agricultural runoff, and human activities. Water pollution is a pressing global issue that affects the health and well-being of both humans and ecosystems [2]. In Malaysia, rivers play a crucial role in the country's water supply, transportation, and recreational activities [3]. Importunely, many of these waterways are heavily polluted, particularly with plastic waste. According to a study conducted by the Institute of Ocean and Earth Sciences, University of Malaya, the Klang River in Malaysia alone collects an estimated 15,000 tons of plastic waste annually [4]. Plastic pollution in waterways poses a significant threat to aquatic life. Ingestion and entanglement in plastic waste can lead to injury, suffocation, and starvation in marine animals [5]. Additionally, microplastics can be mistaken for food by smaller organisms, leading to the accumulation of toxins in the food chain [6]. This can have far-reaching consequences for the entire ecosystem and ultimately impact human health through the consumption of contaminated seafood [7].

The specific aim of this research is to design and development of a remotely operated small-scale waterways cleaning robot that can efficiently remove waste and debris from rivers and other water bodies. By designing and testing a prototype of such a robot, the research aims to contribute to the ongoing efforts to clean and revitalize waterways, particularly in Malaysia, and support the achievement of the United Nations Sustainable Development Goals related to clean water and aquatic ecosystems. The development of this technology can also promote innovation and sustainable practices in the field of water resource management.

2. Methodology

This part including designing the robot's structure, including mechanical and electrical parts, fabricating the prototype, and testing its functionality in various waterway conditions.

2.1 Design Structure

The design process flowchart as displays in Fig. 1 outlines the steps of a project. The project begins with defining its purpose, scope, and objectives, followed by thorough research, information gathering, and detailed planning, including resource allocation, timelines, and risk assessment. Next, generates creative concepts, selects suitable materials, and evaluates the proposed design through testing and analysis. If the test analysis is okay, the final design is selected, and the actual construction or development takes place. This could involve manufacturing or assembling components. The completed product undergoes testing, if any issues arise, it loops back to fabrication for adjustments and if not, comprehensive documentation is created. This includes user manuals, technical specifications, and project reports and the final product is implemented.

The process begins with collecting waste, which could involve trash collection, The collected waste then undergoes a cleaning mechanism. If the cleaning is successful which it can collect the waste, the system proceeds to a series of tests evaluating its movement capabilities, including forward movement, port (left side), and starboard (right side) tests. If all tests are successful, the collected waste is properly disposed of, such as through recycling or landfill. The process then ends as seen in Fig. 2.

