Chapter 1: Introduction

This chapter presents the motivation for undertaking this project. It also emphasises the need of water quality monitoring and our objectives.

1.1 Motivation

At present, in India, lakes and wetlands are in varying degrees of environmental degradation due to industrial pollution. Despite knowing their environmental, social and economic significance, city planners have neglected these water bodies. Today these water bodies are at a high risk due to sewage and garbage disposal.

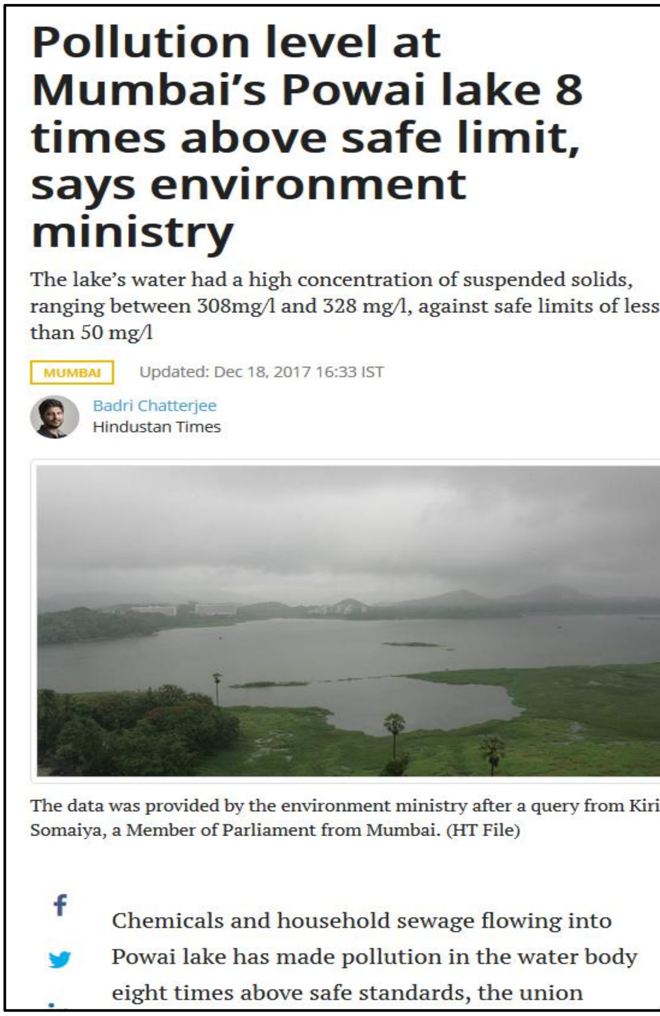
Pollution in large water bodies has resulted in a lot of disasters affecting aquatic life and the complete biocoenosis. Carcasses of aquatic animals are washed off shore due to mixing of pollutants, oil spills, etc. Thus, we felt a need to monitor the health of such large water bodies, using sensors and GPS control, in order to maintain balance in the ecosystem.

After a discussion about our project with an Indian Navy officer at INMEX SMM 2017 we realised about the problems faced by port authorities, to maintain channel depth to prevent grounding of ships. In most ports, channel depth is identified separately by a coast guard. However, this can be done by a rover which can use SONAR and model the underwater bed of waterways so that we can keep a track and maintain a pathway for boats.

Flooding of cities and villages happens due to various reasons. On 29th August, 2017 Mumbai was flooded. In the aftermath, it came to light that a doctor lost his life because of an open manhole. We believe that in the aftermath of floods, our autonomous rover will be capable of detecting such manholes via SONAR and pave a road where it is safe to walk. Also, emergency supplies like medical aid/food can also be delivered to stranded people at required locations using the rover by rescue officials.

After speaking to scientists at National Institute of Oceanography, Goa we understood that underwater imaging is required to study the geological features of the coast. Traditional surveillance boats cannot be operated in these shallow waters hence the Autonomous Water Rover can be used to get underwater images in these regions.

The following articles published in leading newspapers emphasize on the water quality



Pollution level at Mumbai's Powai lake 8 times above safe limit, says environment ministry

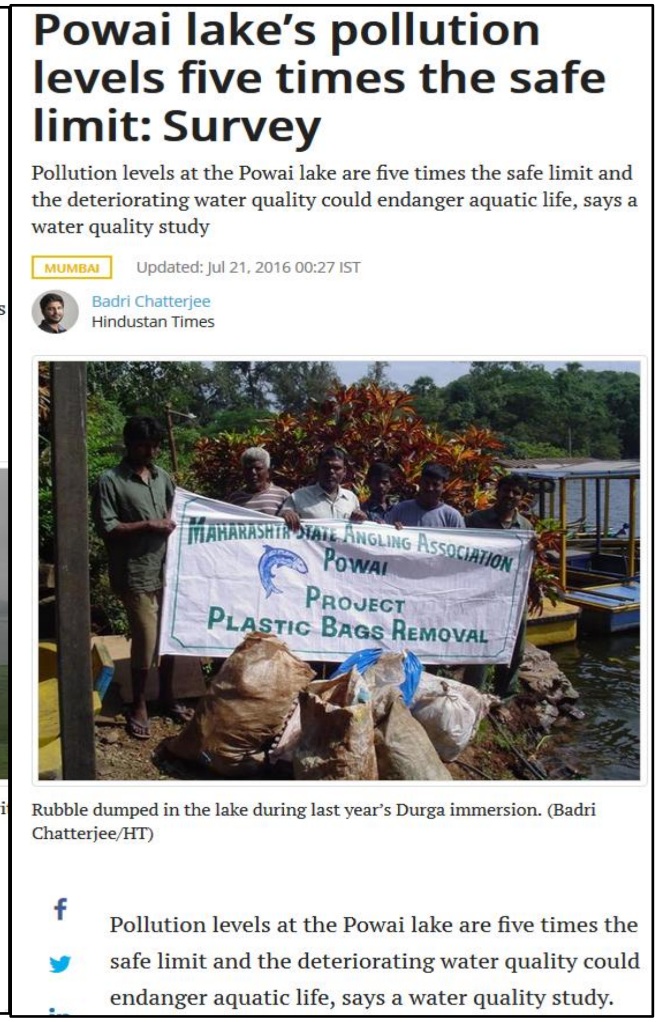
The lake's water had a high concentration of suspended solids, ranging between 308mg/l and 328 mg/l, against safe limits of less than 50 mg/l

