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Thesis on Submarine Remotely Operated Vehicle

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“SUBMARINE REMOTELY OPERATED VEHICLE”

This is to certify that the work presented in this thesis is an outcome of the investigation and work carried out by the authors under the supervision of Md Thesun Al-Amin lecturer department of electrical and electronics engineering Islamic University of Technology Dhaka.

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ABSTRACT.

Precisely a remoted operated vehicle have 3 major areas of operation which are land air and water.

An example of ROV that operates in the air is a quadcopter, on land is a line follower robot and in water is the submarine robot.

I choose to operate with the submarine Remoted operated vehicle popularly the underwater drone.

This project is design to work underwater with the controls of it on the surface manually.

Its design to move in various directions and carry out tasks and survey underwater. Controlled by series of wires that can cover a limited range of area due to some factors of limitations but a standard that covers a very vast area under the sea can work in availability of resources and equipment's.

The project is developed according to the guidelines of basic marine physics, electrical and electronics robotics and automation basics and advanced knowledge.

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INTRODUCTION

The purpose of this thesis is to show the basic principles, operation and construction of an underwater Remotely Operated Vehicle. The aim is also to document in detail how a remote operated vehicle is constructed from the start all the way to the uses and commercialisation of the project. This thesis provides theoretical information about sROV, as well as explanations of how each component of the project is brought to use and operation.

It is designed capable of limited area movement, performing tasks and surveying a targeted depth under water. With ROV's there the need for established industry which will has many opportunities for growth and bettering the understanding of our underwater environment. Part of the reason much growth is possible comes from the fact that many of the instruments used are industry specific with minor attempts at expanding the applications for these tools.

ROV technology is still relatively new due to the fact the operating environment is within water causing communications and waterproofing issues. But according to my keen observations of the water surrounding Bangladesh I find myself looking at the nature of the environment blessed with aquatic gifts I start to think of how to utilize the gift of these environment and explore my Engineering life in the marine the same way most young engineers are focusing on land.

Let's get into detail of the project and see from the scratch of how the courage to start something new was given birth and how long can it live.

OVERVIEW

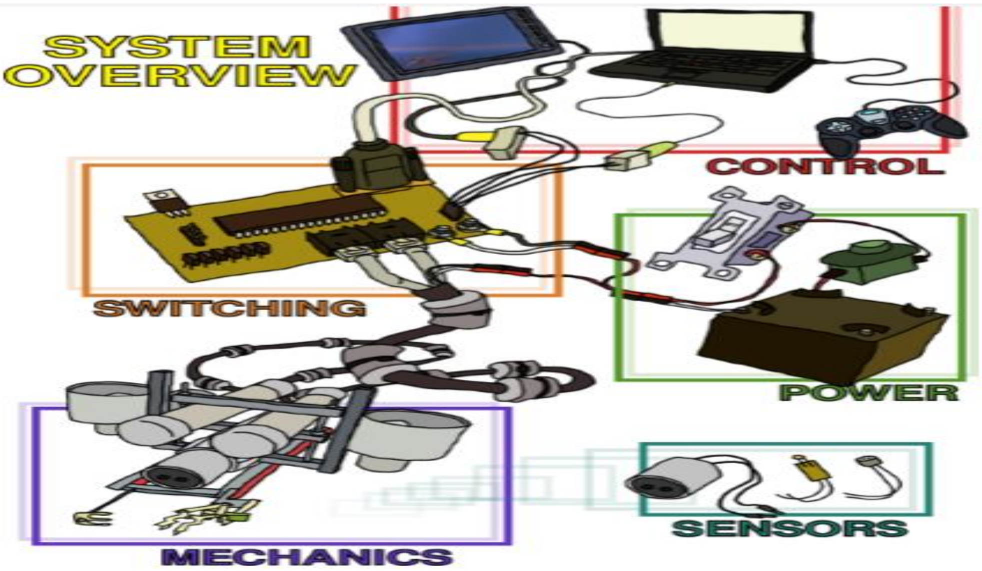
Description:

The entire system is built upon 3 major components each having a subdivision of distinguished segments which allow them to operate separately as well directing towards a goal of movement operation and effectiveness of the ROV. The first and the most vital part is the Control section which compose of the camera display and the joystick that is directly controlling the arms through a medium of an Arduino Microcontroller. The entire control section is kept on the surface or outside of the water connected to the brainbox through a thick water resistant lengthen conductors which are to be segmented by different colours for easy identification.

