Notions Company for Advanced Marine Technology and ROVs

Enhancing The Marine life

Alexandria, Egypt

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- Eng. Mamdouh Azmy
- Eng. Ehab Ahmed

Abstract

Speaking of World War II Shipwrecks, you will notice that they contain potentially hazardous materials as oils, munitions ….etc. These materials have been resting on the ocean's bottom for nearly 70 years so imagine how much destruction have they caused until this moment ?These wrecks make a very real threat for life underwater as they deeply affect the eggs, larvae, young fish and other forms of life. This will eventually lead to an environmental disaster and affect the balance of our ecosystems.

Being so concerned about the marine life and the consequent hazardous effects of these wrecks, our company has designed ROV to collect and transplant the endangered corals, fully scan the shipwreck by measuring its dimensions, creating a map for it, determining its orientation and detecting the dangerous materials inside it then removing them. Our ROV has two manipulators to optimize picking up the corals, a digital compass for orientation determination and a metal detector to detect the dangerous metals in the wrecks. The primary elements of our ROV are speed, relatively low cost and easy control. We designed and implemented two control systems, a simple control system consisting of a number of switches and another advanced system using a joystick. We also installed one camera which provides a good and visible field underwater. Our ROV will prove to be the most efficient and less expensive solution that would clear the sea's floor from the dangerous materials and significantly minimize the drastic effect of shipwrecks.

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Photos of our ROV:

