Remotely Operated Underwater Vehicle with Robotic Gripper

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Abstract— **This paper has been endeavoring to enforce modern technique in the field of electronics. It is focused on a 6-Degree of Freedom (DOF) and an under actuated system. For the underwater controlling and modeling of the vehicle, it has used an Internet Protocol (IP) camera for underwater surveillance. The most important task which the project will do is that it has an image processing feature that will enable the vehicle to find and detect lost or floating objects and picked it out through robotic arm. The Sonar sensor shows the depth of the vehicle and the distance from objects and the barometer shows the surrounding pressure, temperature and altitude of the vehicle. The real time controlling is carried out with the prototype and the results shows that the system is fully capable of accomplishing tasks such as wireless communication, object detection, object recovery and can detect major environmental changes such as pressure, temperature, obstacle avoidance and other real time information processing effectively and efficiently. This report has been so devised to be of special value to research organizations. It introduces a model for simulation and control purpose. The Remotely Operated Underwater Vehicles (ROVs) are remote control underwater robots, driven by an individual on the surface. The whole system model is discussed and finally the results are conveyed.**

Index Terms— **Remotely Operated Underwater Vehicle (ROV), MATLAB, Pulse Width Modulation (PWM), Image Processing, Robotic Arm**

I. INTRODUCTION

The submersible is a small vehicle or watercraft that is able to perform underwater operations. It is usually supported from the surface by using shore teams, ship platform or some times bigger submarines. Submersible is contrary from submarine in that a submarine has a full capacity to renew, its own power and breathing air and doesn't required to be operated by an individual from the surface. There are many types of submersibles including both crewed and un-crewed crafts which are usually known as Remotely Operated Underwater Vehicle (ROV). They are used for different purposes like adventure, ocean exploration, oceanography, equipment maintenance and recovery [3].

The Remotely Operated Underwater Vehicle is generally known as ROV. The ROVs are secure and extensively serving in a range of commercial, military, and scientific needs. ROVs are equipped with a series of propellers, impellors, cameras and lights causing highly maneuverable underwater robots operated by an individual from the surface.

In the present era there are a number of companies developing ROVs. They are also used for numerous applications and with the passage of time the area of its operations is increasing at a very rapid speed. One of the ultimate goals in the research of robotics is the ability to detect variations in the environment, implement execution strategies without human intervention and learning ability to improve performance. The development, of underwater robots having complex behaviors, is necessary to meet technological demands. There has been significant importance of developing stabilizing algorithms, for under actuated systems because of extensive range of the applications of these systems in marine vehicle e.g. submersible, surface vessels [1].

The controlling of underwater robots is of critical importance in an area that causes many problems for the researchers. These robots show some important physical effects such as fluid dynamic effects, due to this fact it is complicated to design a real time control system for underwater robots. [2]

The manipulator attached in the system is called 'Robotic Gripper' and it is used to grab any object and picked it up from the ground. Internet Protocol (IP) camera is used to observe the full underwater environment and to detect any object by using image processing.

This paper, firstly describe the working principles of ROVs and then present its results in real time environment.

The rest of the paper is organized as follows:

The section II, defines the objectives of the project. Section III, gives a brief description of ROV and its analytical behavior. Section IV, demonstrate the image processing used in ROVs and the detection of object in water. Section V, represents the simulation results of ROV and real time sensors reading obtained from the system.

II. OBJECTIVES

Objectives of the project are as follows:

- Controlling of ROV in water wirelessly
- Detection of object in water using image processing
- Obtaining the real time sensors results on the ground
- Grabbing of object using robotic gripper

III. RESEARH METHODOLOGY

A. Background

On the bases of current information, it is impossible to say who invented the first ROV, regardless of that, there are two persons who deserve the credit for the upbringing of this

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technology. The Programmed Underwater Vehicle (PUV) was a torpedo developed by Luppis Whitehead Automobile in Australia in 1864; however the first tethered ROV, named POODLE was developed by Dimitri Rebikoff in 1953 [5].
ROVs are underwater robots which are remotely controlled by an individual from the surface. These robots are controlled by wireless or wired communication systems that send signals between the ROV and the operator. The underwater robots are equipped with video camera, lights and thrust system. Some other components are also added depending on specifications required.