The second section is the frame or the body of the ROV which to it all task performing components are attached and it goes directly under the water. This is the framework of the drone consisting of the propellers for movement, cameras for sightseeing the robotic arm for task execution and the brain or microcontroller.

Finally the most important section is the section which provides electricity power to the general system and that is of course the wet cell battery kept on the surface away from the water and very well quoted with insulating material.

Diagram:



FORMULATION

Objectives:

The main objectives of this project is to enable the whole frame of the ROV to submerge and resurface, move towards all directions and the hand attached to it can be able to turn in all directions for tasks can be perfumed diligently with least consumption of power. At the same time the cameras attached should be able to give a live feed even under a dark or blurred condition that vision is normally obstructed the machine could deliver perfectly, and as well events can be saved if the need for record keeping may be. The ROV is expected to be controlled smoothly from the surface.

Specifications:

Some of the components of the project have the need for selectivity due to their salient features and variations from the market. Every component listed here have a description that suits the part of it and can withstand the necessary expectations and according to the affordability and satisfaction of the project plans. These components are the;

- Cameras

There are two types of cameras needed which are the recording camera and live feeding camera as shown below

live feeding Camera diving Camera

- Motors and Propellers

The motors as well that controls the propellers have variety of alternatives nevertheless the one that satisfy the necessary conditions is selected

Brushless DC Motor Propeller

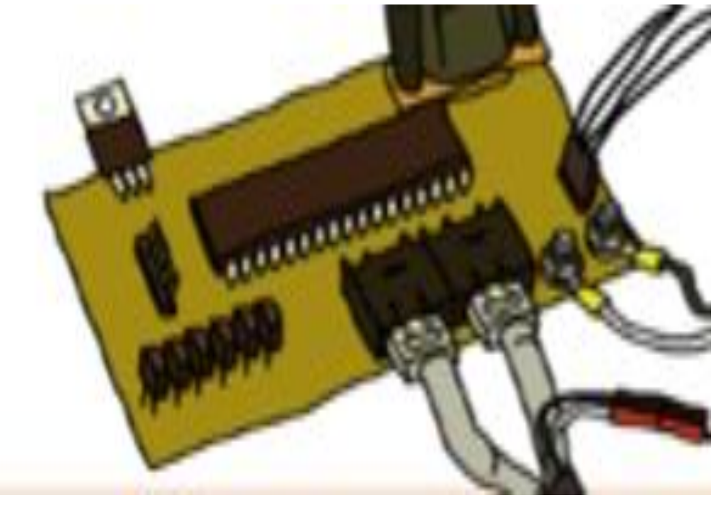
- Conductors

Indeed the conductors have to be of different types depending on the type of connection to be established but in this case some specific conduction wires are selected and mention altogether to be used throughout the work

Insulated conductors

- Microcontroller

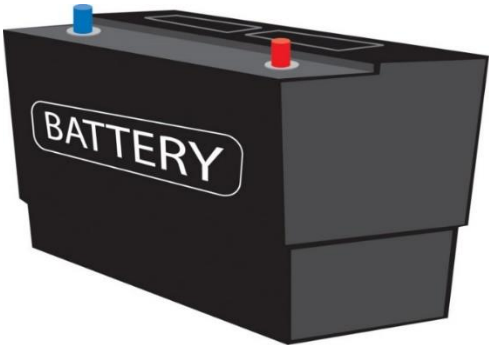
Under favourable conditions the microcontrollers are design according to taste but in the contrary case an Arduino is selected.