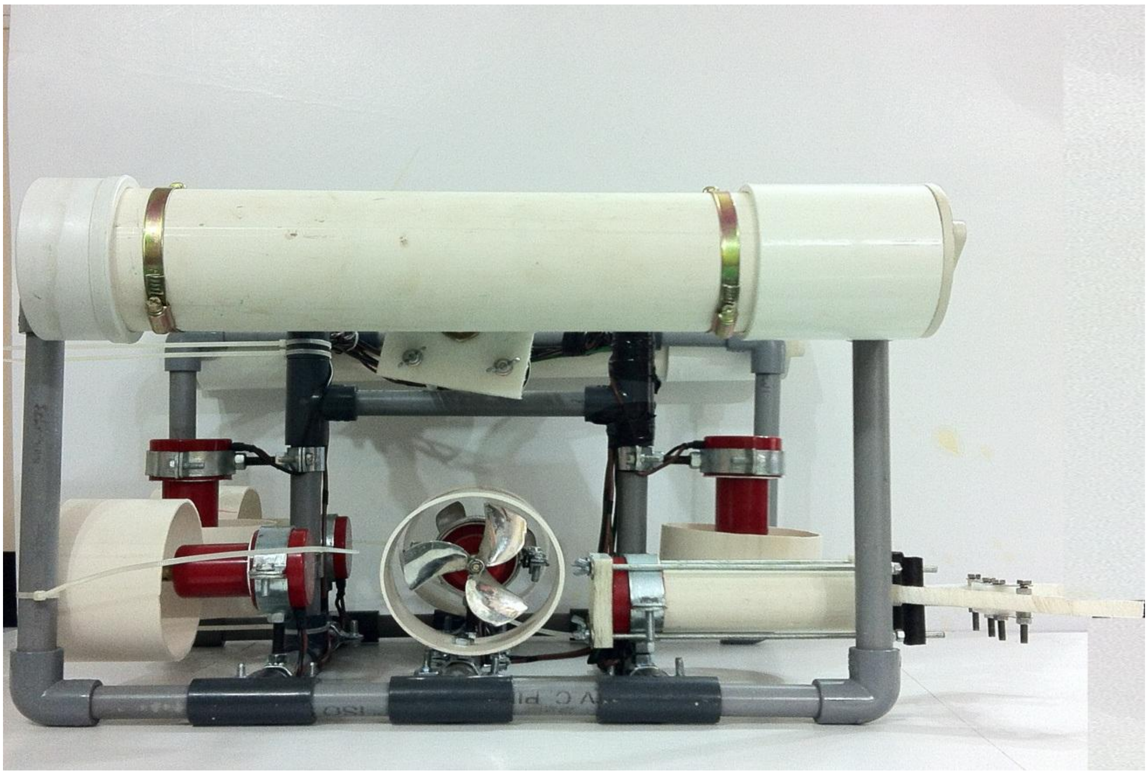

Fig1: Our complete ROV side view

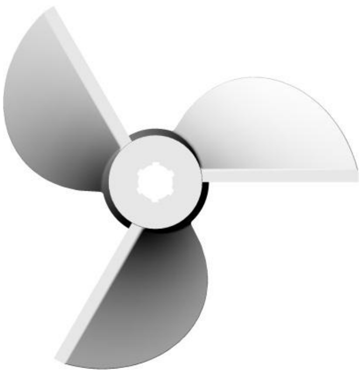

Fig2: simulation of the propeller

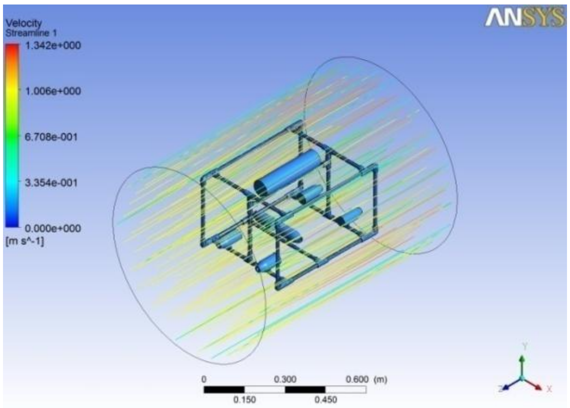

Fig3: ANSYS water flow simulation

Budget sheet

Category	Items	Estimated price	Actual price
Structure	PVC tubes Acrylic tube Tubing and motor housing	$30 $20 $60	$25.5 $20 $55
Motors	Motors Propellers and Axels	$417 $150	$417 $130
Sensors	Proximity sensor Digital compass sensor Accelerometer sensor	$25 $15 $50	$25 $20 $50
Electronics	Relays Boards Micro controllers ICs	$10 $30 $15 $10	$10 $30 $15 $10
Mission structures	Ertalon Nylon Epoxy glue	$25 $10	$20 $10
Others	Underwater camera 2 CCTV cameras	$180 $45	$130 $40
Total		$1092	$1008

We would like to thank Notions Academy for donating the tools for us (saw $10,drill $20 ,vise $7,cutter $3).

We would also like to thank Eng. Kareem Youssri for donating some electric appliances (LCD $10, Max232 ICs $10, switches $5, joystick $20).