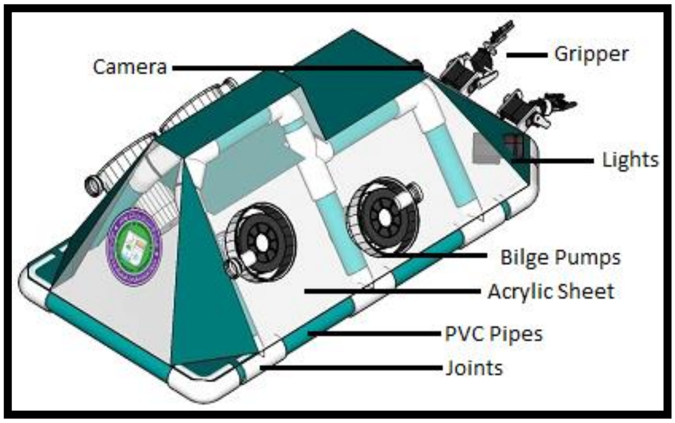
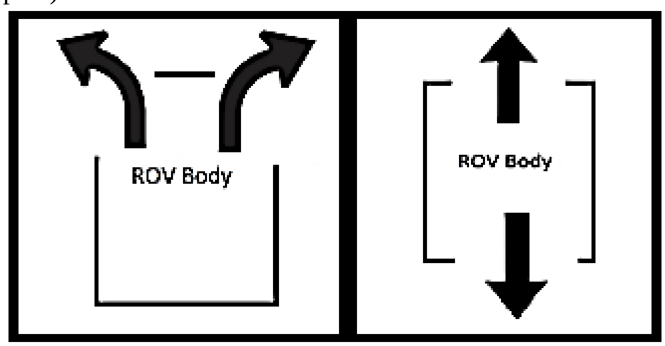


Fig. 1: Remotely Operated Vehicle with Gripper

It is an electronic and mechanical based project in which we control the robotic gripper through the help of both i.e., this project is a combination of electrical and mechanical based technologies. In this section an analysis of the state of the art is presented, for ease of understanding.
This study aims to review ROV control strategies ranging from position trajectory to station keeping control, which are two of the main challenges to be dealt with. There is a great number of research works in the international literature related to several control approaches such as PID-like control, standard sliding mode control and Fuzzy control, among others.
The ROVs are controlled by human from the shore or from the ship dock that is why they are mounted with cameras and lights. This kind of technology, made the complex underwater job much easier. In the past when there was no efficient ROV technology available, the professional divers were used to carry out underwater tasks, which present a lot of risk to the lives of divers. Due the intervention of ROV technology, the humans can carry out underwater jobs without being exposed to any harm [4].
Image processing in water somehow created problems because the refractive index of air is different than the refractive index of water i.e., the reflection of light with the lens of camera makes different angle in air as compared to water. We can overcome this problem in MATLAB by varying the threshold values of colors, for easy processing of image in water.

B. Modelling

The project provides a complete nonlinear model of the fluid The project provides a complete nonlinear model of the fluid dynamics of a quad impellor underwater robot, including fluid dynamic model and engine model for nonlinear system analysis. The location of both, Center of Gravity (CG) and mass moment of inertia are determined by experimental and software, methods.
Six Degrees of Freedom (DOF), equation of motion for the quad impellor underwater robot is derived, with a model for electric motor response to rms input voltage and complex model for coefficients of thrust, drag, torque and movements about the direction of travel. The derived nonlinear model includes; the gyroscopic effects resulting from the rigid body rotation in water, friction due to quad impellor underwater robot motion, fluid dynamic effects due to impellor rotation and flapping inertial counter torque due to change in impellor rotation speed.
The project provides a variety of linear and nonlinear controller designs for full control of quad impellor underwater robot. This prototype of ROV is designed to have four thrusters in total; two of them are in vertical and remaining two are in horizontal direction [6].
The Fig. 2 shows the top view of ROV in which the horizontal thrusters were to provide the left-right motion and forward-backward motion while the vertical thrusters were to provide the up-down motion. The depth, to which the prototype was expected to go, was within 2-3 meters (depth of a swimming pool).



Left - Right Forward - Backward

Fig. 2: Motion of ROV (Top View)

The Fig. 3 shows the side view motion of ROV. The ROV was designed to perform maneuvers in such a way that it could turn sideways to get itself attached to the frame of the ship and this motion is to be achieved by vertical thrusters. In order to turn the ROV sideways the speed of the motor one or thruster one has to be reduced while the speed of the second thruster has to be increased.