MUMBAI Updated: Dec 18, 2017 16:33 IST

Badri Chatterjee
Hindustan Times

The data was provided by the environment ministry after a query from Kiri[t] Somaiya, a Member of Parliament from Mumbai. (HT File)

Chemicals and household sewage flowing into Powai lake has made pollution in the water body eight times above safe standards, the union



Powai lake's pollution levels five times the safe limit: Survey

Pollution levels at the Powai lake are five times the safe limit and the deteriorating water quality could endanger aquatic life, says a water quality study

MUMBAI Updated: Jul 21, 2016 00:27 IST

Badri Chatterjee
Hindustan Times

Rubble dumped in the lake during last year's Durga immersion. (Badri Chatterjee/HT)

Pollution levels at the Powai lake are five times the safe limit and the deteriorating water quality could endanger aquatic life, says a water quality study.

problems observed in India :

Fig. 1.1 Water Pollution in 2018

Fig. 1.2 Water Pollution in 2016

From above two articles it can be seen that the pollution in Powai lake has increased 1.6 times in just two years and if active measures are not taken to curb pollution it will likely increase in the coming years.

1.2 Objective

The Autonomous Water Rover (AWR) is aimed to be an unmanned surface vehicle that is capable of traversing water bodies in remote controlled or in autonomous mode.

The AWSR is aimed to be developed as a novel marine monitoring and surveillance technology that can continuously collect data on water quality in lakes, rivers, channels, ports and estuaries. The water parameters targeted are pH, temperature, turbidity, salinity and depth. The list of parameters were finalised after interaction with scientists from Naval Materials Research Laboratory and National Institute of Oceanography.

The AWSR will traverse a water body by following the path specified by the user using GPS coordinates along with active obstacle avoidance. It will also have a manual mode accessible through a website.

It will have surveillance equipment in the form of waterproof camera for underwater imaging, a sonar which will illustrate depth contours, fish targets and other structures. These features are of utmost importance for defence and hydrography purposes.

Our aim to track pollution by using Autonomous Water Rover will take the aquatic surveying industry closer to industry 4.0 by incorporating Internet of Things, Robotics and Cloud Computing along other cutting edge technologies. The next chapter summarises research done on unmanned surface vessels for various applications.

Chapter 2: Literature Survey

This chapter presents the overview of the technological research and advancements and the comparative study of various USV technologies and products available commercially along with their applications in research and bathymetry studies.

Papers from 1994 are taken into consideration for this project. Some of the papers were used to understand autonomous vehicles and their functioning along with applications, while some were on combined works in all the 3 fields. The research work on all the fields mentioned above is given below.

2.1 Autonomous water vehicles and applications

Exploring water bodies using manned and unmanned vehicles dates back to post WWII. Since then many developments have been made, which can be broadly classified as Remote-controlled vehicles and autonomous vehicles.

Some papers have aimed at collecting data from bottom transecting vehicles (ROVER) [1], while some provide robust designs for research in cooperative autonomy [2]. Rest of the papers focused on developing different methodology for achieving specified targeted goals.

<table>
<tr><th>Sr. No.</th><th colspan="2">Category</th><th>Author(s)</th><th>Year</th></tr>
<tr><td>1</td><td colspan="2">Unmanned Surface Vehicles [3]</td><td>Justin E. Manley</td><td>2008</td></tr>
<tr><td rowspan="3">2</td><td colspan="2" rowspan="3">Research</td><td>J. Curcio, J. Leonard, A. Patrikalakis</td><td>2014</td></tr>
<tr><td>Erion Plaku, James McMahon</td><td>2016</td></tr>
<tr><td>Geoffrey A. Hollinger, Urbashi Mitra, and Gaurav S. Sukhatme</td><td>2012</td></tr>
<tr><td>3</td><td>Other Applications</td><td>Inspection</td><td>Pere Ridao, Marc Carreras, David Ribas, and Rafael Garcia</td><td>2010</td></tr>
</table>

			Brian Bingham, Brendan Foley, Hanumant Singh, and Richard Camilli	2010
			Thomas Birtchnella & Chris Gibsona	2015
		Defense	Thomas Pastore, Vladimir Djapic [4]	2010
			P.E Hagen, N Storkersen	2003
			Liam Paull, Sajad Saeedi, Mae Seto	2012
			E Bovio, D. Cecchi, F. Baralli	2006

Table 2.1 : List of papers based on applications

2.2 Combined study

While few researchers were studying about aquatic life, developments were made simultaneously in existing models by other engineers and researchers, which involved combining concepts of machine vision, AI or IP or by satellite control. Their research works are listed in the table below.

Sr. No.	Category	Author(s)	Year	Specification
1	Surface Monitoring and sampling	Goudey, T Consi J. Manley, MGraham	1998	Fish Monitoring
		Caccia M, Bono R, *Bruzzone Ga*	2005	Sea Surface sampling
		J.E Manley	1997	Surface robot
		J. E. Manley, A. Marsh, W. Cornforth	2000	Surface craft
		Iuliu Vasilescu, Keith Kotay	2005	Data collection
		Matthew Dunbabin, Alistair Grinham, James Udy	2009	Surface monitoring

2	Fish Monitoring	M Dunbabin, L Marques	2012	Monitoring
		P. Newman	2002	Operating Suite
		J. Vaganay, J. Leonard, J. Curcio, and S. Willcox	2004	Navigation
		Elgar Desa, R. Madhan and P. Maurya	2006	Ocean Data
		Yun-Heh Chen-Burger , Gayathri Nadarajan, Robert B. Fisher	1995	Tracking Fish
3	Depth and bed surface monitoring	T Vaneck, M Schmidt	1996	Bathymetry
		L. L. Whitcomb, D. R. Yoerger, and H. Singh	1999	Navigation of underwater vehicle
		C.C. Eriksen, T.J. Osse, R.D. Light	2001	Depth monitoring and research

Table 2.2 : List of papers based on combined applications

2.3 RESEARCH GAP

In all, 23 research papers were studied. These papers were categorized according to the categories mentioned above. Above literature review shows that studies are going on simultaneously on autonomous water vehicles as well as their advancement. Thus, selecting a proper research gap has become an important in this case. A small summary was made in order to identify the research gap as shown below.

2.3.1 Area of Research

In this section, all the papers are broadly classified as per the major area of research. Main categories are: Research, Monitoring and Defense.