Control System Diagram

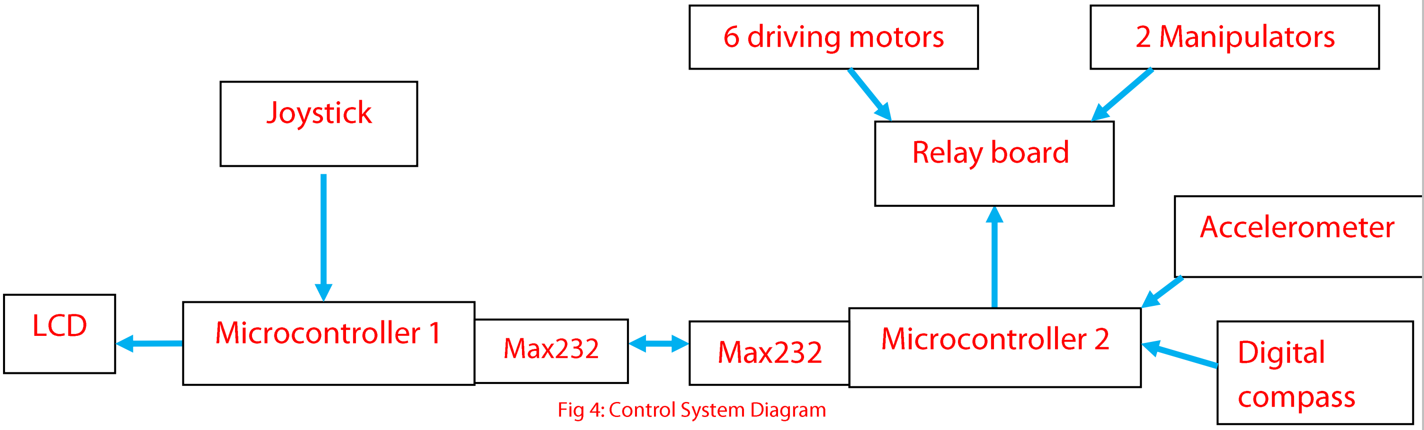

Fig 4: Control System Diagram

One of the most important parts of our robot is the controlling circuit. We placed our circuit into an isolating acrylic cylinder. Our circuit consists of a relay board, 2 Max232 and 2 microcontrollers to which the mission devices are connected. We have 16 Bi-Directional relays. We also have 2 microcontrollers, one on board (microcontroller 2) and the other is up outside (microcontroller 1). Microcontroller 2 interfaces with the sensors (digital compass, accelerometer, proximity) and the relay board, communicates with the serial data coming from microcontroller 1 and sends compass, proximity and accelerometer data to microcontroller 1 to be displayed then on the LCD screen connected to microcontroller 1. Microcontroller 2 interfaces with the digital compass using I2C communication protocol. Since we use an accelerometer with analog output, we need to convert this analog signal into digital with the ADC in microcontroller 2. The accelerometer has a built-in temperature sensor so it measures both the angle of tilting and the temperature. If the angle of tilting is more than 30 degrees, microcontroller 2 sends a signal to the opposite motor to stabilize the robot body. Also it passes the signal to microcontroller 1 which then passes it to the LCD screen. Max232 helps also in communication between the microcontrollers as it amplifies the signals travelling through the wires.

We also intended to place a 25 amp fuse at the circuit's beginning for safety.

To fully control our ROV, we created two control systems, a simple one and an advanced one. The simple one is a PlayStation 2™ controller. Each button controls a switch controls a motor relay. So when a button is pressed microcontroller 1 senses the signal and sends a packet to microcontroller 2 over the communication link. The other system is a joystick which has an analog output. This output is converted to digital by microcontroller 1 which then decides the direction of motion and then sends it to microcontroller 2 which operates the corresponding motors.

