Underwater Remotely Operated Vehicle for Surveillance and Marine Study

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***Abstract* - Oceanic exploration has become an emerging field of research due to many resources located in the deep sea. Robots are used in sea exploration as it is very difficult for the human beings to carry out exploration work due to harsh sea environment. Development of underwater Remotely Operated Vehicles (ROVs) is an important area of research. This paper describes a simple ROV prototype based on low cost boards, Raspberry Pi and Arduino UNO. The underwater platform consists of simple control system, camera, gripper and basic equipment. The manoeuvrability consists of forward-reverse motion, submerge under surface motion. The ROV has been tested for the above basic operations.**

Keywords: Underwater exploration, ROV, Arduino, Raspberry.

I. INTRODUCTION

The ocean covers three quarters of the Earth's surface and has an average depth of 4 kilometre. 97% of earth's water is contained in the oceans. The greatest abundance and diversity of living organisms is found in these water bodies. Diving in sea is like diving into history of life on earth, where the life forms precede human form by hundreds of millions of years. Terrain below the ocean holds most of the world's mountains. Entire chains of peaks run down the major oceans like giant backbones. Most of the planet's volcanoes is in the sea. Thus the sea is a large hub for undiscovered minerals and resources. About 95% of the ocean is yet to be seen by human eyes, let alone explored. Apart from the unknown, the already discovered parts of the ocean have been driven to endangerment by dumping a large amount of toxic waste and by the ridiculously massive amounts of fishing [1]. But, due to harsh conditions of oceans it has been a challenge to increase our knowledge in this field. Thus, underwater Remotely Operated Vehicles (ROV) was developed [2-4]. There has been minimal interest in exploring small water bodies. Thus, we decided to develop a cost and space effective ROV that has various features.

II. PROPOSED ROV

The basic underwater system consists of a ROV, a surface station and a ground station as shown in Fig.1. Since the transmission of data using wirelessly has not been developed completely in a cost effective way, we have used wired transmission from ROV to surface station floating on water. The ground stations send control signals to the surface stations wirelessly. The division of communication has provided the maximum amount of freedom possible by wireless transmission from land to water surface.
The ROV consists of the main frame structure, the ballast system, robotic gripper, thrusters and the camera. The surface station consists of the mainframe electronics such as microprocessors, Bluetooth module, motor drives, relay circuits, and power sources and its booster modules required to supply power and control of the ROV.

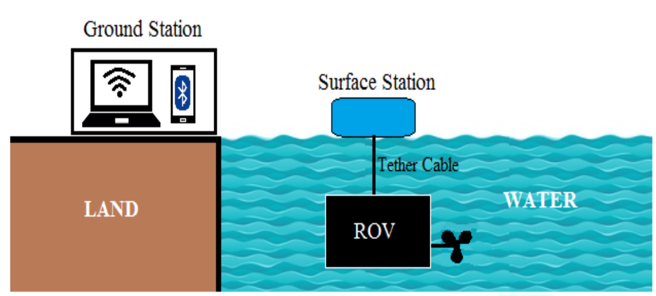

Fig.1. Block diagram of the proposed ROV and communication system.

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The ground station consists of the Android application using which the user operates the ROV and a laptop system to view the video feed and the distance of the nearest obstacle. The surface station controls the functions of the ROV through the tether cable. The video feed from the ROV is received wirelessly by the user via the surface station.

III. MECHANICAL DESIGN

The main aim is to keep the ROV lightweight, relatively small and inexpensive. The mechanical configuration of the ROV is designed to facilitate control design namely in what concerns buoyancy, weight, and drag symmetry. Due to viscosity, manoeuvring and depth control is a challenge[5]. High power motors and appropriate thrusters have to be used to achieve this. Also, as we go deeper the pressure increases, so the model has to be as light as possible.

The ROV frame and the flotation compartments are made of composite materials for improved weight or buoyancy ratios. This is done in order to maintain the equilibrium in water. The total weight of the frame, electronic components and other hardware equipment's is balanced with appropriate weights and floats added to the frame. This is done to achieve neutral buoyancy of the ROV in water [6]. To abide to all the above factors the best material for this purpose is PVC pipes. This is because they are highly resistant to corrosion and also withstand the pressure of water easily. In addition they are inexpensive and easy to machine.

For manoeuvring the ROV thrusters, i.e.; propellers attached to DC motors are used. The DC motors used are 12V and help propeller to cut through water to move in different directions. Two thrusters are placed at the back of the ROV for the manoeuvring, i.e., forward, backward, left and right movement.