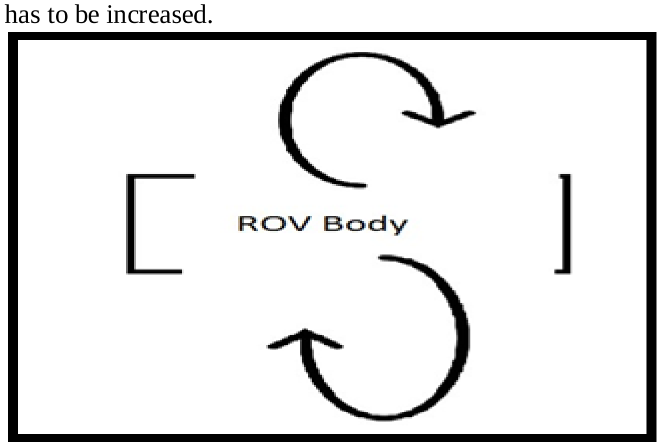


Fig. 3: Motion of ROV (Side View)

Since the density of ROV is similar to the density of water, the other inertia terms must be introduced, in account for the valuable mass of surrounding water that must be accelerated with the vehicle. These additional mass coefficients are defined as proportionality constants, which relate each of the angular and linear accelerations with each of the movements and hydrodynamic forces they generate.

The force which is directly proportional to the square of the corresponding relative motion of the vehicle is called drag. The drag depends on the properties of any fluid and on the size, shape, and speed of the object. One way to express this is by means of the drag equation i.e., Eq. (1).

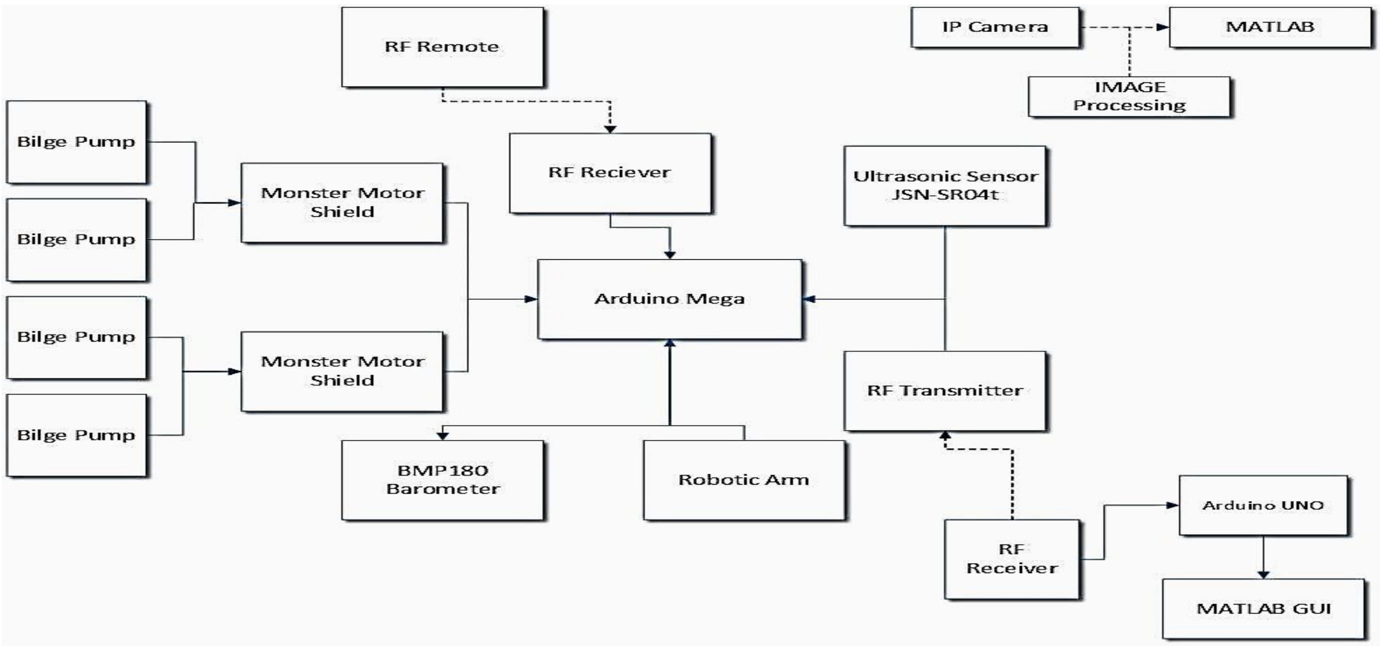


Fig. 4: Block Diagram of ROV

$$F = \frac{1}{2}\rho v^2 C_D A \tag{1}$$

In underwater engineering the axes are directed, as in the positive x direction with the right side corresponding to the positive y direction and the vertical underside corresponding to the positive z direction. These three angles are individually called roll "∅", pitch "θ", and yaw "ψ". Considering a right hand oriented coordinate system, three single rotations are described separately by Eq. (2), Eq. (3) and Eq. (4) respectively [7].