Fig5: Joy stick controller

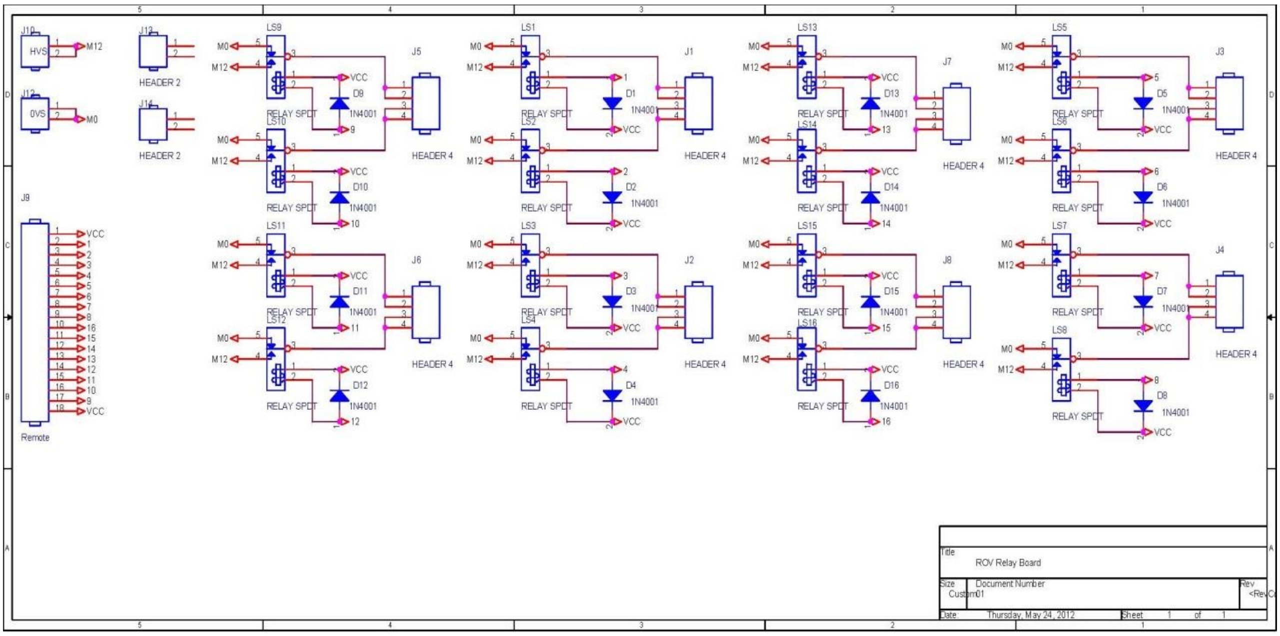

Fig6: relay board schematic

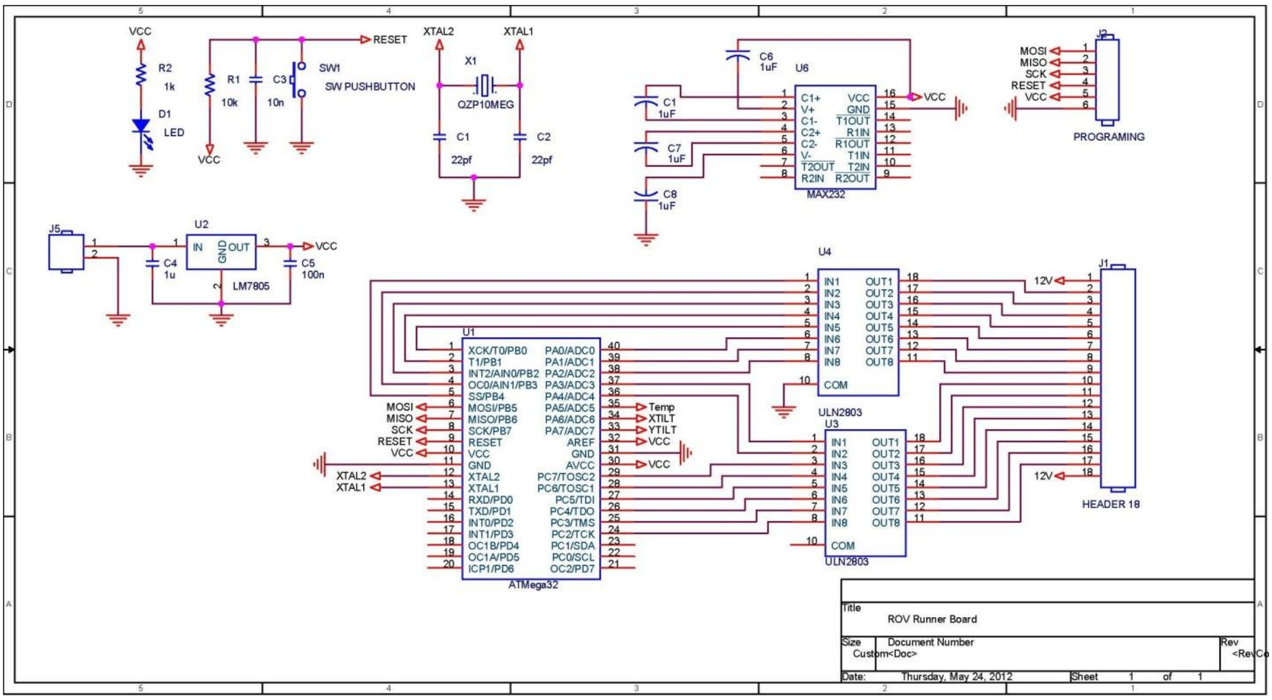

Fig7: runner board schematic

Developing the Design

After the regional contest we tried to upgrade the robot design by simulating it and calculating its center of gravity and other variables. We made a prototype of the design using LEGO™ pieces and calculated the center of gravity of the robot using AutoShape™ and adjusted it to the center of the robot. The symmetrical frame of the robot eased this for us.

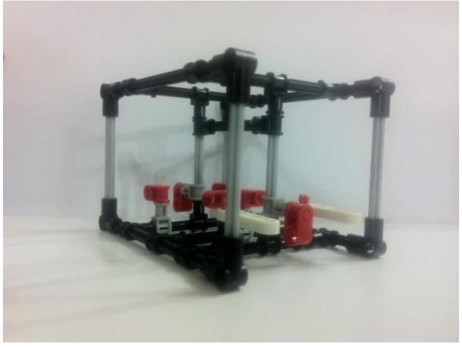

Fig8: Lego prototype of our ROV

We also used ANSYS™ to simulate water flow and pressure before building the new design.
Here in figure 9 we simulated the water flow of speed 1 m/s. It is obvious how the flow is affected by the cuboidal shape. The speed is maximum in the area directly around the robot. It also represents the flow and how it is affected by the robot components especially the motors which significantly decreased the flow. This simulation helped us to reach the optimum design.

