

Design and Analysis of Rescue Operations Bot in All Terrains

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ABSTRACT: Natural calamities are on a rise with each passing year. Disasters like floods and fire take many lives all around the world, especially in remote areas or less developed countries. One such incident was the Kerala Floods in India where rescue services had difficulty reaching to all the people on time since a huge landmass (more than 9 districts) was flooded and hence villagers or other people risked their lives to save others in danger without proper safety equipment. Amazon Rainforest Fires was another example for a major destruction of an ecosystem. The main reason for lack of facilities in such remote parts is, it's difficult for governments of developing nations to provide expensive rescue equipment across all regions. There is a need for less expensive and proper rescue modes which could be useful in multiple natural calamities. This topic of this thesis was inspired from many recent natural calamities that have taken place all over the world.

An effort has been made through this project to develop a Wireless Unmanned Rescue Vehicle named ROBOAT especially for rescue missions in Water. This vehicle is also aimed to be used for various rescue Inspection purposes on land in all terrains. The development stages of this prototype include many features already and a huge scope for adding more in the future.

KEYWORDS: Text detection, In painting, Morphological operations, Connected component labelling.

I. INTRODUCTION

The main objective of this thesis was defined after observing the number of increased natural calamities all around the world. This includes some recent incidents like the Amazon rainforest, Kerala floods India, Australia wildfire, Bahamas' Hurricane etc.

Weather conditions are significantly changing with passing decades and hence resulting in more powerful natural calamities. The 2019 Kerala Floods in India had more than 9 districts affected, and more than 100 people lost their lives. In 2018 the same region was affected causing more than 470 people to lose their lives [1]. The Amazon Rainforest fires in 2019 had a huge impact on the forest ecosystem and its habitats. Also, several hurricanes in the recent past have caused a lot of destruction in various areas.

Though governments always put their best in overcoming such situations, there is always a need for more manpower and good equipment resources for rescue operations over widespread areas. The governments of developing nations strive hard to provide these resources but are restricted to the buy the quantity that can fulfil the requirements of all its regions due to the availability and high cost of these equipment. This became a motivation towards the aim of this project to build a less expensive and effective machine which could be used for inspection and rescue operations in water and inspection operations on land.

This report outlines the research and development work which has been performed stage wise on the different mechanisms involved. It includes the detail description of the hardware and software development with the parts and necessary drive selection. The design methodology is elaborated with a brief elaboration of all the components used.

Hence the focus of this project is to design an unmanned Robot which could be operated wirelessly for rescue operations on both land and water as per the demand of the situation. The Robot could be well equipped with necessary aid which could be provided before the rescue teams reach the people in need after locating them successfully. An attempt to make a fully functional prototype of the ROBOAT will be made in order to test its capabilities.

1.2 Purpose and Capabilities of ROBOAT

These rescue operations that take place after natural calamities have certain limitations in some developing countries. They require a lot of human intervention for conducting rescue, many people need to be present and at such times it becomes difficult for so many forces to reach on time. The main purpose of the rescue teams is to use low risk methods to rescue the victims. At such times, some easy methods like communication with the victim, reaching him on time and temporary relocation to a safe place being some of the low-risk methods is important which will be attempted by the help of this prototype [2]. The main aim of this thesis was to develop a light weighted, automated vehicle that could travel in the water by using remote control to save the life of the people stuck in water. It would be designed in such a way that it could travel on land as well as water. It would have camera mounted on top which would help in navigation and searching for victims, it would also have an audio video module using which communication could take place between the victims and the people on land [3]. It would have a rigid and aero foil structure that would bear the force of rough waters and could also be able to cut through them. The structure would be such that it could be easily dismantled if required in any conditions. The material used for the construction of the vehicle would be of plastic, due to which there would be no scope of rust on it. This vehicle has been intended to detect the location of the people stuck at various locations in floods, with the help of its powerful jet propulsion drive unit as its drive system. An audio video module is to be installed on ROBOAT which will help in wireless communication with people in danger to instruct them about basic instructions of safety till human help arrives. In such scenarios it can also carry first aid kits or food if needed at priority basis.

The powerful drive unit of ROBOAT can drag another independent unit like a rescue tube or buoy. When drowning or if a person is in danger, every second counts hence, this feature could be brought into use to help the rescue teams on beaches, where ROBOAT could reach the subject at faster speeds and helping the subject to hold on to the rescue buoy till human help arrives. (For future development of the ROBOAT this feature is intended to be made autonomous in next versions of this prototype)

It has a capability to navigate in dangerous or compact zones at slow speeds when it is on inspection operations where it is difficult for humans to reach. Also attempts will be made to make this robot compatible with carrying a human and bringing him safely to land in case there arises a situation to do so. After experiments this section will be concluded with the specific results obtained.

