BTP Report

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Custom 3D Printed Submarine

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Introduction

Almost three-fourths of the Earth's surface is covered with oceans, rivers, and water bodies which inhabit a large variety of flora and fauna. Most of it remains unexplored to date. Studying these underwater ecosystems is crucial for humankind today. Sending humans and manned vehicles underwater is dangerous, less economically viable, and has its limitations. ROVs and AUVs have provided us with a better alternative. They are safe, cheaper, can go deeper, and reach less accessible places.

ROVs are remotely operated underwater vehicles that are controlled by a crew either offshore or aboard a ship. ROVs are highly maneuverable. A tether is used to control the vehicle, receive information from onboard systems, and supply power. These underwater robots are extensively used for scientific research, military purposes, and broadcasting aquatic environments. They use various sensors, cameras, etc., to collect data and take pictures. Underwater images play a crucial role in ocean exploration. Still, they often suffer from severe quality degradation due to light scattering by particles, and light absorption causes color attenuation in water medium.

In this project, we will review methods for improving a previously built ROV. We have thought of making modifications to the hull shape, optimizing the distance and position of thrusters, adding image processing tools to our existing model, and adding a mechanical arm to it. We also review different algorithms and methods to give more precise ideas on the techniques present in underwater image processing.

This paper will review existing literature on ROVs, mechanical arms, image processing, controlling, etc. We will then discuss the problems found in the existing model and identify their solutions based on the current literature. We will also analyze existing literature and perform simulations for the new additions planned for the ROV.

Literature Review

Since early ages, humans have been settling around rivers and water bodies to utilize their resources. They play an essential part in the development of humankind. ROVs can be an excellent tool to explore these underwater environments and collect data such as temperature, pressure, the composition of water, depths, etc. It can capture images to analyze flora and fauna, collect riverbed samples, do 3D mapping, study water pollution.

The design of ROV is a significant factor affecting its performance. While designing an ROV, one should keep in mind that the design should be such that drag is minimum, enough space for onboard systems is present, is water-tight, easy to manufacture and assemble, and disassemble. One should keep in mind that the ROV is neutrally buoyant, and the thrusters should be kept such that the ROV can be lifted without any tilt or torque.

The ROVs can be broadly classified into two categories which are:

- Torpedo Shaped:
    - Less drag and faster speed
    - Useful for longer range and at low to moderate currents
    - Suitable for low-resolution surveys of larger areas
    - Hard to maneuver precisely over small areas
    - Need translational speed for complete control of the vehicle
    - Generally, have 6 degrees of freedom, namely x-y-z translation, roll, pitch, and yaw. (Current model has 4 degrees of freedom)
- Non-torpedo Shaped:
    - More drag and less speed compared to torpedo-shaped design. Higher drags make them challenging to use in significant currents.
    - Useful for short-range, high-resolution surveys.
    - Better suited for optical and bathymetric surveys.
    - It can be controlled more precisely in lower speeds and shorter ranges.
    - The multiple hull design is more stable in pitch and roll.

Our previous model is torpedo-shaped, so initially, we will also be working with a torpedo-shaped model. In most cases, a non-torpedo-shaped design is adapted for mechanical arm addition. The use of external frames can provide an additional base to mount various sensors, cameras, PS, lights, thrusters, etc. They can also be used to attach the hull(s), which houses all the electronic parts of the ROV. The hull contains the onboard computer, housing for sensors, wirings, deadweights, batteries, and sometimes even the camera, among other things. This is due to why the hull should always be water-tight. Most commercially used ROVs or the ROVs used for scientific research use a mechanical arm and a sample collection box. The mechanical arm is a robotic arm that is remotely controlled and is used by the ROV to perform operations underwater. These operations generally comprise taking samples from the riverbed, and the sample collection box is used to store the sample. The mechanical arm is more suited when at the bottom of ROV, as seen in most commercially available ROVs like the Girona 500 or Triton concept. This way, the CG is as down as possible, and the arm can easily access everything from the bottom as most of the sample collection work is generally done from the riverbed itself. The challenge here will be controlling the arm and making sure the ROV's motion is not hindered or imbalanced due to the movement of the arm. As we plan to capture images and do image processing to get high-resolution data, a critical factor will be the camera and its positioning. While going through the literature present, we have analyzed that the best position for the camera is at the front of the ROV for a horizontal torpedo-shaped design. While designing an ROV, we need to keep it in mind to minimize the drag in all ways possible. This will help us navigate better, reach more considerable depths, and carry out our tasks easily. The design of the hull needs to be streamlined to minimize drag; the previous design lacks this as its top portion is flat-ended, much different from its initially proposed design, which can lead to increased drag. The thrusters aid the ROV with its movement. Their positioning, orientation, number, and distance from the hull significantly determine the vehicle's performance. Their positions need to be optimally chosen to strike a balance between maximum power and better control. Even a slight mishap in the thruster position can lead to unbalanced torque and thus to instability in the vehicle.