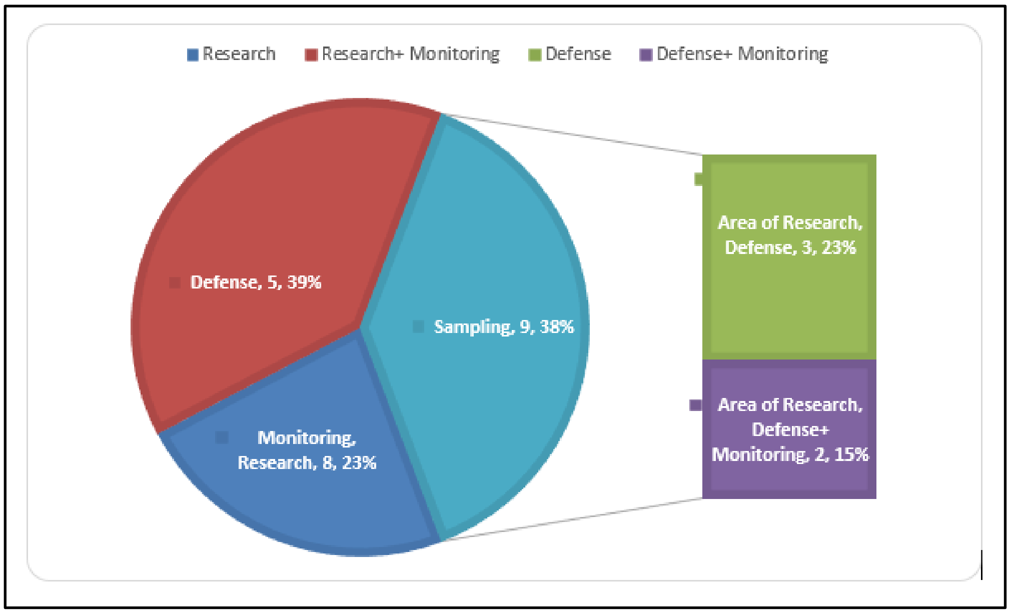


Fig 2.1 Application based categorisation of literature

From the above chart, it is clear that till date, surface water vehicles are used for data acquisition mostly targeted on water beds. Least research is in field of dredging and surface quality monitoring. Hence these field are chosen.

2.3.2 Year of Research

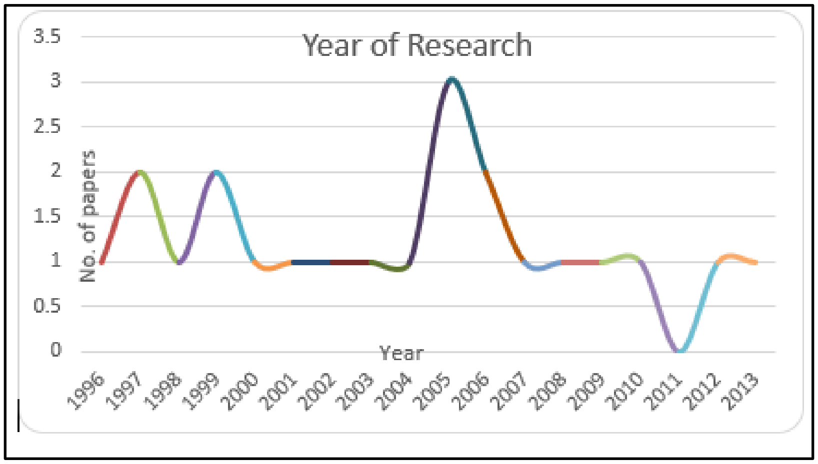


Fig 2.2 Categorisation of literature with time

The above chart shows that research is continuously going on from year 2010 in these fields. Thus, there is no saturation in our area of research and there is continuous development in this stream.

2.4 A review on water quality mapping in Powai lake

The paper "Water Quality in Powai Lake, J.G Kiloyar, N.S Rokade, Taal2007: presented at the 12th World Lake Conference, 2008" discusses the water quality of Powai lake which is a large artificial lake, situated in a northern suburb of Mumbai. The purpose of this paper, in this survey is to collect information concerning use and value of water quality monitoring at Powai lake that might affect aquatic life. This paper studies the changes in different parameters of water as the season changes. For this, it maps the presence of impurities in the lake and many different parameters like DO, COD, Nitrogen, TDS, COnducting, Salinity, Chloride, Total Hardness, pH and Alkalinity.

It was observed that during the month wise sampling of the various physio-chemical parameters of the lake, the samples collected were position specific. However, the process of collecting the sample was manual and the positional accuracy might have varied over the months. Also, a more precise and accurate data variation can be structured if the number of samples obtained are more.

The graphs below show the variations of conductivity and pH as measured every month at six stations over a period of six months.