Similar Previous Works

There have been previous attempts to make water rescue robots in the past. One of the recent examples being the robot named EMILY. EMILY, an acronym for Emergency Integrated Lifesaving Lanyard is a rescue robot designed to save the swimmers stuck in water [4]. It is remote control operated and works on battery, once dropped in the water from the shore, boat or helicopter. It uses an impeller propeller to travel through water due to which it reaches victims in less time as compared to the time taken by a lifeguard swimming in water to rescue. It is compact, is less expensive to maintain compared to a manned boat. It has a maximum speed of 48km/hr, weighs 11 kg, is 1.4m long and 38cm wide. It can travel 10 km on a single battery charge and is buoyant enough to save 5 people at a single time. Its body is made up of a high strength Kevlar material, which helps it to navigate in sturdiest conditions.

II. LITERATURE SURVEY

- Robin R. Murphy (2004) – “Trial by Fire: Activities of the Rescue Robots at the World Trade Center from 11–21 September 2001”

This study highlighted the real-world application of rescue robots during disaster scenarios. It demonstrated how robots can assist in navigating hazardous environments and locating victims, while also identifying challenges such as limited mobility and communication constraints.

- Alonzo Kelly et al. (2006) – “Toward Reliable Off-Road Autonomous Vehicles Operating in Challenging Environments”

This research focused on improving robot mobility in rough terrains using advanced navigation systems. It emphasized the importance of terrain adaptability and robust control mechanisms for rescue operations.

- Howie Choset (2005) – “Snake Robots for Search and Rescue”

The study introduced snake-like robots capable of maneuvering through narrow and confined spaces, making them suitable for operations in collapsed structures and debris-filled environments.

- Siegwart Roland & Illah Nourbakhsh (2011) – “Introduction to Autonomous Mobile Robots”
This work provided a comprehensive overview of autonomous navigation techniques, including SLAM, obstacle avoidance, and path planning, which are essential for modern rescue robots.
- Sebastian Thrun (2005) – “Probabilistic Robotics”
This research introduced probabilistic approaches for localization and mapping, significantly improving the ability of robots to operate in uncertain and dynamic environments.

III. METHODOLOGY

Drive Motor and Control Unit

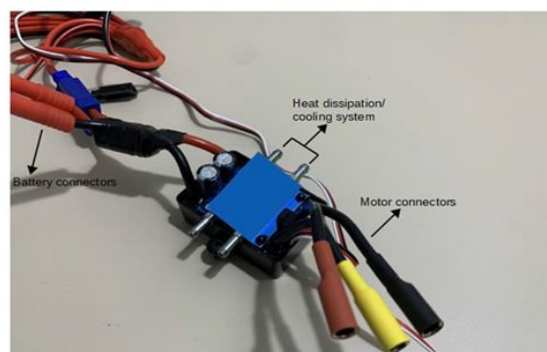
Water jet drive propulsion system uses a propeller, which rotates at very high speeds to create thrust, that helps propel the boat forward at high speeds. For this requirement there was a need for a motor that could deliver very high rotational speeds. Brushed DC motors due to their brushes have a limitation of rotational speed. Therefore, brushless motors were the first choice for this application. A 3180 KV brushless DC motor with 4 poles was selected for this purpose.



Brushless DC Motor, 3180 KV.

The selection of this motor is based on certain specifications such as the size of the boat hull used and the number of LiPo cells used in the battery. Motor size diameter 36mm and length 50-75mm is suitable for boat hulls ranging from 55cm to 86cm. Also for a LiPo battery having 4 cells, a BLDC motor with a KV range of 1350-2365Kv is suitable [9]. The dimension of the prototype boat hull being 55.9cm in length and 28cm wide, the BLDC motor used for this prototype fits perfectly for this application also because it perfectly fits the motor dimensions which is 36mm in Diameter and 60mm in

Length, and it could also be run in the range 1350-2365Kv which is below its maximum 3180Kv. As the 3180 KV Brushless DC motor operates at very high speeds it requires a separate controller for proper functioning. A separate Electronic Speed Control Unit was used which would communicate with the microcontroller based on the user data and control the brushless motor based on the data received.



Electronic Speed Control Unit for Brushless DC Motor.

Boat Flipping Mechanism

For flipping to be possible an object or device that could counteract the weight of the boat would be needed. Inspiration was taken from pontoon tubes, floats that would be able to provide buoyant force sufficient enough to rotate the boat around a pivot point in line with its centre of gravity of the boat [11]. Hence two cylinders could be tested upon in various situations with normal air pressure inside them as well as what would happen if compressed air is filled inside them.

Hence two cylinders could be able to flip the boat, but to implement this there was a need for a mechanism. The legs that are used for the ROBOAT for locomotion on the ground were used for the flipping mechanism as well. This was possible by mounting the two cylinders on the legs of the ROBOAT. Conceptually these cylinders could also assist the boat to maintain stability in rough waters and help for flipping.