Arduino Mega

- Battery

One of the very vital work is making the choice of the right power supply therefore depending on the amount of power needed, I this case



The Wet cell Battery

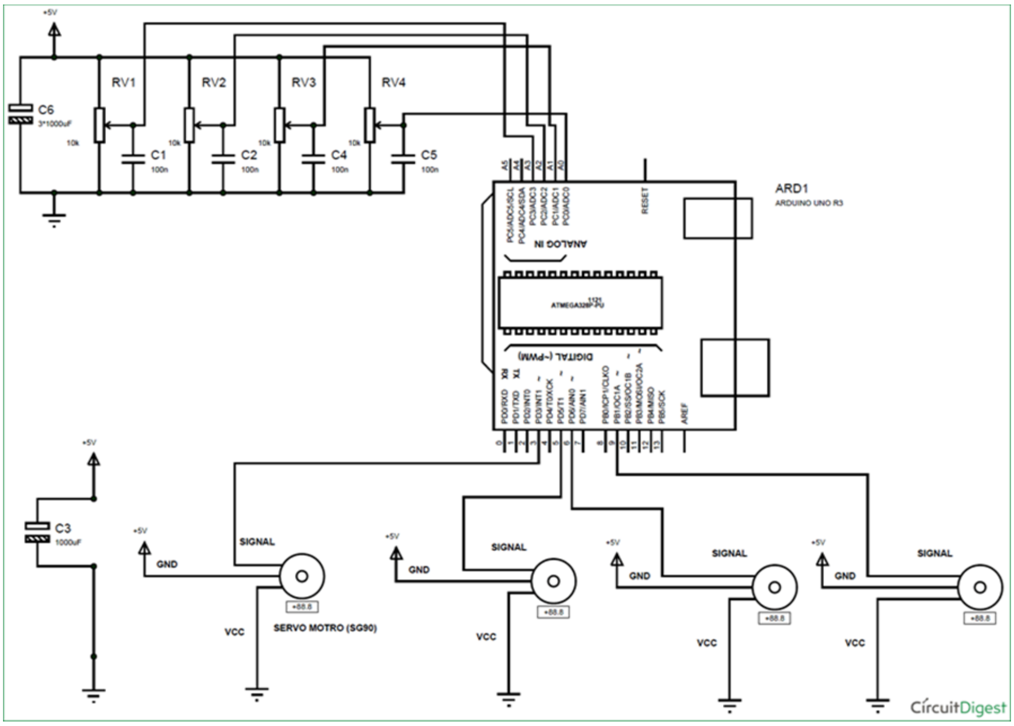
Implementations:

Global Implementations: Many considerations for our design were made with respect to the potential impact it may have globally. These range from the fact that with a low cost it is more easily accessible by small companies and countries with less financial resources then current people with ROV access. Additionally with the relatively low cost this particular unit can be thought of as essentially a minor loss upon catastrophic failure if it were to be implemented in hazardous areas. These attributes to this design will hopefully influence the market and the usage of ROV's beyond the current demographic and will hopefully stimulate aquatic research since the required supporting technology is rapidly becoming cheaper.

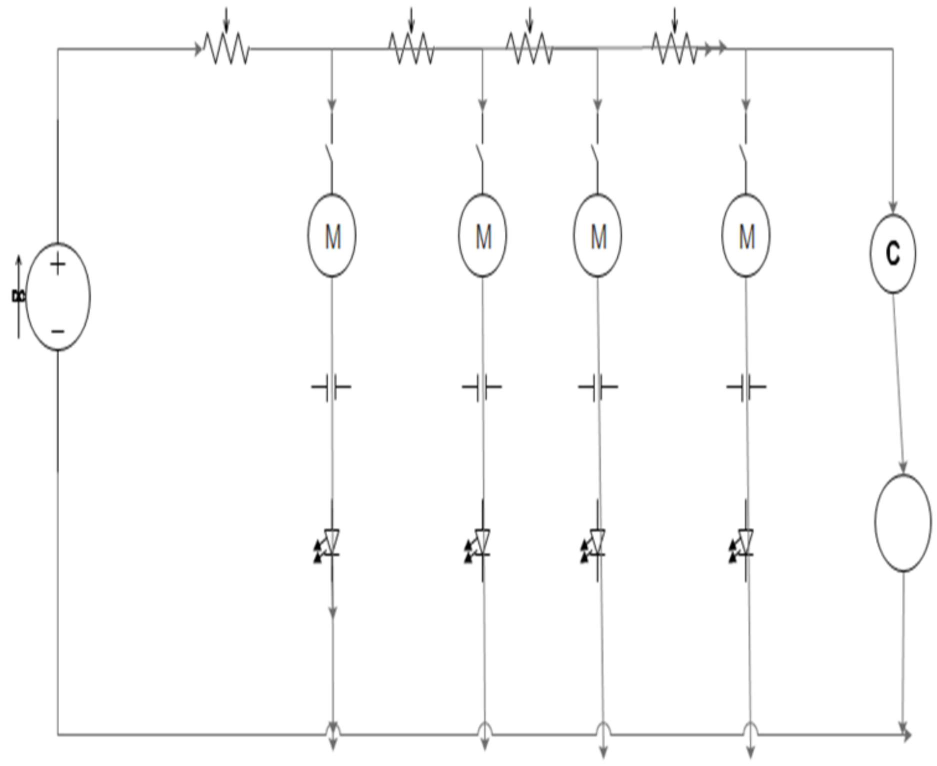
DESIGN LAYOUTS:

Primarily the design thought process was guided by minimizing the effects of drag in a three dimensional operational field and enhancing manoeuvrability to ensure the ROV can freely move throughout a heavily constrained environment such as around reefs and within shipwrecks. Drag can be reduced primarily by minimizing the surface area normal to the direction of travel. Manoeuvrability can be increased by having multiple thrusters located throughout the design with positioning contributing to rotational and translational movement. It is very integral to make the design modular and maintain a low cost to make this product more easily attainable. To achieve a modular platform a skeletal frame was a primary consideration to allow many mounting points for various hardware configurations. With considering manoeuvrability and minimizing cost it was decided to have the ROV able to travel vertically and along a primary horizontal axis with turning controlled by two horizontal thrusters to enable turning by powering motors in opposite directions or varying speeds. By eliminating a sideways travel path additional thrusters are eliminated. This basic motion decided requires the use of three thrusters with additional thrusters for additional operational directions or rotations. Other necessary designing factors are; waterproofing electronics, gripper operation, and the control system. A neutrally buoyant design was determined to be ideal in order to minimize the operation of the vertical thrusters to maintain depth. In addition to the magnitude, the central point of buoyancy must be determined which will help the ROV maintain its natural underwater orientation. To keep the ROV upright it was determined to locate the centre of buoyancy slightly towards the top region of the ROV with centre of mass being slightly towards the bottom region of the ROV. To waterproof the electronics a pressure vessel must be designed which will provide positive buoyancy so location will be towards the upper region of the ROV, this will also help with the design having buoyancy properties similar to what the team is trying to attain. This pressure vessel must hold all of the required electrical components and upon researching the various controllers that may be implemented was decided to hold at least a 3 inch by 7 inch chipset. Depth due to pressure changes, and a camera to see where exactly the ROV is going. It was decided to house the webcam in a separate but similar pressure vessel as the other electrical components to add symmetry to the ROV and make the design requirements of the pressure vessels capable of being performed with one design and set of analysis procedures, which will help keep the location for buoyancy relatively close to the centre of the ROV design. As the application of the gripper was assessed it was realized that it must be able to change its orientation to freely grab objects underwater, but movement of the gripper would require moving the camera. In addition to moving the camera the servo motors used to move the gripper would have to be waterproof which adds to more cost and complexity to the overall design. To overcome this, the decision to make the entire ROV tilt was made which required adding a 4th thruster oriented in the vertical axis. Based on being able to have a secondary vertical thruster the net thrust in the vertical axis can be divided between two thrusters. The design proposal was made lucrative.

Circuit



Control circuit1



Control circuit2

Brain

The crucial part that controls the entire operation of the ROV is coordinated by the brain which is no doubt cased waterproof in order to allow the controls possible to communicate with the body. It can be controlled by 4 potentiometers attached to a server motor. Server motors are proposed for low speed, medium torque and accurate position. All the components are wrapped around in a sealed plastic case together with the microcontroller which is the brain box sealed and quoted with absorbent to avoid any chance of moisture.