$$R_x(\emptyset) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & cos\emptyset & sin\emptyset \\ 0 & -sin\emptyset & cos\emptyset \end{bmatrix} \tag{2}$$

$$R_y(\theta) = \begin{bmatrix} cos\theta & 0 & -sin\theta \\ 0 & 1 & 0 \\ sin\theta & 0 & cos\theta \end{bmatrix} \tag{3}$$

$$R_z(\psi) = \begin{bmatrix} cos\psi & sin\psi & 0 \\ -sin\psi & cos\psi & 0 \\ 0 & 0 & 1 \end{bmatrix} \tag{4}$$

$$[x \quad y \quad z] = [X \quad Y \quad Z] R_z(\psi) R_y(\theta) R_x(\emptyset) \tag{5}$$

$$[x \quad y \quad z]$$

$$= [x \quad y \quad z] \begin{bmatrix} 1 & 0 & 0 \\ 0 & cos\emptyset & sin\emptyset \\ 0 & -sin\emptyset & cos\emptyset \end{bmatrix} \begin{bmatrix} cos\theta & 0 & -sin\theta \\ 0 & 1 & 0 \\ sin\theta & 0 & cos\theta \end{bmatrix}$$

$$\begin{bmatrix} cos\psi & sin\psi & 0 \\ -sin\psi & cos\psi & 0 \\ 0 & 0 & 1 \end{bmatrix} \tag{6}$$

C. Block Diagram

The Fig. 4 shows a block diagram of the proposed system, where Arduino Mega 2560 is behaving as a main controller of the system. The further details of it are as follows:

- As shown in figure i.e., Fig. 4, the main controller we used is Arduino Mega 2560 through which the monster motor drivers are connected and controlling of bilge pumps has taken place. We are using four bilge pumps in which we can alternatively on and off the pumps using the driver. The main reason for using monster shield is that it can bear current of up to 15A. The commands given to the monster shield, connected to the Arduino, is from the RF remote transmitter whereas the RF receiver is attached with the Arduino.
- All other sensors, such as barometer, ultrasonic sensor etc., are also connected to the controller, on which temperature, pressure, altitude, distance from object, readings are being observed and we can obtain the real time results on the MATLAB GUI through RF / Serial communication.
- Lastly the robotic arm, which can be used for grasping objects, is also connected to the controller. The input signal is given by the RC remote through which the Arm is controlled. The camera attached with the body, shows the underwater environment

and live streaming on MATLAB where image processing has taken place and the detection of object is being observed on the MATLAB GUI.

D. Project Designing

This project used different types of components, which are shown in Table I.

Table I: Components List

Name	Quantity
Lipo Battery 5200mah.	1
Lipo Battery Charger/ discharger.	1
Arduino Mega 2560	1
Robotic arm.	1
6 channel transmitter/ receiver.	1
Monster Motor Shield	2
Barometer (BMP180)	1
Ultrasonic Sensor (JSN-SR04t)	1
Relay Module	2
Bilge Pump (1500GPH)	4
Solenoid Valve	1
Suction Pump	1
Endoscopic camera.	1
Jumper wires	----
Body	1

At present, the main controller is the Arduino Mega 2560 from which different sensors are connected, Arduino overall controls the functionality of the project. It is well said that it is the brain of the project.

There are sensors, in which Barometer “BMP180” and Ultrasonic Sensor “JSN-SR04t” are attached in the project. The barometer detects the temperature, pressure and altitude whereas the ultrasonic sensor detects the distance from the object and the sensors values are observed on the MATLAB GUI via serial communication.

The monster motor shield acts as a controlling device for motors, where Pulse Width Modulation (PWM) controls the speed of the motors.

The Robotic arm is also used in the project i.e., the grasping of objects, is done through it and it is controlled through RF remote.

The movement of the bot is from bilge pump which is of 1500 GPH. The left, right, forward, backward motion is held through it.

For the buoyancy factor, the PVC pipe is attached below the body in which solenoid and suction motor is attached. The solenoid valve is used for water input and suction motor pumps out the water, controlled by the relay module.

The objective of image processing is accomplished by the endoscopic camera attached on the body. Through image processing the object in the water can be detected. This project has the capability of detecting red, green and blue colored objects.