In submersibles and submarines, ballast tanks are used to control the buoyancy of the vessel. They flood ballast tanks to submerge, then to re-surface by getting rid of the water, becoming buoyant again. This is done in a very big scale. The same concept has been used for the depth control of the ROV. The ballast system consists of three major components as shown in Fig. 2. These are:

- A 24 V solenoid valve
- A tank – a small pipe to store water
- A 12V submersible water pump

The initial setting of the ROV is such that it is neutrally buoyant when it is in water. The operation of depth control takes place as follows:

- In order to make the neutrally buoyant ROV attain depth, a signal is sent to the relay switch that opens the valve. This allows the entry of the water into the tank. As the water enters and the amount of water in the tank increases, the ROV becomes heavier thus changing the buoyancy of the ROV. Hence the ROV sinks.
- The depth of the ROV is controlled by the controlling the amount of water entering into the tank.
- In order to resurface the ROV, the water pump is used to pump out water from the water tank. This decreases the amount of water in tank which alters the buoyancy of the ROV bringing the ROV back to its initial neutral buoyancy.

The pan-tilt camera setup consists of a stand, two brackets and two servo motors which are used to turn the camera in the required viewing direction. The camera is mounted on the brackets. The camera can move in four directions: left, right, up and down hence giving an Omni-directional view. Below the camera a laser is attached for range finding of the obstacle in front of it.

A robotic gripper is attached to the frame which operates using a 12V DC motor. It opens and closes using a gear system. It is used to collect samples for exploration and small-scale removal of wastage.

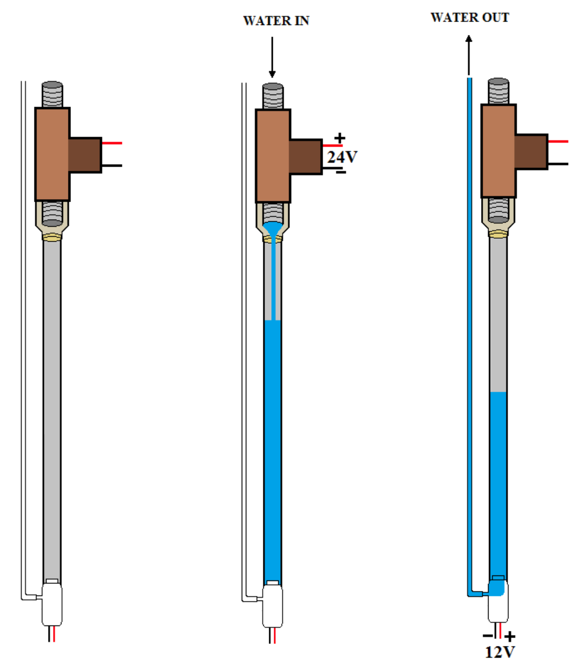

Fig. 2: a) Ballast system b) Increase depth by filling water using valve c) Decrease depth by emptying water using water pump

IV. ELECTRONICS

The electronic control circuit is used for calculating the distance, video recording and ROV movement control. The conventional method used to detect the range of an underwater object is by sending and receiving some form of acoustic energy. The available underwater SONARS' in the market cost hundreds of dollars which is neither feasible nor cost effective. Hence, affordable laser range finder is used to serve the purpose.

The electronics of the ROV is divided into two parts on the basis of the data transmission:

- Wi-Fi transmission:

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This portion uses a camera interfaced with Raspberry Pi for live surveillance. The combined data of camera and laser is used to calculate the distance of the nearest obstacle.

- Bluetooth transmission:
  This portion controls the movement involved in the ROV. In particular it includes functions of thrusters, ballast system, movement of the camera and gripper.

The Bluetooth module, HC05 is interfaced with Arduino. Raspberry Pi is connected to a Wi-Fi Dongle, which creates a local hotspot as shown in Fig. 3. The video is recorded and then sent to the laptop which is configured to the Raspbian OS. As the video is viewed the distance is calculated between the ROV and the object for each frame.

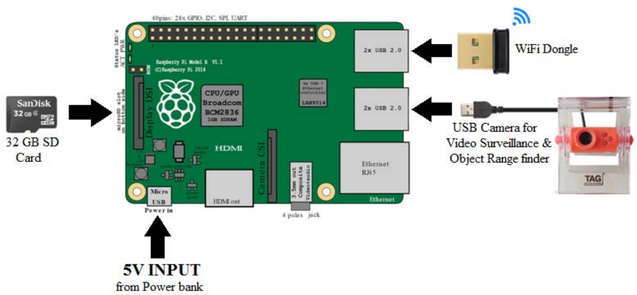

Fig. 3: Multiple interfaces of Raspberry Pi.