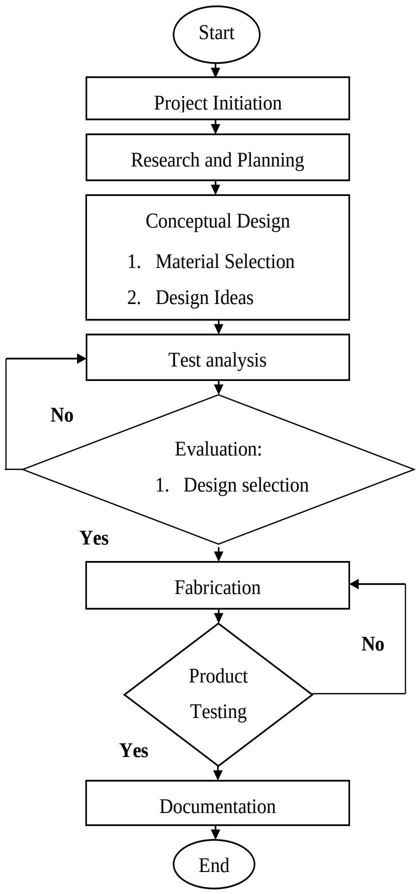


Fig. 1 – *Design Process Flowchart*

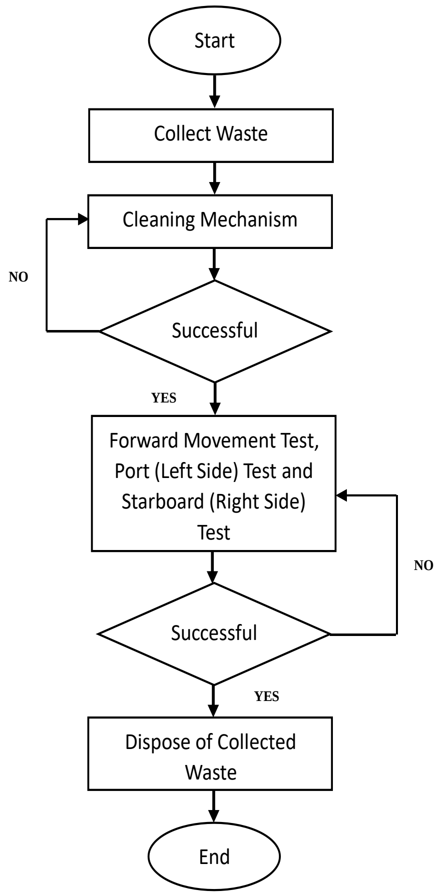


Fig. 2 – *Design Concept Flowchart*

2.2 System Design

The schematic diagram in Fig. 3 and Fig. 4 begins with a PS2 Controller, which the commands are sent wirelessly to the Bluetooth which then passes them to the microcontroller board, PSC28A board. This board uses these commands to control various components of the robot, such as the Conveyor Motor and Propeller. All these components are, - powered by a LiPo Battery. Lastly, the controller then be connected to the PSC28A board.

