Conceptual design of locomotion mechanism of an amphibial robot

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Abstract - *This paper focuses on the locomotion aspect of remotely controlled semi-autonomous amphibious robot with a primary aim of surveillance in aquatic and terrestrial environments. The proposed system can be used for unmanned marine monitoring applications. The direction of motion can be controlled by a wireless module. This paper discusses the locomotion mechanism of the robot in both water and land. A separate mechanism is also discussed which explains how the system will move around at different depths underwater. For terrestrial locomotion chassis is used which is controlled wirelessly by the user. The emphasis is on the stability of the system in underwater conditions.*

***Key Words*: amphibial, surveillance, aquatic, terrestrial, chassis, wheels, propeller**

1. INTRODUCTION

Robotics is one of the most rapidly advancing domains in technology. The significance of unmanned exploration and surveillance cannot be undermined in the near future. Autonomous robotic systems are rapidly and effectively reducing the human element in surveillance programs. A robot is an automated mechanical device. It can be developed and programmed to function in hostile environments. Various kinds of robots have been developed along with the advancements in computer and information processing technology. There is a great need for these robots in unfavorable environments especially underwater.[6] Application of underwater robots and vehicles has increased dramatically in recent times. Though most of the underwater robots and vehicles are developed for scientific underwater explorations, there also commercial and military applications. For instance submarine investigations are performed with the help of these, the Gas and Oil industry uses underwater robots for laying pipelines etc.[12]

To perform any sort of underwater robotic research, an appropriate platform is necessary. First of all it must be watertight. Even a single unit of water can stop the whole system from operating.[7] So it must be shielded completely to prevent the entry of water. Next the weight of the platform is important. If it is too heavy, the platform will sink, and if it is too light it will be hard to sink. Therefore design of the device must be effectively water resistant. Hence design of the outer chassis must be made meticulously. In this design the emphasis is on the stability of design. [1]

1.1 Need for Amphibial Surveillance robots

The needs for monitoring and surveillance have increased enormously in the near past, motivated by the wide range of application scenarios that can be realized practically and by the level of maturity achieved by the main enabling technologies. Underwater ROVs, or Remotely Operated Vehicles, have become a significant underwater technology.[9] These aquatic unmanned vehicles are widely used by the oil and gas industry, researchers, enthusiasts and the military and. ROVs enormously enhance the competence of organizations for exploration and maintenance of underwater environments and resources. They are looked upon as cost-effective solutions and a safer option than sending in people to work at depth. They are majorly utilized for myriad underwater surveillance operations. There is no surprise that ROVs operate in some of the harshest environments conceivable. UGVs or Unmanned Ground Vehicles are similar to what underwater ROVs can do; the only difference is that they operate exclusively in the terrestrial domain. UGVs are widely used for military purposes, space rovers and such applications in the similar vein.[10]

The idea of an amphibious robot is simply the amalgamation of the features of both Underwater ROVs and Terrestrial Unmanned Robotic vehicles. [15] This results in a robust design that can operate in various situations and environments. This provides a perfect solution for the surveillance operations which are difficult to undertake manually. However we need a design that stays untarnished in both land and water domains.

1.2 Challenges faced

Most underwater robots have now achieved remarkable amount of flexibility in their motion with superior navigation, imaging, and sensing that enables them to provide a superior performance. Still major problems exist which limit their capabilities. Some of the significant problems faced in underwater navigation and locomotion are as follows:

1.2.1 Communication-

Underwater communication systems involve the transmission of information in the form of sound or electromagnetic waves. Sound waves operating in shallow water can be severely affected by surface ambient noise and temperature gradients. EM waves do not work flawlessly in an aquatic environment, specifically due to the conducting nature of the medium, especially in the case of seawater.

1.2.2 Positioning-

Aquatic navigation has always faced the challenge of obtaining precise positioning, and this is especially true in underwater environments. On land the geo-referenced positioning is facilitated by the use of GPS.

In Underwater environments, GPS fails to provide location which affects the positioning of the device.