Controls:

Across the brainbox connected the output which is the control component. It is made up of the display screen which is directly connected to the cameras, the toggle switches that control the motors rotating the propellers in all directions, the lead light indicators that shows the direction of the propellers and other minor components such as switches for light and central power. Another key important factor of the control box is the joystick which is connected to the microcontroller that controls the server motors for coordinating the activities of the robotic arm. Controls are outside of the water connected with the power supply and the frame by the means of conductors and it is strictly precaution against the environment of its facilitation.

CONSTRUCTIONS

Required Components:

In making the construction works, some equipment's and facilities ae required such as the plastic pipe cutters, drilling and boring tools for making the body. Other equipment's like nuts and screws for the fixation of body parts, a test board so that every circuit is tested before implementation and battery indicators all are necessary for the building of the ROV.

Technical installations:

These are nothing but the physical construction of the entire body from the frame architecture to the control box.

Electrical installations:

This involves the circuit connection that generates power from the battery to the point of control and utilizations throughout the ROV.

CODE.

In making the programme different languages such as MATLAB or Python is more suitable but because of the choice for Arduino microcontroller the code is based on Arduino and c programming the code is designed as shown below;

```
#include <Servo.h>
Servo servo0;
Servo servo1;
Servo servo2;
Servo servo3;
int sensorvalue0;
int sensorvalue1;
int sensorvalue2;
int sensorvalue3;
void setup()
{
  pinMode(A0,INPUT);
  pinMode(3,OUTPUT);
  servo0.attach(3);

  pinMode(A1,INPUT);
  pinMode(5,OUTPUT);
  servo1.attach(5);

  pinMode(A2,INPUT);
  pinMode(6,OUTPUT);
  servo2.attach(6);

  pinMode(A3,INPUT);
  pinMode(9,OUTPUT);
  servo3.attach(9);
}
```

```
void loop()
{
  sensorvalue0 = analogRead(A0);
  sensorvalue0 = map(sensorvalue0, 0, 1023, 0, 180);
  servo0.write(sensorvalue0);
  sensorvalue1 = analogRead(A1);
  sensorvalue1 = map(sensorvalue1, 0, 1023, 0, 180);
  servo1.write(sensorvalue1);
  sensorvalue2 = analogRead(A2);
  sensorvalue2 = map(sensorvalue2, 0, 1023, 0, 180);
  servo2.write(sensorvalue2);
  sensorvalue3 = analogRead(A3);
  sensorvalue3 = map(sensorvalue3, 0, 1023, 0, 180);
  servo3.write(sensorvalue3);
}
```

ANALYSIS.

Environmental Impacts:

Due to the nature of the environment to avoid fatal obstacles during operation such as restrictions due to sea weeds or planktons, unclear water exposed to refuse dumping and other aquatic creatures activities which can alter with the vision and movement of the ROV. Depth and shallow nature of the water is another factors to be considered in such a way that the ROV can dive at a reasonable depth without encountering the muddy button of the water. Buoyancy is also a key effect on any object operating under water therefore care is taken in such a way that the buoyancy is not altered with especially in designing the propellers. Marine environment is quite different from land therefore it should be necessary to consider every possible challenges that can hinder the activities of the drone beneath its surface.

Due to waves and currents that can cause the ROV to stray off course or struggle to push through the surf due to the small size of engines that however, creates many difficulties

CONSIDERATIONS.

Assembly:

Assembly of the ROV consists of bolting the plastic connecting parts between the frame plates. Once one frame plate is bolted to the structure the electronics tubes and thruster ducts can be installed paying attention to wire routing to minimize the potentials of wires being able to enter the thruster ducts. This is done by utilizing bolts with a minimum length to allow thread engagement. Longer bolts can be implemented for adding and distributing counter weight to adjust trim and buoyancy properties or for additional hardware. Upon implementing the gripper it must be noted that the plastic connecting rods in the front of the ROV must be the rods with additional holes tapped in their centres. After the ROV is bolted together final assembly can occur with wiring signal wires and any additional hardware to the Arduino as outlined in the frame description. At this point grease can be applied to the origins. Now the conducting wires can be attached to the ROV and the USB connected to the Arduino. The connections may only be made in one possible orientation and the colour considerations also put in place on the connections to identify each and every conductor. Upon establishing the power and the Arduino's USB connection then wires may be fed into the allocated ducts. Prior to applying the grease air must be slowly bled out from the tubes by stuffing a material which tapped out pressure from the plastic interior. The final endcaps on the cameras and light housing are also ready to have be greased and pressed on to seal the forward electrical compartment. At this point waterproofing may be checked by submerging the sub for a period of time, retrieving and inspecting to see if any water has entered the electrical tubes. If the waterproofing integrity is intact the ROV's USB cable may be connected to the control box, the user control interface can be connected and power may be sent to the ROV. Once these connections are established the program may be ran and operation of the ROV may begin upon completion of the arming sequence. After operation of the ROV it must be rinsed with freshwater to clear potential oxidizing deposits and lubricant should be applied to all metallic surfaces to inhibit oxidation. Upon removal of every components servicing and thorough checking is required.