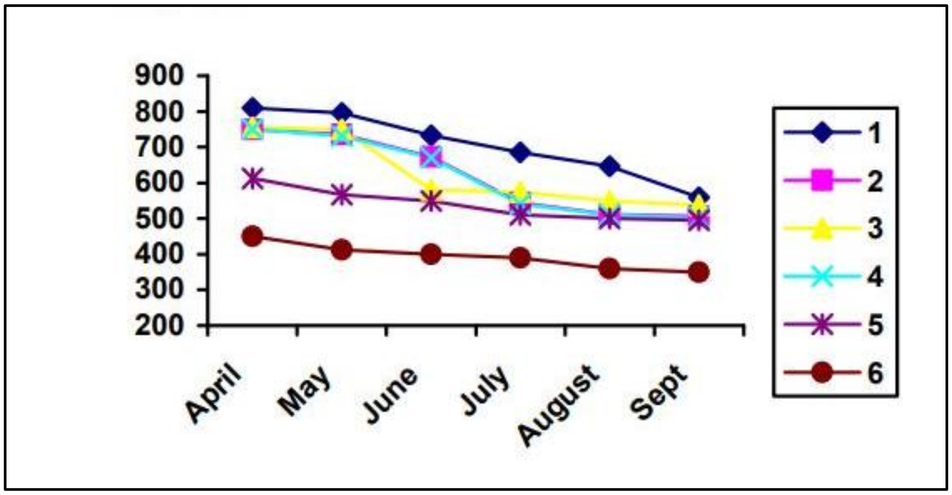


Fig 2.3 Variation of conductivity with time and location

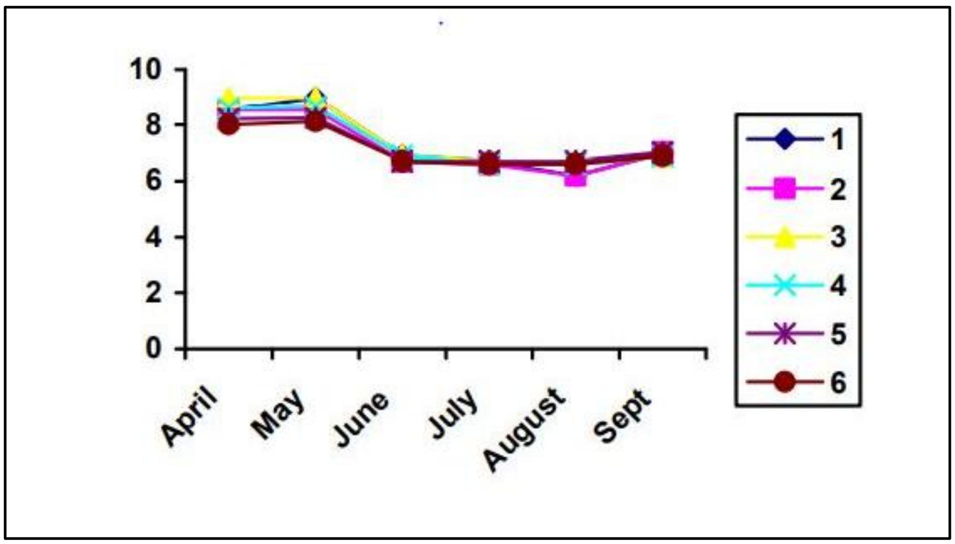


Fig 2.4 Variation of pH with time and location

2.5 Commercially available Unmanned Surface Vehicles

Commercial products were also studied to analyse the existing technologies and the capital associated to address these problems.

Kongsberg Gruppen located in Norway, has developed GeoSwath 4R USV, for bathymetry and hydrography surveying. It is capable of :

- Ultra high resolution wide swath bathymetry (FOV 240 - degrees)
- Geo-referenced side scan
- Radio control up to a range of 2 km
- Enduring 2.5 hours of continuous operation

Oceanalpha Company Limited located in Guangdong, China has developed ESM30 USV, for water quality monitoring and sampling. It is capable of :

- Measuring parameters such as pH, DO, temperature, ORP, conductivity and turbidity.
- Sampling water at four locations for further analysis in labs.
- Autonomous navigation, remote operation along with obstacle avoidance.
- Video streaming upto 2 km and data communication upto 5 km
- Enduring 3.5 hours of continuous operation
- Cost $52,000/-

Fig 2.5 GeoSwath 4R USV

Fig 2.6 ESM30 USV

After going through the ongoing research and development in the field of unmanned surface vessels, the design and development of Autonomous Water Rover will be explained in the next chapter.

Chapter 3: Project Design

3.1 Design Considerations

The requirement of the surface vehicle with the targeted objectives was the first consideration for selecting the base of the rover. The rover is required to provide maximum payload capacity in minimum volume. There should be a container inside or on the rover which can contain the electronic components for the entire rover. The compartment must be waterproof and must prevent water from entering the container. Also while providing with waterproofing the compartment should also not interfere with any signals that is being transmitted or received by the transceivers inside the compartment like GPS and compass. A camera is required for first person view of the rover which should have sufficient field of vision to cover the entire forward path. In addition the rover should also feature a propulsion system to drive the rover and a maneuvering system for controlling the heading direction. Additionally, to increase the mission duration of the rover, it should be provided with a secondary power source preferably solar power.

3.2 Support Structure

3.2.1 Hull selection

After considering our application it became evident that speed was not of great importance for our use and emphasis was given to simplify the manufacturing process and keep our project cost-effective. Most boats feature a hull made of aluminium, while most of the unmanned vehicles tend to feature fiber reinforced polymers. Analysis for selection of the material of the rover's hull was done with feasibility and time as the major decisive parameters.

Hull material options:

Metal: Most rovers and made with metal hulls. They generally fall in two categories: Aluminium and Steel. Metal hulls provide high strength and more impact damage resistance. Relative to their weight, aluminium provide incredible strength and are highly ductile. The pitfall with metal hulls in water rovers are their vulnerability to corrosion, scaling and providing shielding effect for components placed inside the hull. The aluminium hulls are also prone to galvanic corrosion with a stainless steel propeller or bolts. The outside of the hull are prone to rusting and pitting due to this galvanic corrosion.

Wood: Wood is another known material which is known to be used for building boats for a very long time. Wood has less density than water so it floats giving high buoyancy posing as a safe and sturdy vessel. However, using wood as hull also has some drawbacks. If left in water for long time, worms eat away the timber. Termites attack the dry wood. SInce the rover is meant to be used to still waters marine bores poses as a great threat to the hull. Wood hulls are susceptible to to electrolysis damage. Electrolysis can cause damage to the to the wood and turn them into mulch and mush.

Fiberglass: Fiberglass reinforced plastics is the most widely used hull material in unmanned surface as well as underwater vehicles. FIberglass provide thinner hulls with comparable strength. Thinner hulls do then to flex more and can be given any desired shape. Fiberglass vessels also tend to be lighter and provide sufficient strength for long lasting structures. Fiberglass are invulnerable to any kind of electrolytic damage or corrosion. At first glance it seems like fiberglass can be the best available material for the hull of the rover. The only constraint with it is the availability and the capital required for its manufacturing.

After examining the available materials and resources we decided to use PVC pipes for the the support structure for our AWR. The overall benefit of using PVC pipes are: improved stability, increase in the load capacity and reduction in manufacturing cost.

PVC pipes were used for the following reasons :

- They are manufactured to transport liquids (mostly water); for this they are manufactured so as to sustain high pressure. The water at the surface of water bodies exert significantly lesser pressure, making our rover apparently leak proof.
- Sealing the ends of the pipe is possible as standard end caps are available.
- Multiple pipes can be attached according to the requirement of length and width in accordance with maximum roll and pitch the rover needs to sustain.
- Impervious to attack from fungi.

While PVC pipes exhibit high resistance to abrasion, they are affected by the environment. The following are the effects of varying environmental features on the PVC pipes:

Thermal Effects:

The properties of the PVC pipes are significantly related to the operating temperatures. The rover must be deployable in wide varieties of water bodies with varying temperatures. Also the temperature significantly varies throughout the day in a single water body. PVC pipes are rated for maximum performance at 23°C; as the operating temperature decreases, the pipe’s stiffness and the tensile strength increase, thereby increasing the pipe’s pressure capacity.