1.2.3. Unpredictable disturbances-

Disturbances caused due to weather changes, winds, waves, and ocean currents have a drastic impact on underwater robot locomotion and stability. Such environmental disturbances play a vital role in determining the degree of autonomous behavior in underwater robots. The odds of facing a totally new problem in the underwater environment are extremely high.

2. PROPOSED METHODOLOGY

In this project we are interested in the amphibious nature of the robot. Certain additional attributes are included in this overall project. However the locomotion mechanism is the backbone of the entire model. So there arises a need to formulate a proper method to navigate the model in both land and water domains. Simple and practical solutions are proposed in the following sections. These formulated solutions can be implemented albeit in an advanced manner for the high power, heavy duty systems. This model being just at the prototype stage is unable to solve all the issues faced at the advanced levels. Hence only the basic underlying issues are considered.

To simplify the understanding let us look at the underwater and terrestrial locomotive mechanisms separately. In the underwater system we need to navigate the object in two dimensional axes. In other words the model can move up and down in one axis, and in the other axis it can move forward, backward, left or right. This is the most basic concept which is required before we see that how we actually realize this model. Being in the aquatic domain, we need such system which will push the water backwards so that the device moves forward in the required direction. Thus we need something to constantly push the water backwards to ensure that the model moves forward and we get uniform motion. To go down, the model designed must be heavy and bulky enough so that it goes down in water as per our requirements. To bring the model upwards we need to push the water down such the resulting force will propel the model up. For lateral and forward backward movement an identical method is used.

For the terrestrial locomotion, we need wheels or legged locomotion, whichever is feasible as per our requirements. The legged locomotion follows a different mechanism altogether, which is not discussed in this paper. The wheels are the simplest option for land movement. The motion of the wheels can be controlled by connecting them to a motor, which will provide the revolutions to move the device forward.[4] Now for both the cases the common aspect is application of the force to move the device ahead. The energy required for performing such actions can be provided as per the requirement and the application of the specified device.

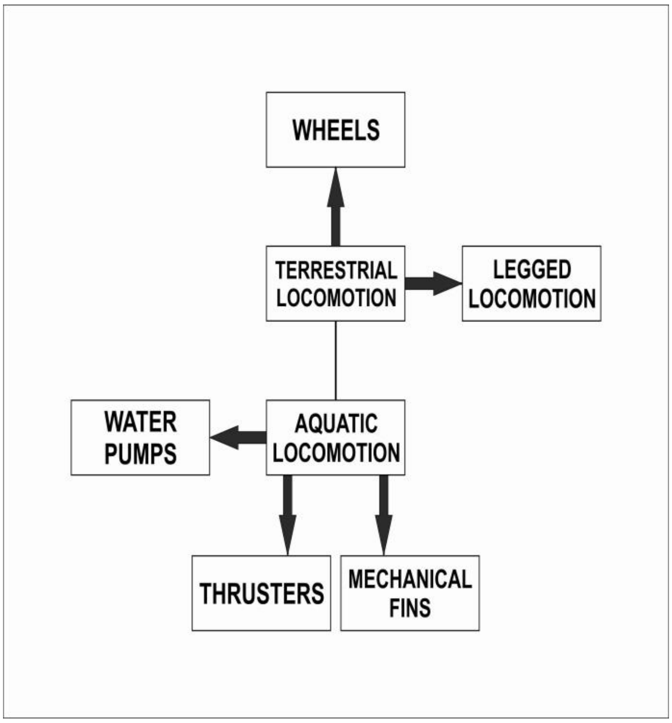


Fig-1: Diagrammatic representation of the proposed methodology

2.1 Terrestrial locomotion

The most popular locomotion mechanism in vehicles is wheeled locomotion; so it is not surprising that it is consistently used in robotics.[11] Reason for this is the simple mechanical implementation of the wheel and there is no need for balance control if the vehicle has at least three or in some case two wheels. Wheeled locomotion is significantly power efficient, even at high operating speeds.[8]

However there are various factors that affect the wheel locomotion. The starting point of considering wheeled locomotion is the wheel itself. There are four major types of wheels used for locomotion. They are as follows

i) Standard wheel – It has two degrees of freedom, these are rotation around the wheel axle and around the contact

ii) Castor wheel – It has two degrees of freedom, rotation around the wheel axle and the offset steering joint.

iii) Omni wheel – It has three degrees of freedom: rotation around the contact point, around the wheel axle and around the rollers.