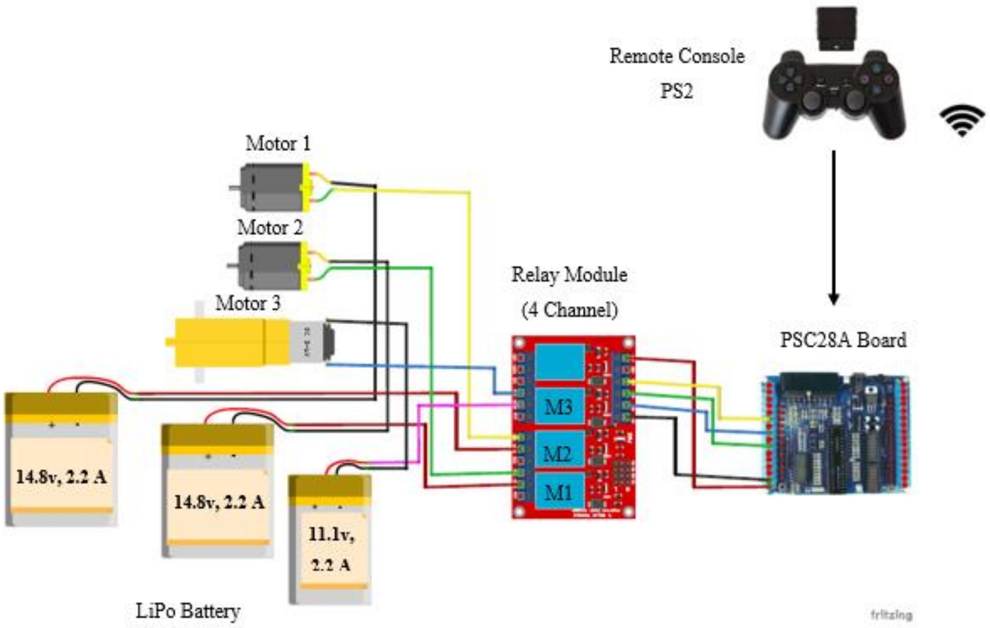


Fig. 3 – *Schematic diagram of Waterways Cleaning Robot*

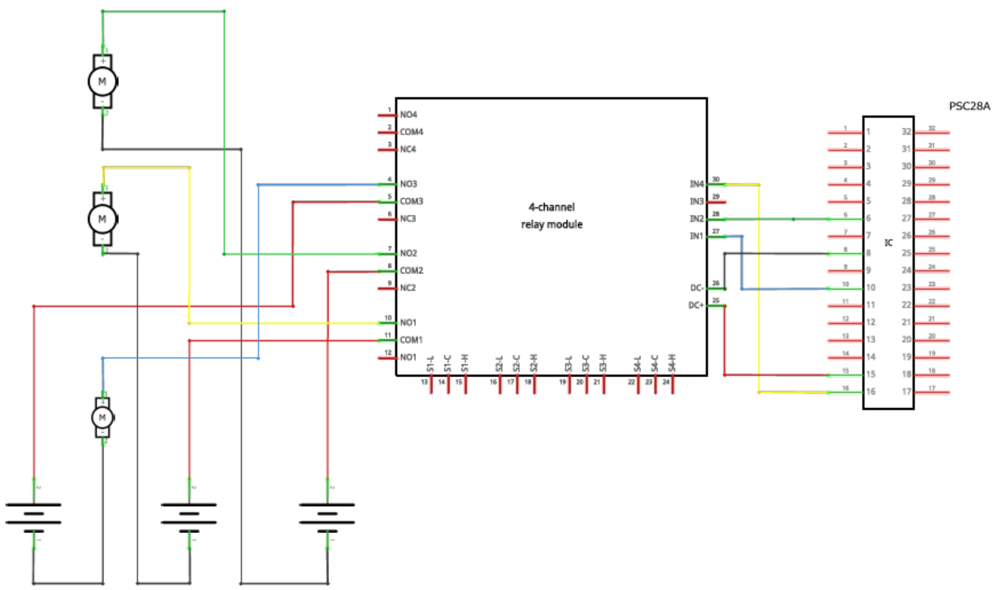
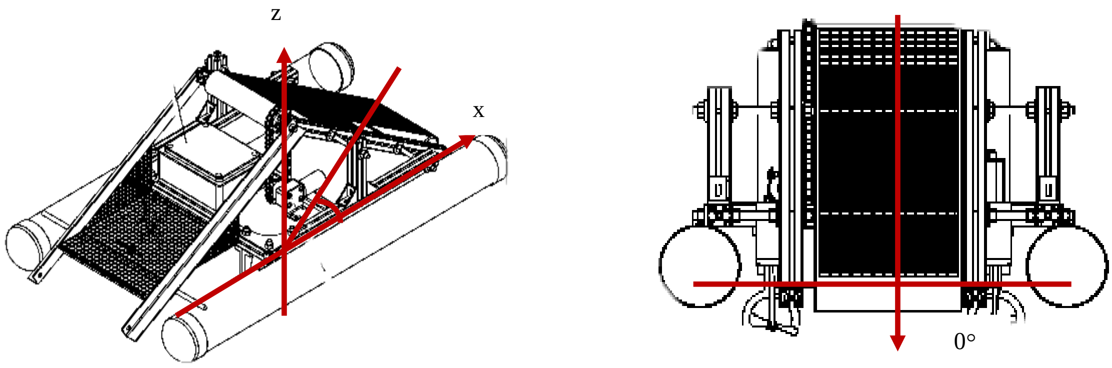


Fig. 4 – *Circuit diagram of Waterways Cleaning Robot*

2.3 System Testing

Functional testing for the robots is to ensure that the essential functions required for effective operation and cleaning performance are working as intended and to confirm that the robot can navigate waterways, collect debris and perform cleaning tasks remotely. Angle of tilt, this test wants to observe stability of the robot during static and movement, as seen in Fig. 5 (a). Furthermore, the navigation test is to evaluate the robot's ability to navigate through waterway conditions, such as calm waters as displays in Fig. 5 (b). The testing is to evaluate the effectiveness of the debris collection system, which utilized a conveyor belt mechanism to efficiently transport the accumulated refuse for proper disposal and recycling as shown in Fig. 6.



(a) (b)

Fig. 5 – *Diagram of (a) Angle of Tilt; (b) Direction Angle*

Fig. 6 – *Testing of collecting debris by using conveyor belt mechanism*

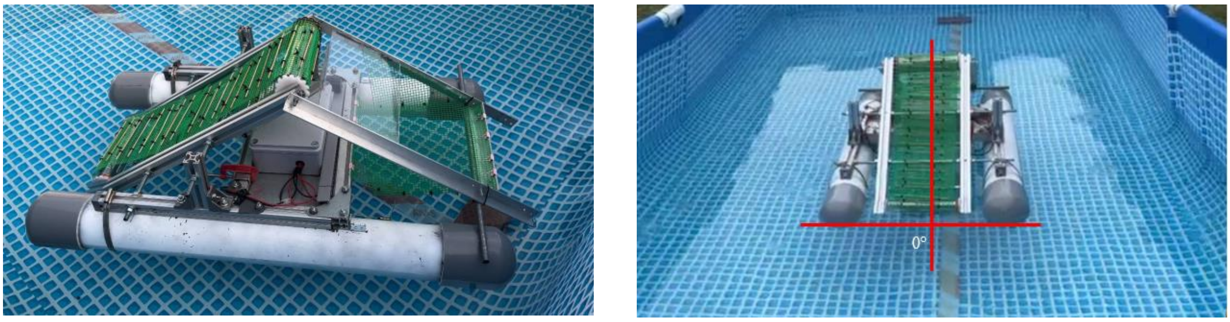
3. Results and Discussion

This part discussed the outcome of the project where analysis and experiments were conducted in order to test the functionality and performance of the waterways cleaning robot and the result.