Biological Attack:

PVC pipes are nearly impervious to biological effects. These attacks can be caused by the action of living microorganisms viz. Bacteria and fungi. PVC pipes will not deteriorate or break down under such attack, nor will it serve as a nutrient to microorganisms, or fungi.

Weathering Resistance:

PVC pipes can incur surface damage when subjected to long exposure to ultraviolet radiation from sunlight. While the rover is supposed to work in direct sunlight it became imperative to rule out the vulnerability. This was achieved by physical coating of the pipes with layers of oil paint. Since the ultraviolet degradation occurs when energy from UV rays leads to excitation of the molecular bonds in the plastic, the layer of paint prevents any direct contact between the PVC and sunlight.

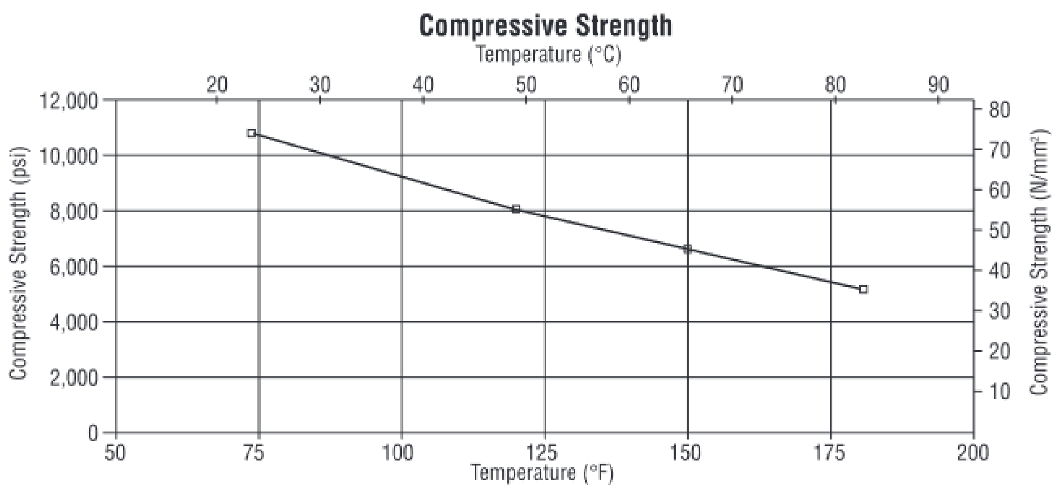


Fig 3.1 Compressive strength graph for PVC

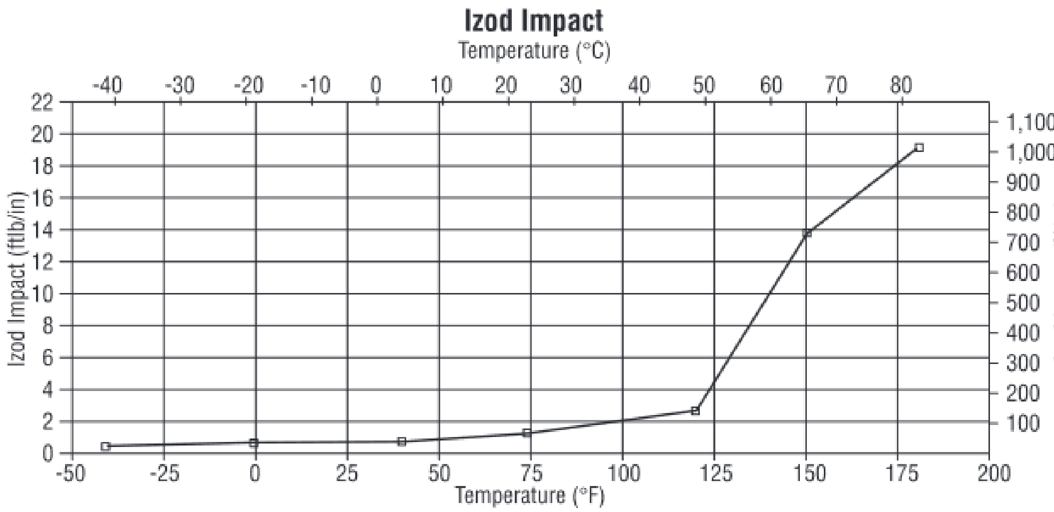


Fig 3.2 Izod Impact test graph for PVC

3.3 Boat Structure:

The primary requirement of the support structure of the rover is to provide stability, buoyancy and a solid platform. Owing to the limited manufacturability of the PVC pipes, we selected the conventional raft type structure.

We selected PVC pipes of varying lengths with outer diameter 16 cm and coupled them together representing a raft for making the support structure of the rover. The middle pipe was kept the longest and one small pipe was attached on front and back each. This provided with maximum roll stability while keeping the weight minimum.

The total number of pipes to be joined was decided as per the payload of the rover. The layer was made by adding 3 pipes of lengths 300 mm, 300 mm and 900 mm.

The three pipes are held together in place using a aluminium strip loop wound around them. The Al strip is kept in tension to retain its shape and an adhesive is used to close the loop while retaining it on the pipe. Additionally copper wires were used to increase the tension in the strip to ensure firm structure of the support.

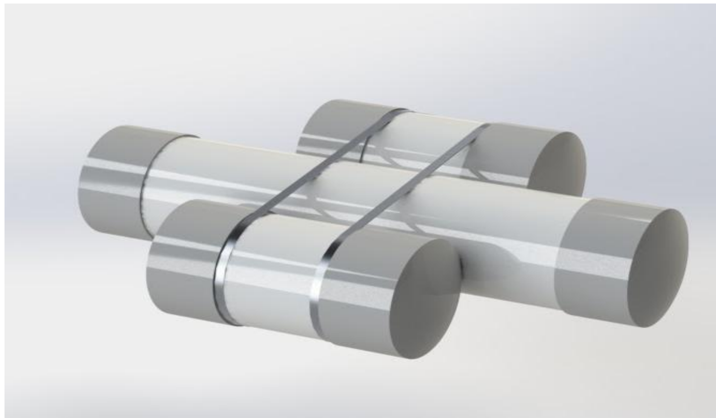


Fig 3.3 Support Structure

3.4 Buoyancy calculation:

Buoyancy = Weight of fluid displaced

Buoyant force is given by:

$$F_b = \rho_w * g * V$$

Volume of pipes :

$$V = 2 * l_1 * b_1 + l_2 * b_2$$

The total weight of fluid displaced is about 30.56 kg.