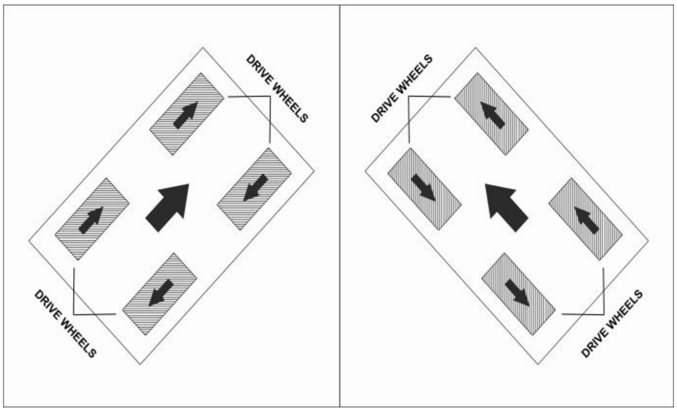
iv) Spherical wheel - This wheel is omnidirectional [2]

The main advantages of the standard wheel are easy implementation, high load capacity and high tolerance to irregularities. But these wheels are not inherently omnidirectional, therefore to make a vehicle using these wheels steerable; the steerable wheel(s) must be steered first along a vertical axis and then moved around a horizontal axis.[16] Specifically in case of heavy vehicles and when it is not moving during steering, this steering method causes high friction and abrasion during steering as the wheel is actively twisted around its vertical axis, this increments the power consumption and reduces the positioning accuracy of the vehicle. [14]

In this model we have used standard wheels as they are easy. We have four wheels attached to the chassis which can be used for changing the direction of the device.

In the figure 2.1.1 the smaller arrows indicate the direction change of the wheels while the big arrow indicates the direction change of the entire device.

Maneuverability of the device can be controlled accordingly using the technique shown in Fig 2. To move right the upper two wheels must be moved in the upper right direction keeping the lower two wheels' direction forward. Doing this same procedure for the leftward movement we can move the device to the left. To make a reverse turn we need to move either two of the left or the two right wheels in their respective directions. By continuing to turn the wheels in that direction the device can make a reverse turn. In this manner we can use the wheels for terrestrial locomotion. It must be noted that here only standard wheels are considered for the proposed design.[3] A complete design for the terrestrial and aquatic locomotion will be discussed in a different section.