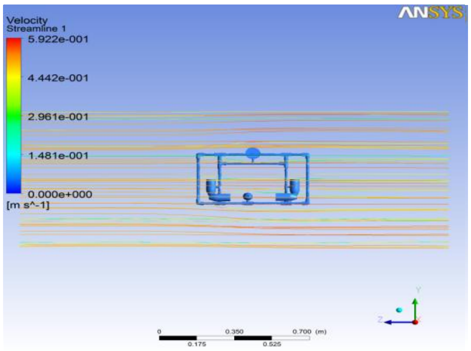

Fig9: ANSYS water flow simulation 1

We also used ANSYS to simulate the water pressure which affected our decision in the design and material. This simulation shows how the front frame faces high water pressure and the pressure reaches a maximum point against the front motors (the arms' motors). Also by calculating the pressure we found that the high density PVC is the most suitable material to use.

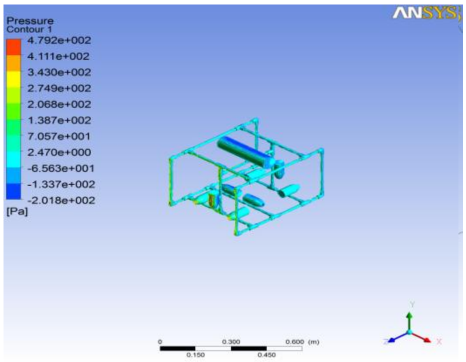

Fig10: ANSYS water pressure simulation

So we started our robot by building the frame with PVC tubes and then fixing the motors symmetrically in precisely calculated places using a pipe collar instead of breaking through the tube.

Design Rationale

In our regional competition, we had had a different robot design but after the competition and trying out the robot and the missions we made a lot of improvements to our ROV to optimize its performance as much as possible.
In our new ROV we made a smaller body, a new manipulator structure that grips things more tightly and added microcontrollers and additional 2 cameras to our ROV.

Frame:

Our primary focus was on speed and manipulation. We knew that our ROV had to be especially light and well balanced. To acquire such aims, we designed a symmetrical frame out of 1/2 inch high density PVC pipes with dimensions 30*40*50 H*W*L. Using PVC tubes is very efficient as it is light, less expensive, highly available and is an excellent safety feature unlike aluminum sheets . This tiny diameter of the pipes makes the robot less resistant to the flow of water as less surface area is exposed. Also we ma de sure to maintain the smallest possible dimensions for the frame as it is designed to exactly contain the motors with their Kort Nozzle and this is also to minimize the body's water resistance for easier flow. Being symmetrical and with a relatively smaller height, the frame became so stable and well-balanced. The frame used in the design of our ROV is suitable to carry different components in their correct locations as the cuboidal frame allowed us, with various options, to locate the vertical and horizontal motors and gave us a suitable space to fix the robotic arms at the low front of the robot and a camera above it providing enough space for payload and used objects.

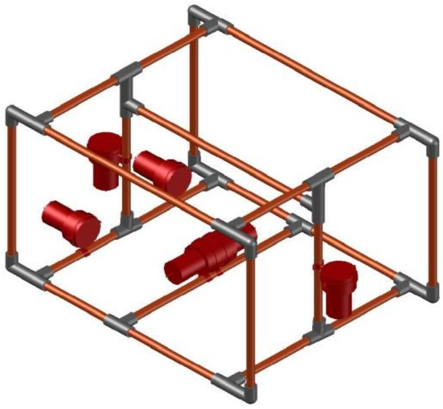

Fig11: The frame with motors simulation

Motors:

We used 8 Bilge pump motors of 4,160 LPH which consumes 12 V each. These are of really high efficiency as they are already water-proofed and the axels can be attached to them relatively easy. We placed two opposite motors (left and right) where they totally control the horizontal left-to-right movement and two motors on the back to control the forward/backward horizontal movement and two motors facing down for vertical movement. Each motor is tightly fixed using a pipe collar instead of making holes through the pipes to ensure a full control of the ROV and prevent the displacement of motors.