3.5 Top Plate: The PVC pipes provides round surface which cannot be used for any kind of mountings. Furthermore to secure waterproofing it was opted to avoid any kind of drilling in the pipes. So a 2 mm aluminium sheet was used as the top plate to provide a constant surface. This allowed all the components, equipments and thrusters to be mounted on the rover with additional reinforcements.

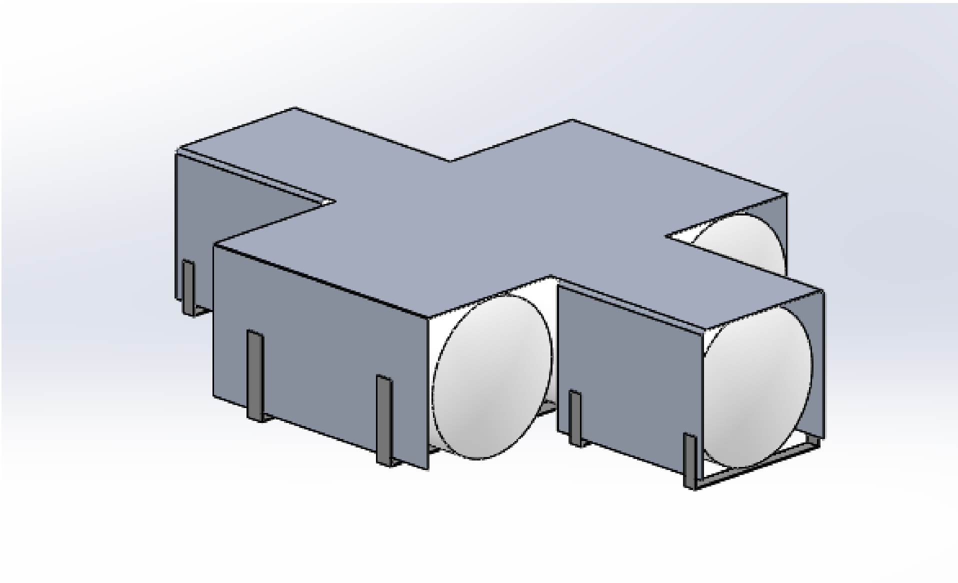


Fig 3.4 Reinforcements

3.6 Propulsion System:

Motor Selection:

The target waters for AWR are still and weedy waters. Conventional propulsion system has a potential to clog in weeds and needs to be cleared. Instead it was decided to use differential reaction drive for propulsion using two submersible pumps.

The reaction drive works by having an intake which is located below the hull submerged in water. Water enters the pump through the inlet. The pump is usually centrifugal pump for higher speeds or axial flow type for medium or low speeds. The water pressure in increased inside the pump and is directed outward through a nozzle.

3.7 Thrust Calculation:

Thrust from a propeller is given substituting Bernoulli’s equation into thrust equation (momentum equation)

$$F = A * \Delta P$$

$$\Delta P = pt_e - pt_o$$

$$\Delta P = 1/2 * \rho * (V_e^2 - V_o^2)$$

Substituting in Bernoulli's equation:

$$F = 1/2 * r * A * [V_e^2 - V_0^2]$$

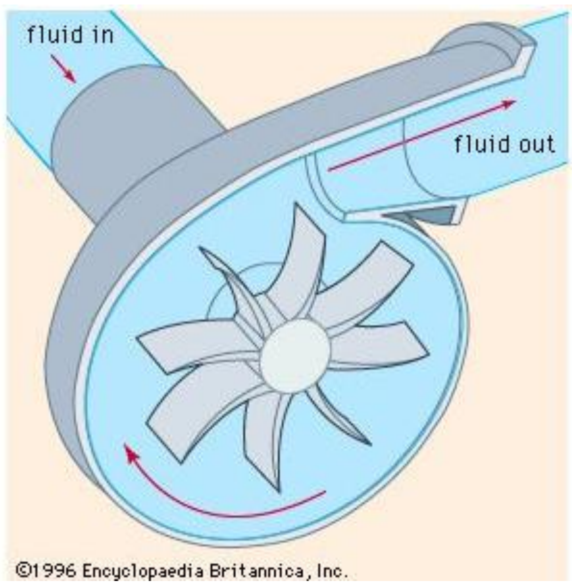


Fig 3.5 Working of Bilge Pump

The pump selected was Vetus V1000.

Output:	3800 L/hr
Max. Head:	4 m
Outlet Diameter:	28.5 mm
Dimensions (Ø x H):	90 x 120 mm

The bilge pump exhibits the following superiorities which made it most viable propulsion system for our rover:

- The bilge pumps are submersible water pumps. So there was no need of waterproofing the motors.
- Since the impeller is directly attached to the motor shaft in the pump there was no need for transmission shaft.
- The pumps can be directly mounted outside and there’s no need to locate them inside the rover body.
- A filter is provided to prevent seaweed from getting stuck in the impeller.
- Speed can be adjusted by controlling the rotation speed of the motor.