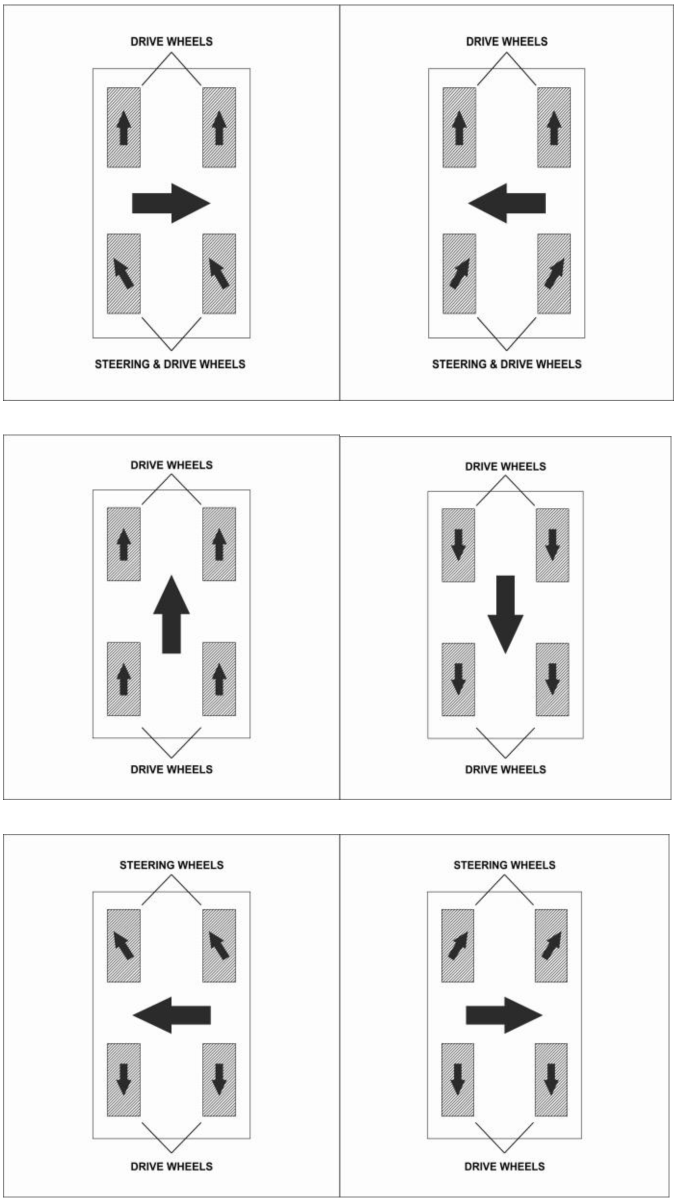


Fig- 2: Terrestrial locomotion by maneuvering the wheels

$$P = \tau \omega$$

Fig -3: Relation between Torque and power

An engine produces power by providing a rotating shaft which can exert a given amount of torque on a load at a given RPM. The amount of torque the engine can exert usually varies with RPM. Here P stands for power, τ stands for torque and ω stands for angular velocity. We can infer that, greater the torque, greater is the power of the system.

2.2 Aquatic Locomotion

Locomotion in the underwater domain is always a challenging prospect for an amphibial robot. The pushing mechanism is utilized to push the water and to thrust the device forward.[13] Ducted fans are used to push the water in this case. Alternatively a DC pump can also be utilized to thrust the device forward.[5] This model is driven through water using a propulsion mechanism that thrusts by moving water at a certain velocity. Propulsion is one of the main sources of power consumption. Therefore, selecting the convenient mechanism depends on factors such as the size, cost, power consumption and produced thrust.[10] Propellers and jets are some of the options for underwater applications.