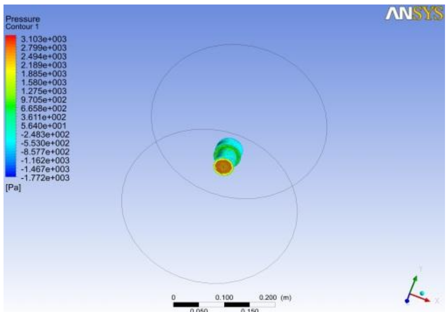

Fig12: pressure on motors without housing

One of the most important and highly effective steps we made while building our ROV is the motor-housing. We simulated our ROV using ANSES and simulated the pressure on the motors which made us discover that there is too much pressure on the motor body as water collides with it. Before placing the motor-house, when the motor was operated water flowing through the

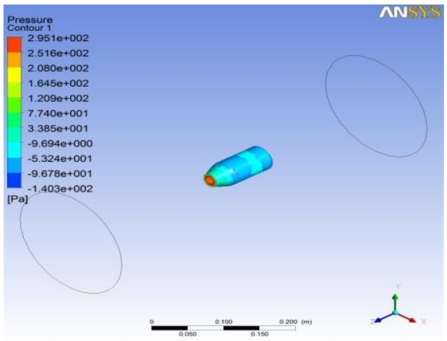

Fig13: pressure with motors with housing

propellers collided with the motor body itself and then was reflected back creating a turbulent movement through the propellers. Consequently, this created more pressure on the motor to maintain its optimum function thus consuming extra current. So by placing the motor-house, water flows on its sloping surface in one direction only not affecting the efficiency of the motors. We put a ball bearing around each axel of the propellers and then we fit it in the motor-house which has a sloping surface. This didn't only reduce the constant vibrations of the axel while operating the motor but also reduced the current consumption of each motor to its half (from 3 A to 1.5A). This together with the ball bearing highly affected the motors' performance.

Fig14: Motor Housing

Propellers

Our propellers are mounted 3.1 cm from the motors using custom built prop-extensions to allow the maximum water draw. Also we found that a three bladed propeller for each motor is the optimum combination in water propulsion.

Fig15: Propeller

Cameras:

We use 3 cameras, one main underwater camera located at the top back of the robot for a full broad view underwater. There are two other micro CCTV cameras fixed inside the transparent acrylic cylinder in which the electric boards are placed. These two cameras are focused one on each arm as our ROV is designed with two arms.

Manipulators:

To optimize mission tasks, we used 2 manipulators each manipulator is located at the front of the robot in symmetric positions. Each manipulator is made of Ertalon Nylon clamps, screw, nut and one motor to control the movement of the clamps. The nut is connected to the clamps with steel sheets through which the screw is driven by the motor. As the motor rotates and the screw moves in one direction, the nut moves the other direction so opening or closing the manipulator. This gripping system is very useful and efficient as we can grip objects with different sizes with changeable tightening. We placed the motor in a 1.5 inch PVC pipe so as to hold the manipulator together.

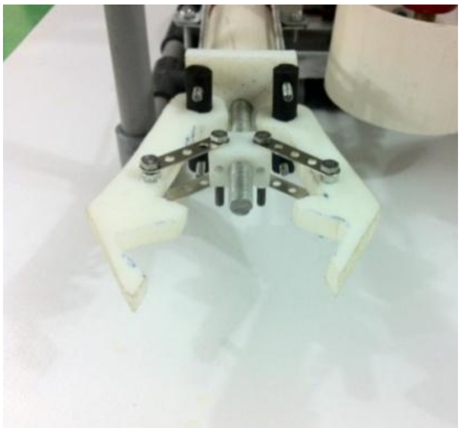

Fig16: Manipulator Design

Proximity Sensor:

One of the important tasks our robot performs is detecting whether the debris are metal or non-metal. To do that we used the proximity sensor which gives an electrical signal on touching metal objects.

Fig17: Inductive proximity

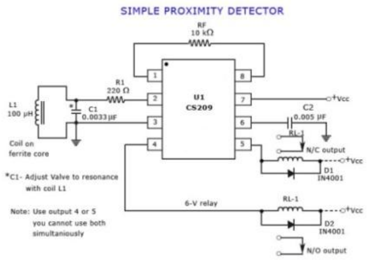

Fig18: Proximity schematic

Tilt Sensor (Accelerometer):

We work with an accelerometer with analog output. It measures the tilting angle and sends the data to the microcontroller to be processed. Also it has a built-in temperature sensor which measures the temperature of the circuit so as to be aware if overheating occurred.