The laser range finder is developed for finding the distance of the object. A webcam is fixed onto the required place on the ROV with the laser fixed right below the lens of the webcam such that the camera lens and the laser are under proper vertical alignment. The reflected laser light from the object is viewed in the camera. The distance between the laser and the camera along with the webcam image is used to position of the object as shown in Fig.4.

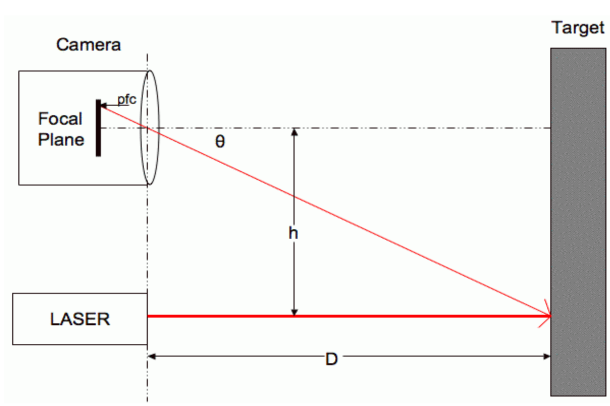

Fig. 4: Calculating distance using basic trigonometry[1].

The distance of the object from the laser D is given as

$$D = \frac{h}{\tan\theta} \quad \text{..(1)}$$

$$\theta = P_{fc} \times R_{pc} + R_o \quad \text{..............................(2)}$$

Where,

P_{fc} = number of pixels from the centre of focal plane

R_{pc} = Radians per pixel pitch

R_o = Radians offset

From the above equation we know that the distance to the object equals the distance between the webcam and laser, divided by $\tan\theta$. The angle θ is derived from analyzing the webcam image. Pixels from centre of the focal plane P_{fc} will change depending on how far away the image is. Pixels from focal plane just mean how many pixels the laser is from the centre of the image. The radians per pixel pitch of the webcam and the radian offset are constants for a particular webcam. These are R_{pc} = 0.001145 and R_o = 0.0154 for the webcam used. [7-8].

An Android application is used to communicate with the HC05. The application used is called Androad Pro. This application is made in order to communicate with Arduino using Bluetooth. It can be customized by adding buttons, joystick, slider, switch and so on. This application has been customized for remote operation of ROV. Bluetooth control panel as seen in the application is shown in Fig. 5.

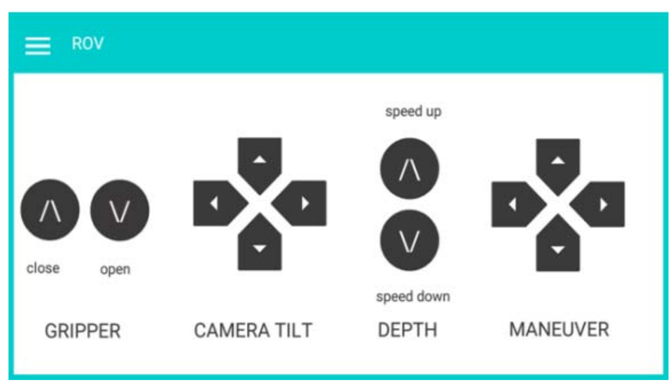

Fig. 5: Blue tooth control panel

After the data is transmitted from the application, it is received by Bluetooth module, HC05. This in turn performs the appropriate function. Bluetooth module is connected to Arduino as shown in Fig.6.

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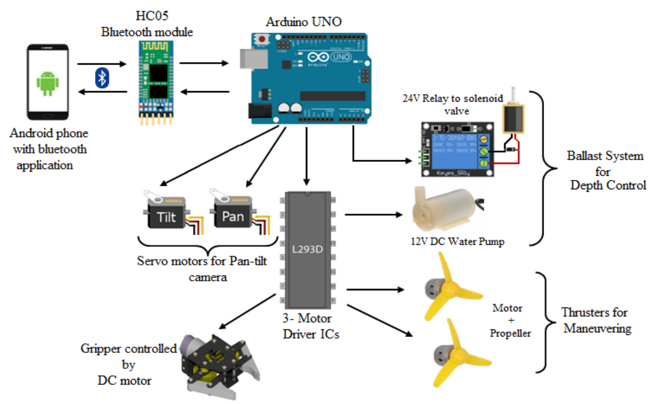

Fig. 6: The interconnections of Blue tooth module, Gripper, Maneuvering system, Ballast system and Pan-tilt Camera

The Arduino is also used to perform following control functions:

- Maneuvering:
  The Bluetooth maneuvering commands are given in Table I. 12V DC motors have been used along with propeller. The L293D motor driver IC is connected to two thrusters responsible for the movement of the ROV. It receives movement and direction commands from Arduino board and hence controls the movement of ROV.