3.8 Final Design:

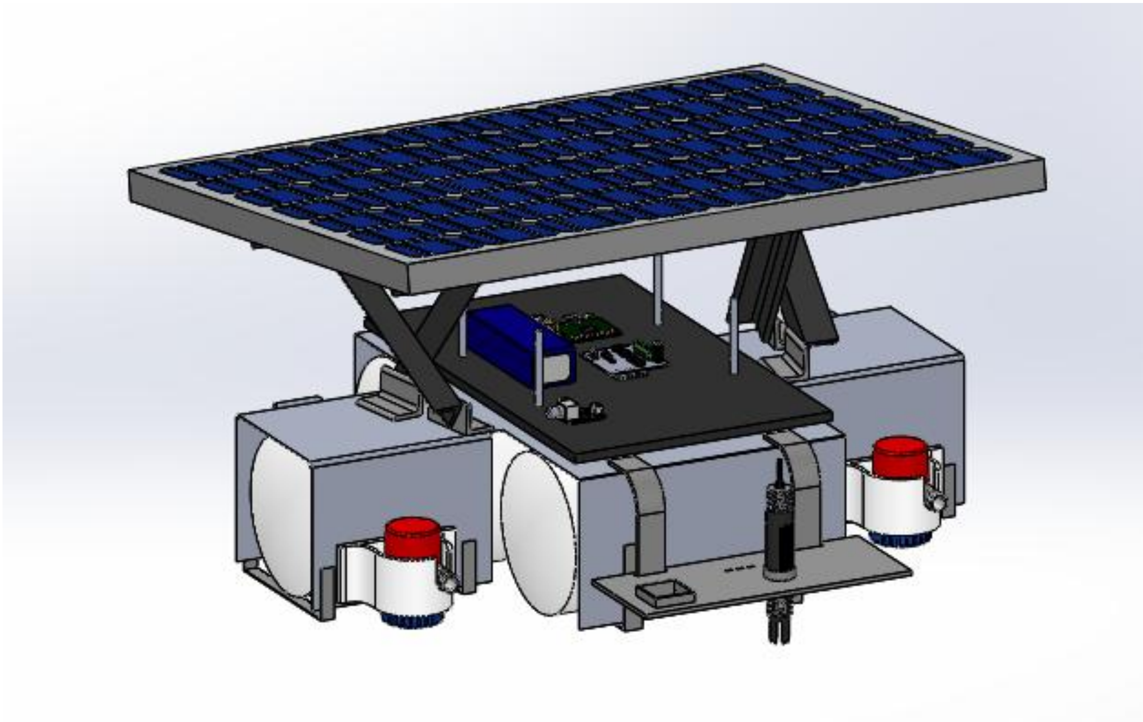


Fig 3.7 CAD of Final Design

The final design includes a polypropylene sheet on top of the aluminium sheet for insulation from circuits. A solar panel is added to recharge the battery and add to the run time of the rover.

Principal axes of inertia and principal moments of inertia: (grams * square millimeters)
Taken at the center of mass.

Ix = (0.00, 0.00, 1.00)	Px = 897234608.07
Iy = (0.96, 0.27, 0.00)	Py = 1136627042.03
Iz = (-0.27, 0.96, 0.00)	Pz = 1291193297.90

Center of mass: (millimeters)

X = 2.38

Y = 171.37

Z = 349.05

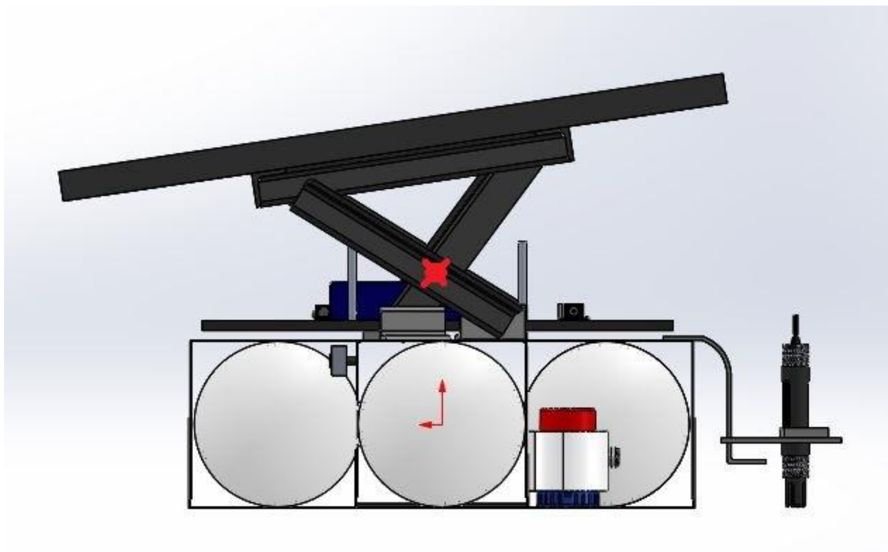


Fig 3.8 Center of mass position (Side View)

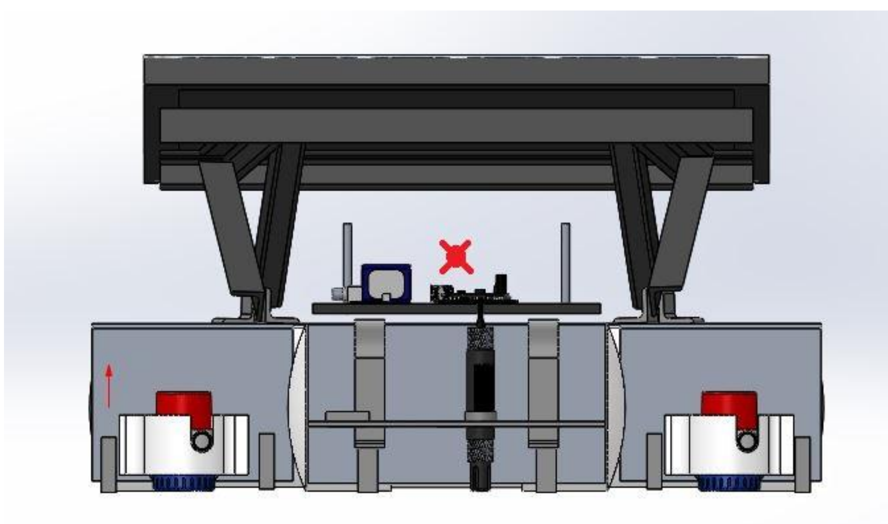


Fig 3.9 Center of mass position (Rear View)

Chapter 4 : Implementation Details

This chapter presents the hardware design, software implementation, cost report and testing results for the various components of the Autonomous Water Rover. It also presents the image processing algorithm used for enhancement of underwater video feed.

4.1 System design

The figure below illustrates the various components in the Autonomous Water Rover and their relation with one another. Some of the components like the thrusters and the solar panel were explained in the product design section. The hardware and software components will be covered in this chapter.