Maintenance:

This system needs maximum maintenance aside from a freshwater rinse of the system and lubricating the metallic surfaces to inhibit oxidation. For detailed maintenance the propellers can easily be removed by chocking the motors and loosening the bolt of the propellers. Propellers can be inspected for fouling that may occur over time and replaced on an as needed basis. Major maintenance must be conducted in a safe manner due to the electrical components that can be a catastrophic loss. Primarily waterproofing failure is the most critical concern of the ROV system. Upon discovering a potential leak connections to the ROV should immediately disconnected to minimize electrical failures and the electronics tubes must be checked for moisture. To determine where a leak may be originating paper may be packed in each end of the electronics tubes and the unit may be submerged and inspected to see which side may be the source of the leak. Upon detection careful inspection of the Origins must occur with replacement and re-lubrication if necessary. If it is discovered that the leak is occurring through the wiring not being adequately sealed polyether leak Stop may be applied to that cap and wires to reform a barrier. If mot failure occurs the motors can be unbolted, de soldered after carefully cutting the heat shrink and sealant and replaced with a similar brushless DC motor. Upon any failure the faulty system must be removed from the electronics duct, the wires from the must be cut and a replacement must be soldered into place. Replacement of the Arduino can simply be conducted by unplugging the Arduino and making the appropriate connections to the replacement. Every component should be replicable in case of any emergency breakdown.

Safety:

Due to the high speeds of the propellers within the duct, caution near this area must be exercised. To convey the general caution warning it was decided to paint them a colour that has common affiliations with hazardous areas. This was decided over simply labelling the area due to the fact this system is in motion so reading a warning may not always be a possibility. These typical hazard colours would consist of black, red and yellow. Within water certain frequencies become dampened as depth is increased. Research was conducted to discover which colour would be best to implement with the most effective visible range. Because of colour losses within the depths of water and common colours for alerting people to potential hazards yellow was decided to be applied to the duct assemblies since it is visible from the greatest depth. In addition to simply providing a visual reference towards a potential danger other efforts were made to mistake-proof the design. By routing the wiring through more permanent structures the wiring of the ROV will be less likely to become loose and become a hazard. These efforts include wiring efforts with labelling the harnesses to ease making connections to the Arduino. Beyond this efforts were made to enable full disassembly of the ROV for adding to service ability. Shielding is necessary due to the aquatic environment and marine habitants as well the entire system must be ready for total power termination when the need arises to cut all the power supply to avoid further accidents.

APPLICATIONS.

Broadcasts:

ROVs take many shapes and sizes. Since good video footage is a core component of most deep sea activities, ROVs tend to be outfitted with high-output lighting systems and broadcast quality cameras. Depending on the activity being conducted, an ROV will be equipped with various sampling devices and sensors. Example is the broadcast of marine and aqua life from different discovery and geographical channels

Educational Outreach:

ROVs are also used extensively by the scientific community to study the ocean. A number of deep sea animals and plants have been discovered or studied in their natural environment through the use of ROVs: examples include the jellyfish and the eel. In the USA, cutting edge work is done at several public and private oceanographic institutions, ROVs are widely used by several leading ocean sciences institutions and universities for challenging tasks such as deep-sea vents recovery and exploration to the maintenance and deployment of ocean observatories.