TABLE I. THE MANEUVERING COMMANDS

Bluetooth Data	Left motor	Right motor	Direction of ROV
F	Clockwise	Clockwise	Forward
B	Anti Clockwise	Anti Clockwise	Reverse
L	Anti Clockwise	Clockwise	Left
R	Clockwise	Anti Clockwise	Right
N	Stop	Stop	No Movement

- Depth Control:
  Depth is controlled by a 24V solenoid valve and a 12 V water pump. Valve is controlled by the relay. The relay receives the command from Arduino board Similarly, the water pump is controlled by L293D. Table II shows the operation of ballast system.
- Pan-tilt camera:
  The direction of the camera is controlled by servo motors.These servo motors have three terminals: Vcc, ground and signal. Signal is connected to Arduino digital pin to rotate the servo motor in degrees. In this design, each time the button to move the servo is pressed, it rotates by five degrees. Here, the pan servo is connected to pin 10 and tilt servo is connected to pin 11. Table III shows the directions the servo motor rotates the camera.

TABLE II. THE DEPTH CONTROL (BALLAST SYSTEM) COMMANDS

1	Open	-	Down
2	Close	-	Stop
3	-	Running	Up
4	-	Stop	Stop

TABLE III. THE SERVO MOTORS COMMANDS

Bluetooth Data	Pin 10	Pin 11	Pan Servo	Tilt Servo	Direction of Camera
W	HIGH		Anti Clock-wise		Up
Y	HIGH		Clock-wise		Down
Z		HIGH		Anti Clock-wise	Left
X		HIGH		Clock-wise	Right

TABLE IV. THE GRIPPER MOVEMENT COMMANDS

Bluetooth Data	Pin 12	Pin 13	Gripper DC motor	Gripper movement
C	LOW	HIGH	Anti Clockwise	Close
G	LOW	LOW	Stop	Stop
O	HIGH	LOW	Clockwise	Open
H	LOW	LOW	Stop	Stop

Fig. 7 shows the power distribution circuit. We used two widely available 10000 mAh powerbanks to provide power to run the entire ROV. The power booster modules are used to boost the current and voltage from the power bank to the motor driver circuits and also the solenoid valve in the ballast system. The power banks provide power directly to the Arduino and Raspberry Pi.

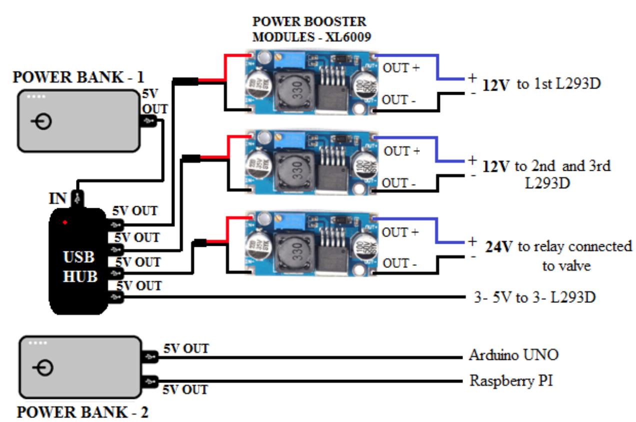

Fig 7: Power Distribution Circuit.

All the subsystems of the ROV were assembled to form the complete structure as shown in the Fig. 8. A glass container

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was used for protecting the webcam underwater. The ROV was tested for all the underwater functions.

Fig. 8: Assembled ROV

V. CONCLUSION

The ROV was tested underwater and it performed appropriate manoeuvring of forward, left, right motions. The grippers opened and closed in the underwater environment and also successfully held on to objects. The ballast system successfully performed sinking and floating of the ROV. The range finder made here was efficient for around 150cms. It gave the user enough time to back up and avoid the obstacle. The Webcam allowed us to view the underwater environment and determine the distance of the obstacle In real time better cameras could be used for high resolution video and also for accurate distance.

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