The RF remote is used for the input commands. As the radio signal attenuates very much in the water, for this reason the antenna in this project is kept above the water. The radio waves are affected by the phenomena of reflection, refraction, diffraction, absorption, polarization, and scattering.

IV. RESULTS AND DISCUSSION

Now, in this phase of paper we analyze the performance evaluation of ROV with radio frequency, for this purpose firstly we analyze the simulation results of motors on Proteus software, then we observed the image processing and sensors results on MATLAB GUI.

A. Motors Simulation

For checking purpose that Arduino code works perfectly or not, we used the Proteus Simulator which shows the results accordingly.

The Fig. 5 shows a, diagram of Proteus Simulator, here the checking of motor’s direction and speed controlling, has being observed.

Finally, the results in this simulator shows that the Arduino code is working perfectly and the motors are moving in proper direction and speed is also controlled according to the given command through virtual monitor.

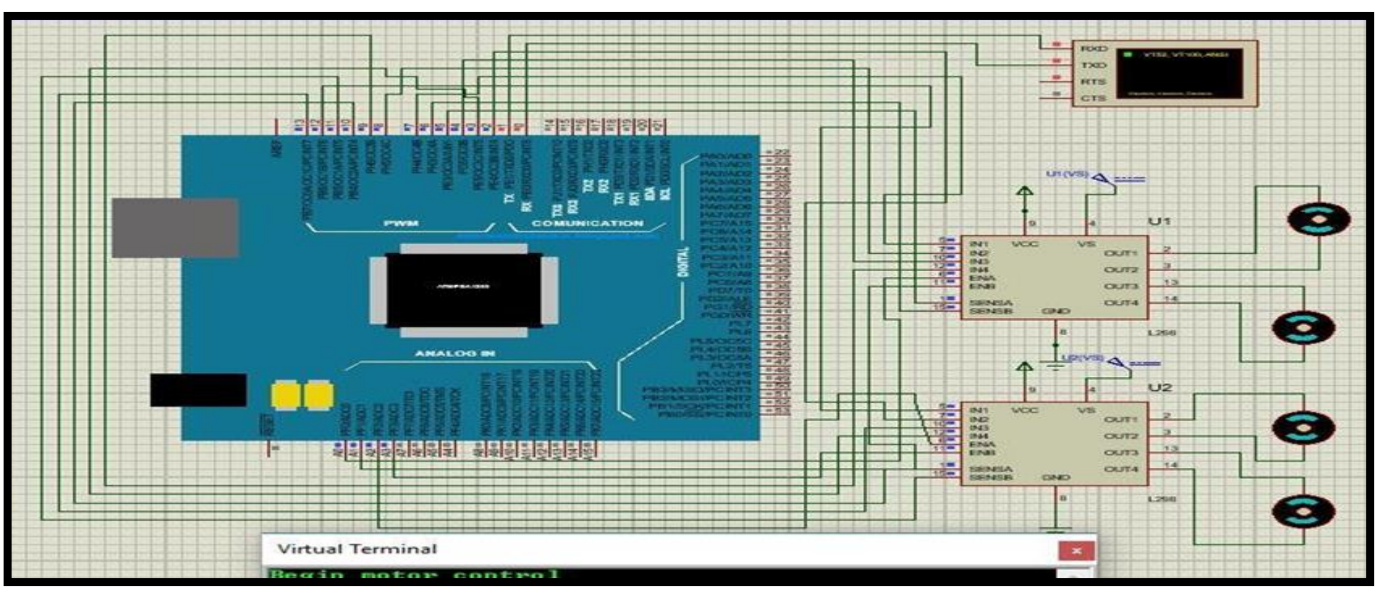


Fig. 5: Proteus Simulator

B. Image Processing and Sensors Reading on MATLAB

Developing stabilization software is a difficult task due to complex relationship between impellors settings and the dynamic effects. There are many potential techniques that could be used however, at the moment there is no possibility for testing them other than implementation in the real time.

Fig. 6 shows that before implementing it on a real robot, a simulator has been developed. A method for programming microcontrollers has been devised i.e., code can be transferred directly to the real controller after testing it on the simulator. The simulator provides visualization for users as a window in which it shows the pressure, temperature, altitude and distance between the arm and the objects.