Naval Military Operation:

ROVs have been used by several navies for decades, primarily for mine hunting and mine breaking. For Instance In October 2008 the U.S. Navy began to replace its manned rescue systems with unmanned ROV called a pressurized rescue module. This followed years of tests and exercises with submarines from the fleets of several nations. Smaller ROVs are also increasingly being adopted by navies, coast guards, and port authorities around the globe, useful for a variety of underwater inspection tasks such as explosive ordnance disposal, meteorology, port security, mine countermeasures and maritime intelligence, surveillance, reconnaissance.

Marine Survey:

Survey or Inspection ROVs are generally smaller than working ROVs and are often sub classified as either Class I: Observation Only or Class II Observation with payload. They are used to assist with hydrographic survey that is the location and positioning of subsea structures, and also for inspection work for example pipeline surveys, jacket inspections and marine hull inspection of vessels. Survey ROVs also known as "eyeballs". Their use is slowing growing in popularity as industry looks for safer alternatives to using divers.

Marine Installations:

In fixing or installations of submarine components such as in the pipeline construction especially in transporting crude materials, alteration with large vessels and cruisers, civil engineering operations in fixing underwater structures, ROVs prove to be very essential in performing tasks of all aspects under the sea.

Scientific Use:

ROVs are also used extensively by the scientific community to study the ocean. Science ROVs also incorporate a good deal of technology that has been developed for the commercial ROV sector, such as hydraulic manipulators and highly accurate subsea navigation systems. They are also used for underwater archelogy projects. One of the first science ROVs to fully incorporate a hydraulic propulsion system and is uniquely outfitted to survey and excavate ancient and modern shipwrecks. The Canadian Scientific Submersible Facility *ROPOS* system is continually used by several leading ocean sciences institutions and universities for challenging tasks such as deep sea vents recovery and exploration to the maintenance and deployment of ocean observatories.

Emergency Rescue Missions:

For divers, aqua sports and other submarine activities ROVs have proven very essential in rescuing drowned victims and equipment's furthermore in naval activities and underwater propeller obstacles can all be supressed and controlled with the use of ROVs.

Hobby/Miscellaneous:

With an increased interest in the ocean by many people, both young and old, and the increased availability of once expensive and non-commercially available equipment, ROVs have become a popular hobby amongst many. This new interest in ROVs has led to the formation of many competitions, including MATE (Marine Advanced Technology Education). These are competitions in which competitors, most commonly schools and other organizations, compete against each other in a series of tasks using ROVs that they have built. Most hobby ROVs are tested in swimming pools and lakes where the water is calm, however some have tested their own personal ROVs in the sea.

EVALUATIONS.

Primary Test:

In this test the ROV chassis was in a near fully assembled state with all of the key components in their designated areas of the ROV and it was placed in a body of water. The horizontal thrusters were not mounted which allowed for sliding them towards the forward of the ROV and the vertical thrusters were mounted in their final location. By being able to move the horizontal thrusters the best location can be found to mount them in a manner to establish a more natural weight distribution for trim across the entire ROV. During this test a few key components of the ROV's construction were examined. Primarily a concern of the ROV was waterproofing of the pressure vessels. Since no power was supplied to the ROV it decreased the risk of shorting the ROV and would only result in some potential swelling of chipsets and mineral deposits on contact surfaces making it a low risk test. If waterproofing was to be examined during testing with power shorting could occur and lead to a catastrophic failure that could cause a loss of key electrical components. The team will work through testing to trim the ROV to attain a closer to neutral profile but as a whole is currently still wishing to retain a slightly positive magnitude to force the ROV to the surface upon catastrophic failure during testing.

Secondary Test:

Every electrical circuit is tested on board in a breadboard before making the connections temporarily on the frame then after every successful test the project is finally implemented. After the completion of ROV's main frame and main tube, the need of putting it into water was important for the acquisition of first impressions. After running this test, verification of the floatation of the frame was achieved. Another important factor that had to be found through the testing process, was to verify that the main tube could stay waterproof after diving into the water. The result after this testing was positive, since the main tube stayed waterproof for one day into 10 meters of depth without the water entering it. This test was the most important since the main tube had all the important electronics and power needed for the ROV. Another important factor that had to be tested was the proper movement of the ROV from the four brushless motors. Configuring them and testing their limits by using the joysticks was achieved successfully. Finally, the most important test was putting the whole construction into its environment. After running this test verification of the main scope of movements was achieved such as moving forward, backward, turning left and right.