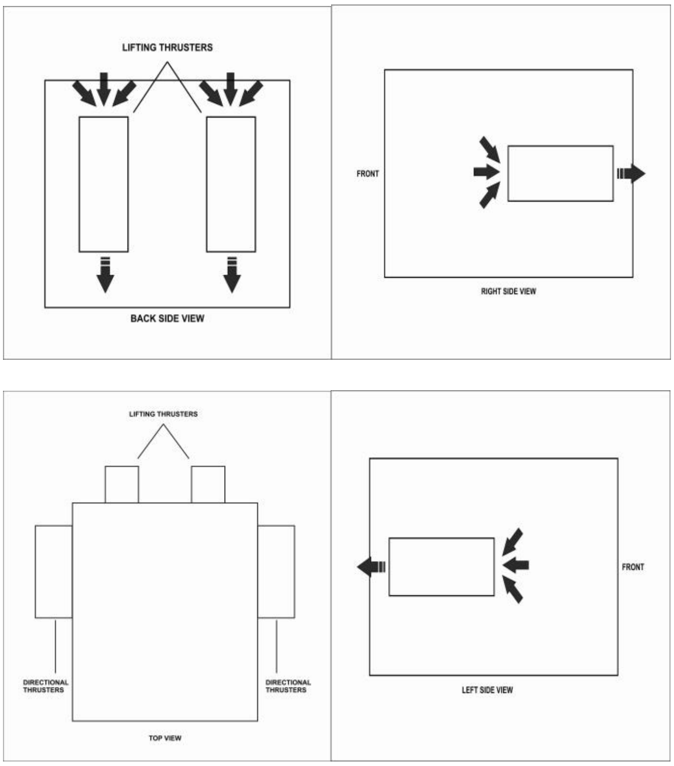


Fig -4: Aquatic locomotion by maneuvering the thrusters

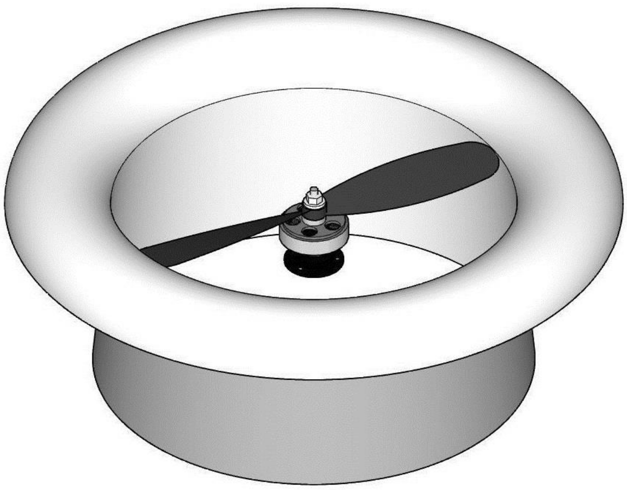


Fig -5: Ducted fan propeller

Propellers use motors while jets use a turbine. We have used motor based propulsion system due to its cost efficiency. Degrees of freedom of the vehicle are affected by the location of the motors. Noise interference with onboard electronic components is affected as well. Hence, special care should be taken deciding the number of motors to be used and their positioning. Ballast tanks or thrusters pointing downwards are two of the alternatives for submerging. Although the implementation of thrusters is simple, it is not optimum for greater depths. Propellers have specific features, which indicate what should be the right combination for the task and size of the device.

3. PROPOSED DESIGN

This project can be used to carry out undersea operations. A pressure hull is also required to place the components, such as electronic components and batteries. The pressure hull must be able to provide a watertight environment. Also, it should be made with special materials to handle the highly corrosive and higher-pressure ocean environment. This design collaborates both aquatic and land locomotion mechanisms for the prototype level. The design of the structure would be optimized with the following features:

- Buoyancy centered along the length of the ROV
- Minimal drag for forward travel
- Adequate buoyancy and room for batteries
- Accommodations for four thrusters (two vertical/side thrusters and two horizontal thrusters)
- Easy access to thrusters
- Thrusters protected from collisions by barriers
- Structurally stable

The diagrammatic representation of the proposed design is as follows.

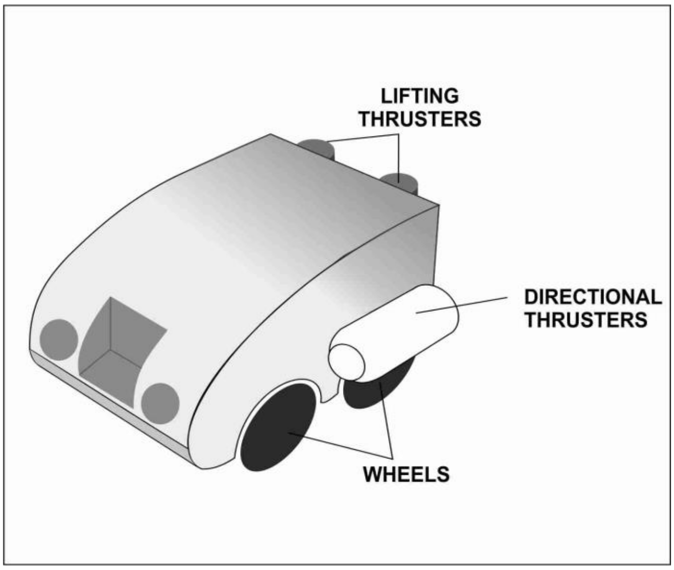


Fig-6: Conceptual working design

This design has four standard wheels for terrestrial locomotion. The movement can be synchronized as discussed in section 2.1. Four thrusters are used for aquatic locomotion. The propeller design is as shown in Fig. -5. The ducted fan is operated by a motor providing 300 RPM.

4. CONCLUSIONS

The project has been developed for surveillance. It can be used to carry out underwater research and analysis. It can be sent to the places where human life cannot go. The extreme environments, that cause a threat to human life, can be studied by using this robot. The use of DC power supply for both terrestrial and aquatic locomotion is a good option as it meets the energy requirements of the system. The proposed system can work effectively on land and water, provided the controlling center of the device is shielded and well enclosed. This model can be upgraded for further higher, heavy duty applications.

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