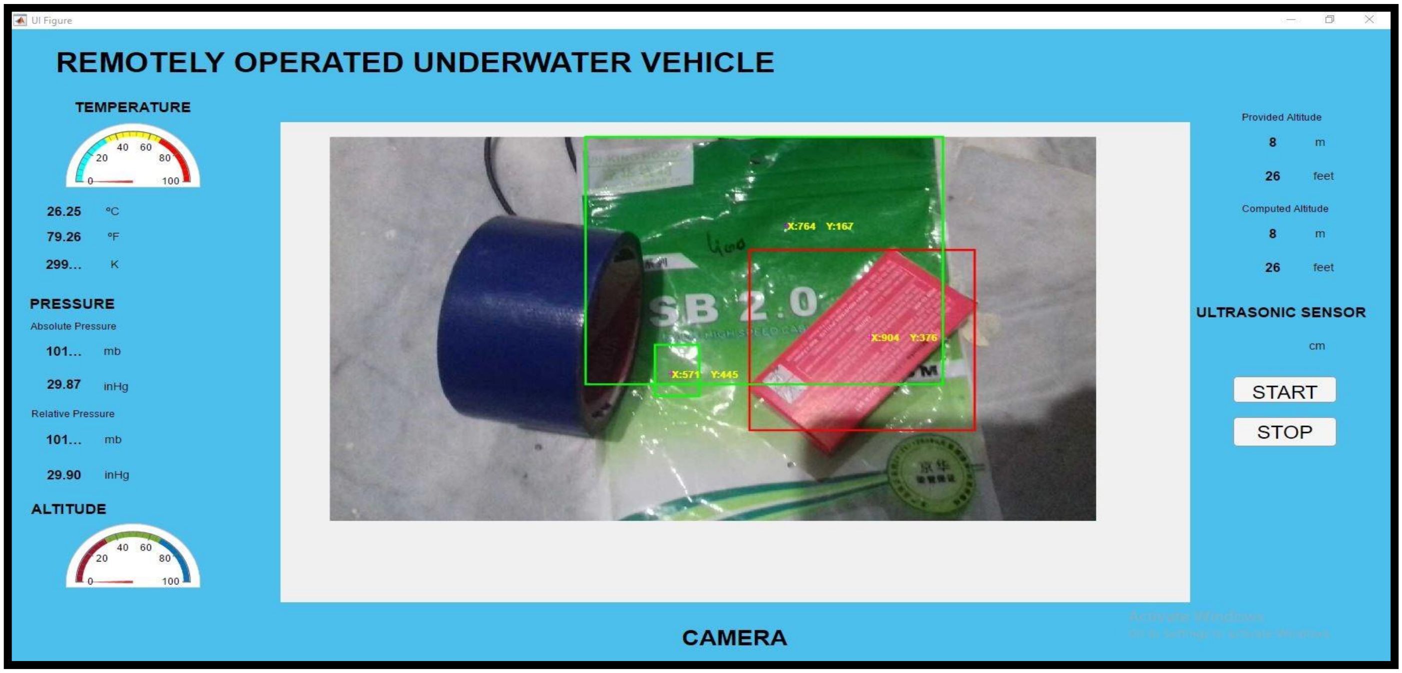


Fig. 6: MATLAB Simulator

The live streaming of an object can also be observed on this simulator and object detection is accomplished by image processing method..

C. RF Communication

Table II shows the RF channel table, in which we check, out the ranges of frequencies for each channel with their respective minimum value, maximum value and mid values**.**

Table II: Range of Frequency in Channels

CHANNEL	MIN VALUE	MAX VALUE	MID VALUE
CHANNEL 1	1070	1740	1401
CHANNEL 2	1085	1630	1350
CHANNEL 3	1150	1710	1410
CHANNEL 4	1040	1740	1300
CHANNEL 5	920	875	--
CHANNEL 6	920	1875	--

The readings from the table i.e., Table II, are essential for the ROV movements as the ranges of frequencies in the channels will brought up to make the conditional statements in the Arduino coding.

V. CONCLUSION

Working on the design and development of the prototype quad impellor underwater robot was a great experience. Such a project involves many engineering fields such as,

- Mechanics: mechanical structure and impellors
- Electronics: sensors, batteries and controllers
- Programming: microcontroller
- Physics: behavior of impellors and modelization of the device

The goal was to investigate the behavior of the prototype robot that would use a novel auto stability principle. In other words, everything had to be realized and designed from the mechanical structure to the electronics. Simulation test and real time experimental tests have shown that the prototype behaved as expected. This project also gives the necessary improvement that will have to be done on future projects as well as design hints. Working on this project was interesting, because of the multi-disciplinarily aspect.

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