Digital Compass:

We used a digital compass to find the orientation of the ship. We placed the compass inside the acrylic cylinder of the electric board. We guaranteed that the compass is not affected by any electric noise.

LCD screen:

Temperature, ship orientation and tilting angle are printed on it.

Additional design:

For easier transportation of the ROV, we separated the tether from the ROV by making a plug after ½ meter from the ROV placing it in an inspection cap. We also fixed a plastic transparent hose to a long screw to make it firm enough to pass into the oil tank. The hose extends up the water where the tether man sucks the oil using a manual pump.

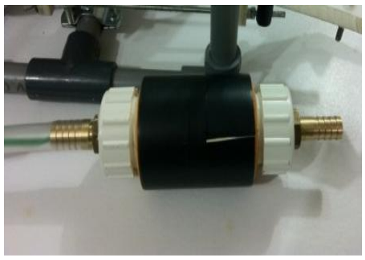

Fig19: tether splitter

Safety:

1. We surrounded each motor with a kort nozzle to safe the propellers and the tether.
2. Measuring the temperature of the circuit underwater by the built-in temperature sensor of accelerometer to detect any overheating.
3. Placing the electric board inside a well isolated acrylic cylinder to protect it from water.
4. Adding a fuse of 25 amperes (maximum) so that any increase in the current does not damage the circuit.
5. We covered all sharp surfaces using heat-shrink rubber tubes.

Mission rationale:

Mission	Payload	Tether man role	Arm used	Description
1. **Lift bag**	Hook attached to the body	Attaching the hose to the lift bag	Hook attached to body	Attaching lift bag to robot to reach the mast
2. **Lift bag to the surface**		Pumping air to lift bag		
3. **Length of the ship wreck**			Meter attached in front of the camera	Attaching meter's terminal to shipwreck and measuring length
4. **Orientation of the ship wreck**			Compass in front of the camera	Fixing the robot by the ship wreck
5. **Detecting metal debris**	Proximity sensor attached at robot frame		proximity sensor	Robot passes by debris touching each by proximity sensor is transferred if the debris is metal
6. **First target**				Driving the robot in front of the target for 10seconds
7. **Corals**			The 2 Robotic arms	Capturing the 2 corals from the wreck
8. **Second target**				Driving the robot in front of the target for 10seconds
9. **Placing corals**			The 2 Robotic arms	Placing the 2 corals on separate places of the grid
10. **Simulations sensor**			Simulated sensor Fixed on robot front	Fixing the robot touching the box of the wreck for 10 seconds then the separate one for 10 seconds
11. **Oil tank**	Drill with hose to break into the tank and a barrel to contain the sample	Pumping the oil out of tank to container	Drill with hose fixed in the robot	Passing the drill into the bottle of oil
12. **Magnetic patch**	A metallic	Attaching the extension to the robotic arm	The robotic arm with an extension	Placing the patch on the bottle's opening
13. **Sample to surface**		Pulling robot out of water		

Challenges

Throughout our work, we have encountered many technical and managing challenges which provoked us even more to work harder.

Some of these challenges are:

1) Placing the electric circuits in the acrylic tube:

After completing our design and building the robot body we got an acrylic tube of length 28 cm and diameter 6 cm to place the circuit inside it for isolation. The great challenge was that it was very small to contain the desired circuits and we couldn't replace it as this was the only size available. It was a very challenging job to replace all of the circuits' wires with the minimum thickness available and to replace each board with a similar one but having a minimum width and checking that the very small distances between the tracks in the board will not affect the current flow and supporting each track exposed to a high current and finally placing each wire in its exact correct place on the board assuring it will not bother the cameras in the tube or the sensors

2) Lack of materials and tools:

Since this is our first experience in building ROVs, it was not easy at all to find the necessary tools and materials and not even enough information about the places where they are available. Finding such information and dealing with different sources to acquire all our needs was a great challenge we faced and had to cope with. Of course this affected our design and forced us to do some obligatory changes in our robot and also consumed a lot of time which could have been spent in improving our ROV structure and design.