In implementing this there was a challenge since for suspension a hinge was used at one of the joints where the legs connect to the boat hull which is explained in detail in chapter 5. This hinge was helping the ROBOAT maintain four-point contact when on ground and in rough terrains. Now to obtain a rapid motion during the flipping mechanism this hinge needed to be disabled so that the shaft of the hinge would cause the leg to rotate. For this purpose, a modified clutch mechanism was used to engage the shaft of the hinge to a motor when in water. Basically, the use of DC motors was considered for this purpose, but the mounting of the mechanism was getting too bulky as shown in the Solid works model in Fig.3.3. This mechanism would also assist in the stability of the boat which needed very slight adjustments helping the floats to be on the surface of water which in turn help the boat to float. Such slight adjustments were possible with a DC motor with the help of encoders, but this would have made the mechanism even bulkier to be mounted outside the boat, also this would increase the weight of the boat overall. Later the use of servo motors was considered since these have a very good precision when it comes to control. Also due to their Gearbox the stall torque achieved is also higher as compared to DC motors which would provide more stability.

**3D printed parts****3D Scanning**

IV. EXPERIMENTAL RESULTS

Jet Drive Propulsion Test

The first stage of testing was conducted for its operation in water after the completion of the prototype. This was to test the capability of ROBOAT to drag an object like a rescue float in water in given time. The jet drive system provides a very high speed for the boat in water, to reach any person in need for rescue, dragging a weight/ payload of 5lbs without affecting the performance. As the weight of the payload goes on increasing it causes a reduction in speed of the boat. Maximum weight that can be dragged in water by the boat is 11lbs for safe operations.



Operation of Jet Drive

Locomotion Test

Second stage of testing conducted included the speed tests of ROBOAT in different terrains like flat ground, sand/ beach, inclined surfaces, and off terrain when operating with the Locomotion system. An inclination test has also been done after the prototype was complete to check the ability of this bot to climb a specific slope if needed in operations for inspection. The highest angle of inclination it could climb with the existing DC motors is 30 degrees

Leg Mechanism Test

The boat flipping Mechanism was tested for the 270-degree angle if it could reach with the help of the 35Kgcm servo, when having all the locomotion mechanism mounted. During the experimental test results the servo was hardly able to lift up the leg assembly as opposed to the theoretical calculations in Section 3.1. Since experimental results did not satisfy this condition and hence a servo of 60Kgcm torque was experimented with of which satisfactory results were obtained from the 60Kgcm torque servo after considering losses and full load conditions. The flipping mechanism could not be implemented because of the weight of the boat being higher as opposed to the proportion of the surface area in contact with the water. If the surface area of the boat is to be increased in later prototypes it will help the flipping mechanism a lot. Also, if the boat is to be flipped in water, a float having more buoyant force should be mounted on the legs of the boat to help the boat flip, which is possible only in lightweight or similar rescue boats like these.



Test for Flipping Mechanism

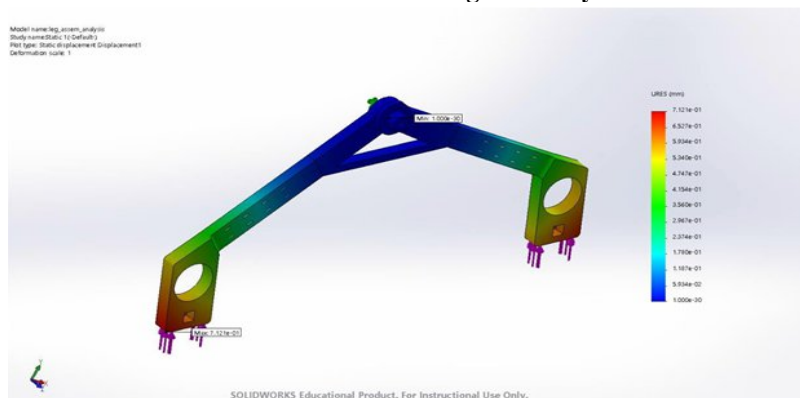
Structural Analysis

The Leg Assembly is the main and the largest structural part in this assembly which is mounted on the boat hull and has the Locomotion assemblies mounted on it. During operation of ROBOAT on land when the Locomotion would be in operation, the Leg assembly would be subjected to maximum stresses and deformation if any. This analysis has been done in Solidworks which has been shown in the Figures below.

As seen in above Figure the intersection where the leg extension meets the bridge support would be subjected to maximum stress of 1.213Mpa which is far within the safety limits of PETG, the material that this part is made.



Stress Results for Leg Assembly



Deformation Results for Leg Assembly

V. CONCLUSION

The Prototype designed and manufactured during this Thesis has given good experimental results for the base frame the ROBOAT. The water jet turbine system has shown such good experimental results that it went up to very high speeds up to 45km/hr when operational in water. When operating at high speeds when the BLDC is operating above 2000rpm in water the steering mechanism does not respond that well because of the water jet running out from the behind of the boat. This can definitely be enhanced by putting a stronger material for the part where the nozzle is hinged to the jet drive. When on land operations the suspension on the model is working perfectly, no matter what the terrain is. Except for in sand the wheels get trapped sometimes and the Roboat would need assistance time and again. To overcome this the wheels can be changed to a different size in later prototypes also the DC motor can be replaced with a motor of higher torque for better traction and if the wheel size increases would also benefit the traction in difficult terrains. It is easily overcoming small obstacles with the size of the wheels mounted.

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