The underwater imaging system has two major problems: 1) Low visibility and blur of the image caused by light attenuation. 2) Color fading caused by light absorption.

Underwater image restoration algorithms can be roughly divided into the physical model and the blind restoration model. The physical restoration model works through calculated model parameters to restore the image. A blind restoration model is used to recover the observed image without prior information on the degradation process.

Based on the Jaffe-McGlamery underwater imaging model, Trucco proposes a simplified version of the filter to adjust the image restoration. A simplified model can get more ideal results based on limited backscatter.

Yang et al. use low-complexity of image enhancement method based on dark channel prior. In scene reconstruction, the median filter is used to estimate the transformation function of the input image and use a dark channel prior to calculating the atmospheric light.

Lu et al. calculated light attenuation and scattering parameters under specific water depth using the dark channel prior, used oriented triangle bilateral filter to remove the fuzz and speed up the calculation, then used Automatic Color Equalization to enhance image information. This method combines the restoration method and enhancement method.

Original underwater images are directly enhanced in part or contain rich information and become easy to recognize and process. Existing underwater image enhancement algorithms can be divided into four categories:

1. Algorithms Based on Contrast Ratio and Histogram
2. Algorithms Based on Retinex Model
3. Algorithms Based on Filtering and Other Signal Processing Methods
4. Algorithms Based on Comprehensive Methods

Objectives

1. Optimizing stability and minimizing drag for the current model
2. Finding the optimal position and specifications for the thrusters
3. Adding camera, lights, and other required sensors
4. Optimizing Image processing
5. Checking feasibility of different hull designs as per the requirements
6. Addition of Mechanical arm and sample collection box
7. Frame structure to mount all the components and provide a platform for the multiple hull design
8. Work on rotatable thrusters
9. Changing the Arduino based mechanism with Raspberry PI
10. Testing of the final model in a lake

Our initial plan is to work on the above objectives on our previous model. If we cannot achieve these objectives on our last model, we will work on an entirely new model and change our goals.

Methodology

We will adopt the following approach for our project:

1. Literature review
2. Identifying problems with the existing model
3. Adopting a theoretical approach to solve them
4. Testing the theoretically feasible methods practically
5. Adopting the viable solutions to our ROV
6. Work on the additions like the mechanical arm, sample box, etc.
7. We are checking if they can be added to the previous design. Otherwise, work on a new design, keeping in mind all the new design additions from the start.
8. Make an ROV from scratch according to the proposed design
9. Keep working to improve its efficiency, controlling, and onboard systems. We can finally think of converting it into an AUV as well.

Work plan for coming semesters

As we move forward, we have planned to do the following:

This Sem: Literature review and making our objectives clear. Proposing a tentative change in design and deciding on how to approach it

6th Sem: We will perform simulations to the existing design and make initial changes to it to test if we can work on the existing model or if we will have to work on a completely new one.

7th Sem: (I*f we work on the old model) Complete work on all the problems* identified with the old model and perform simulations for design additions.

(*If we work on a new model*) Start making a new model, keeping in mind all the problems that the previous model faced.

8th Sem: complete work on the design additions; as we complete it, we will finally make the ROV autonomous.

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