3) Current supply of cameras:

One of the technical challenges that faced us was our first test for the ROV. The cameras did not display the view well. After testing it separately we learned that the motors take so much current so that the current reaching the camera is not enough for a good display. We solved that by putting a regulation circuit which consists of a 6000 µf capacitor and a resistance of 330 ohms to supply enough current for cameras and motors.

Lessons and skills learned

Throughout this work experience we learned various skills and new thinking techniques. We have learned different design models and knew how to optimize our work. A very important skill we acquired was to calculate and estimate each step of our work before starting it. It was obvious in calculating the robot statistics before building it and setting the working plan. We have also dealt with the microcontrollers and programmed them. And this wouldn't only be useful in making our ROV but it's the basic knowledge for many other applications. We think the most important lesson we learned is to be so persistent and determined until we reach your optimum work.

Future improvements

We thought of some future improvements which will enhance the performance of our ROV underwater. First, we want to make a smaller body with motors tilted 45 degrees to minimize water resistance and to allow rotation around the center of gravity of the robot. Also we want to make an arm with degrees of freedom to allow movement of the arm in all directions to ease mission tasks. We want also to design a more efficient propeller with higher pitch to increase the thrust power. Concerning the electrical improvements, we want to improve the auto-balancing algorithm for more precise balancing. We want also to replace the relays with H-bridges to control the speed. We will also add a depth sensor and improve the driving interface by displaying motor's voltage and current, depth; circuits control temperature, ROV's speed and all other variables on the driving screen.

Reflections

As a team, we really enjoyed this experience so much from which we learned various technical and planning skills. It didn't only add up to our knowledge and thinking and designing techniques but it also affected us on a more personal level. We have learned how to successfully manage a working plan and how to work on a team and share ideas. We also learned how to brain-storm ourselves to get the most efficient and applicable ideas and designs. This experience added up to our knowledge and creativity as we learned how to think out of the box. We learned how to work on a team and the importance of our team spirit and cooperation. It taught us some so precious concepts that we call "The Core Values" which are briefly represented in:

1. **We are a team and do the work to find solutions with guidance from our coaches and mentors.**
2. **We honor the spirit of friendly competition and share experience with others.**
3. **What we learn is more important than what we win.**
4. **We share our experiences with others.**

A brief background on shipwrecks

According to research by Dagmar Schmidt Etkin, PH.D. of Environmental Research Consulting (Cortland Manor, NY), there are approximately 8,500 identified large shipwrecks found in the world's oceans, representing between 2 and 15 million tons of oil and other hazardous materials. Of this 8,500, nearly 75% of the total, or 6,338, are World War II era wrecks, a total encompassing 1,065 tankers, 3,887 cargo ships and 1,416 military ships.

Greenpeace finds pollution from Italy cruise shipwreck:

In January 2012 the cruise" liner Costa Concordia" stroke off the Isoladel Giglio. Greenpeace warned that chemicals from a cruise shipwreck were oozing into the sea around Italy's picturesque Giglio Island. Those chemicals threatened lives of different species of sea creatures in the area.

Fig20: Concordia shipwreck

Spanish government suffers from Prestige oil tanker wreck:

On November 13, 2002, while the Prestige was carrying a 77,000 metric tons cargo of two different grades of heavy fuel oil, one of its twelve tanks burst during a storm off Galicia, in northwestern Spain. On November 19, the ship split in half. It sank the same afternoon, releasing over 20 million US gallons (76,000 m^3) of oil into the sea.

After the sinking, the wreck continued leaking oil. It leaked approximately 125 tons of oil a day, which polluted the sea bed and contaminated the coastline and affected reefs and many species of sharks and birds, but it also affected the fishing industry. The heavy coastal pollution forced the region's government to suspend offshore fishing for six months.

Fig21: Prestige shipwreck

Dealing with shipwrecks:

Shipwrecks are classified as High Risk, Moderate Risk and Low Risk, in terms of their potential impact on the environment and navigation. It was decided to intensively study the High Risk ships via ROV (remotely operated vehicles). Submersible ROVs have been used to locate many historic shipwrecks, including that of the RMS Titanic, the Bismarck, USS Yorktown, and SS Central America. In some cases, such as the SS Central America, ROVs have been used to recover material from the sea floor and bring it to the surface.

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