3.1 Testing of Robot Buoyancy and Robot's Ability to Move in Straight Line

The robot's buoyancy test was conducted to ensure that the robot can operate effectively on water. The test involved placing the robot in a pool of water and measuring its buoyancy. The results show that the robot can maintain a stable position on the water, as seen in Fig. 7 (a) that its buoyancy is sufficient for it to operate effectively. Buoyancy testing is an important step in the development of a waterway cleaning robot. It ensures that the robot can withstand the water pressure and maintain its position, allowing it to perform its intended task. Successfully completing the buoyancy test is a milestone in the robot's development, and it paves the way for further testing and refinement.

As seen in Fig. 7 (b), when a waterways cleaning robot has a tilt angle of zero, it means the robot is perfectly level and not tilting to the left or right. During static time, when the robot is stationary and not moving, a tilt angle indicates the robot is balanced and level on the surface of the water. Similarly, during motion time, a tilt angle suggests the robot is maintaining a stable, horizontal position as it travels across the water, indicating that the robot's design and control system are able to keep it level even while in motion.



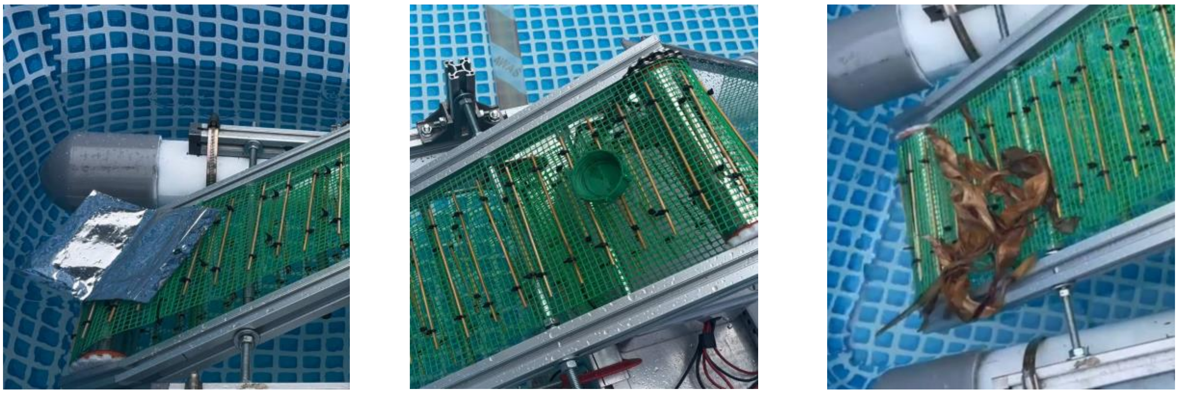
(a) **(b)**

Fig. 7 – *Testing (a) The Buoyancy of a Robot; (b) and The Robot's Ability to Move in Straight Line*

3.2 Testing On Conveyor

Based on Table 1, when different types of debris were tested on the simple conveyor belt, it was observed that some items could be collected while others could not. For example, plastic items such as plastic bags, cap bottle and dry leaves could be collected because they were lightweight and could pass through the net on the conveyor belt as shown in Fig. 8. This was because the net was designed to catch small and lightweight objects, such as plastic debris.

Metal cans like soda or food cans were too heavy to be collected by the conveyor belt, as the net was not strong enough to hold their weight. Similarly, paper items like newspapers or cardboard boxes were too light to be caught by the net, but too large to pass through it, causing them to fall off the conveyor belt.



(a) **(b)** **(c)**

Fig. 8 - *Debris that could be collected (a) Plastic; (b) Bottle Cap; (c) Dry Leaves*

Table 1 – *Testing Data of Waste Collected by the conveyor*

Type of Waste Collected	Can	No
Plastics	✓	
Can		×
Paper		×
Bottle Cap	✓	
Dry Leaves	✓	
Box		×

4. Conclusion

In conclusion, the design and development of a remotely operated waterways cleaning robot have successfully achieved its objectives. It is a promising solution to help keep the rivers, lakes, and oceans free of floating debris and trash. By using a semi-autonomous system controlled by a PS2 controller, the robot can efficiently navigate waterways and collect floating garbage using a motorized propeller system. The robot's ability to operate remotely allows it to access areas that may be difficult for humans to reach, making it an effective tool for cleaning up waterways in a safe and efficient manner.

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