Simulation

After all the implementations and improvements of an aspect of the control system, testing was performed to verify that changes implemented in the code produced the desired effect before the entire system is simulated using proteus, Pspice or Simulink.

CONCLUSION.

Discussion:

The low cost submarine robot is a semi-autonomous submarine robot used for marine environmental research and operations. Through series of tests performed on the ROV we have successfully outlined a fully operational ROV with considerations to making the system as modular as possible. The testing proved to the ROV is currently capable of about 3.4 miles per hour. This velocity does not meet the desired outcome but is still a substantial speed for any underwater vessel at the scale and budget that produced this design. Through implementing a controller with a common configuration and coordinating the controls to relatively intuitive positioning the control of the ROV proved to be relatively intuitive with ease of operation within minutes of the first operating attempt. Because of this design being our first design attempt at developing an ROV many minor issues were discovered through this testing that can be implemented in future improvements to this design or towards a future iteration of this design that may approach a similar task. We aim to develop a low cost, semi-autonomous submarine robot which is able to travel underwater. The robot's structure was designed and patented using the novel idea of the diving system, adjustment mechanism to vary the robot's density. When the robot volume decreases, the density increases, so that the robot can move downward and vice versa. In other studies, the density adjustment can be processed from the moving in and out of water using air pressure. The robot can be of a small size and travel under water over a longer period of time. Moreover, without moving upward to the water surface to collect an air, the robot can be moved upward and downward for many times. However, the communication system of this low cost submarine robot needed to be improved for the wireless system. In underwater, the low frequency sound wave is needed. Extremely low frequency sound waves (3-30 Hz) and super low frequency sound wave (30-300 Hz) would be suitable to be used in the communication. We suggested that the Global Positioning System (GPS) would be additional useful in positioning this low cost submarine robot. The aim of this project was to design and construct a small scale ROV from the start. In order for the project to be successful, all the right parts and components had to be found and put together properly. This was one of the parts during the whole process and took most the time and effort. During this project, some problems appeared. Most of them were solved, but not all of them. Therefore the project has a lot of space for further improvements. Even though the ROV does not have all intended features implemented, the system is functional at this point. Therefore, the main goal, constructing and controlling a small scale ROV, can be considered as accomplished. However, the diving feature and returning on the surface could not be verified. The main reason for these was the weather and the time that the specific tests were run. As further improvements, the ROV could have a temperature sensor that provide the temperature that is inside the water, and compass sensor that shows the direction of the ROV.

Commercialisation:

Based on the cost analysis of the project it can be seen that comparable products all retail for a significantly higher cost then the development costs of the ROV. If accounting for developmental costs by setting a retail price on the ROV at near the cost of the current lowest price capital recovery can easily be attainable. In addition to the financial prospects of the ROV distribution is easily accountable as the required power supply is highly common and available virtually anywhere. Because of the Arduino microcontroller being open sourced support for a variety of potential additions can easily be discovered to expand the application ranges

Future Work:

We are pursuing completing this project in its entirety with taking note to issues that may arise. Upon completion these changes will be noted with an effort to improve on the primary design to increase chances of success. Currently the desired design revisions include the possibility of changing the forward electronics compartment to account for clarity and minimize the potential distortion that may occur in its current form since the tube will result in a convex lens type effect with collected images. Additionally the 3D printed endcaps are likely to be replaced with the next design iteration. When first outlining the goals for this project, many features were envisioned but many features were abolished due to the time constraint, financial and manpower availability becoming an issue. The implementation of an analog joystick makes control of the ROV natural and easy, but unfortunately, the text based interface leaves much to be desired. The implementation of a Graphical User Interface (GUI) would greatly improve the operator experience. A GUI can make relayed data from the ROV easier to understand and utilize in operation, along with providing a more polished user experience. Our choice in using an Arduino compatible microcontroller affords great flexibility in the future development of the control system, and current control software could be ported with relative ease. In future the more advancements will be put in place with the help of the first time experience.