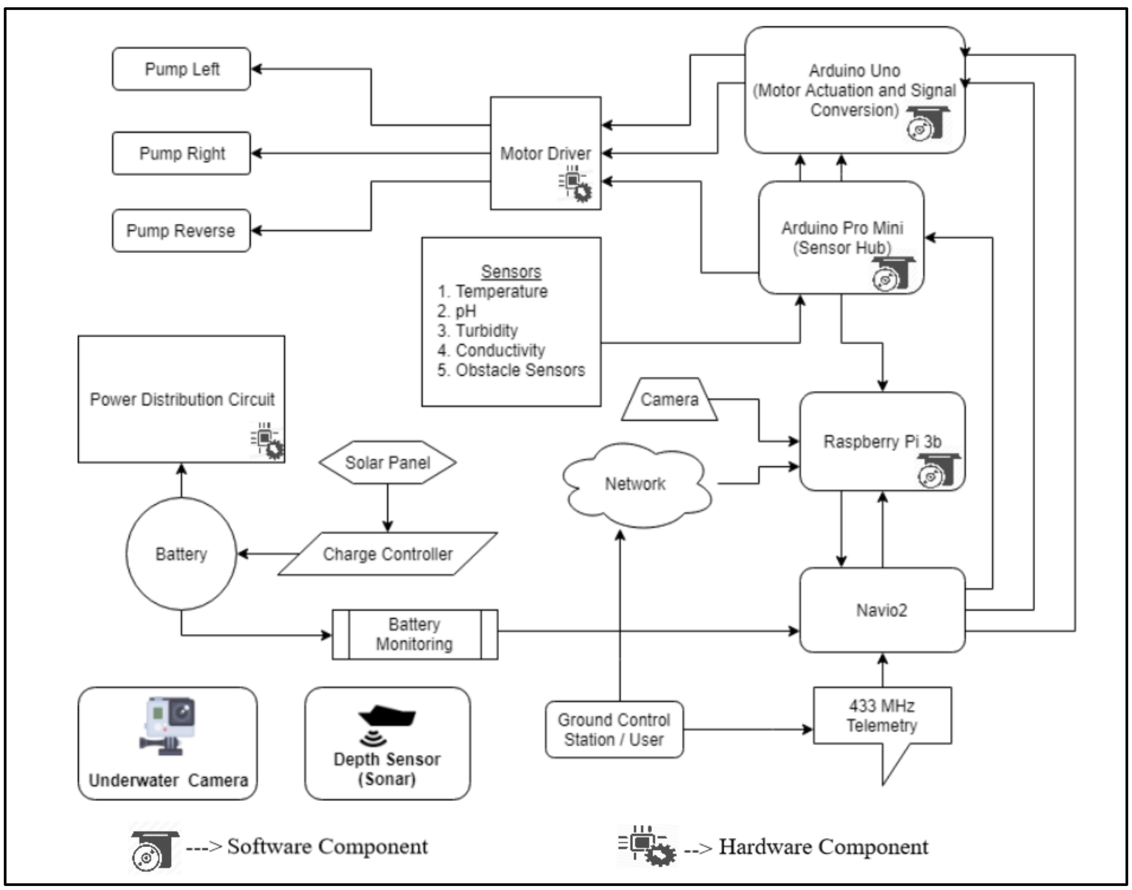


Fig 4.1 System Design

The various components in the above figure are as follows :-

- **Power System**: The power generation, storage and distribution includes the following main components :
    - Battery : LiPo will be used to ensure operation of rover for over an hour on one charging
    - Solar Panel : A 50W Solar Panel is used to charge the 12 volt battery and also increase the operation period
    - Charge Controller : A 20A 12V waterproof solar panel charge controller will be used
    - Voltage regulation : Voltage regulators will be used to always keep the supply voltage for the pumps constant i.e. 12V to obtain similar performance even at different battery levels. Also 5V and 3.3V voltage regulators will be used for obtaining required supply voltage for the Rpi controller board, Navio2, telemetry and all installed sensors on the rover

- **Raspberry Pi 3b** : It is a single board computer which will be used for complex path planning through ardupilot, hosting the web interface, providing live video streaming and communicating with sensor nodes
- **Navio2** : It is an autopilot Hat for Raspberry Pi 3b which simplifies autonomous navigation by bringing multiple sensors on a single board and by seamless integration with Raspberry Pi. It also has analog to digital converters along with pulse generators to produce pulses which can control servo motors. The following sensors will be used by the Autonomous Water Surveillance Rover :
    - GNSS Receiver : Tracks GPS, GLONASS, Beidou, Galileo and SBAS satellites for accurate positioning
    - Dual IMU : Accelerometers, gyroscope and magnetometer readings will be used for orientation and motion sensing
    - High resolution barometer : Senses altitude with 10 cm resolution and can be used to relay accurate location information along with GPS

- Communication Ports : UART interface will be used to relay information through telemetry radio

- **Ground Control Station** : It could be any windows based personal computer having Mission Planner installed
- **Local Area Network** : A LAN is created to access the website hosted on the raspberry pi. It is not needed for operation in autonomous mode
- **Telemetry Radio** : The mRo SiK Telemetry Radio V2 operates at 433Mhz and provides 300m range by default. This radio will be the link to relay localization details and program missions for the rover remotely
- **Underwater Camera** : A GoPro hero is used to gather images of the underwater bed upto three meters. As penetration of light at this depth is sufficient, an illuminating light source will not be necessary. The light source can be fitted to the base of the rover for illumination if surveillance is to be done in the absence of sunlight
- **Camera** : A raspberry pi camera version 2 is used to provide live first person view of the rover to operator
- **Sensor Node** : Data acquisition from the environment will carried out and the information will be relayed to the Rpi. An arduino pro mini is used because of its small form factor for interfacing the sensors and communicating with raspberry pi
- **Distance Sensors** : Two waterproof ultrasound (40 KHz) distance sensors i.e. JSN-SR04T are used to detect obstacles on the surface of the water and in the forward path of the rover
- **Water Quality Monitoring Sensors** : To measure the quality of water following parameters are being measured :-
    - ***pH*** : DFRobot Gravity : analog pH sensor is being used to measure the pH of water. The pH measurements have a resolution of ± 0.1pH at 25 ℃
    - ***Temperature*** : DS18B20 waterproof temperature sensor probe is used to get ±0.5°C accuracy in the range -10°C to +85°C. It uses 1-Wire interface i.e. requires only one digital pin for communication

- *Conductivity* : A generic rain sensitive sensor module is used in analog mode to get the conductivity readings. The accuracy of this module for measuring isn't high but can be used for thresholding purposes
    - ***Turbidity*** : DFRobot Gravity : analog turbidity sensor is used to obtain the turbidity readings which is later converted to NTU units.
- **Fish Finder** : ZEEPIN Fish Finder is a wireless & rechargeable sonar sensor along with a smart portable LCD display which is used to get depth data, temperature data along with the add on of identifying fishing areas

- **Signal Converter** : The output signal from the Navio 2 is in the form of RC pulses of the duration 1ms to 2ms. The external interrupt pins of an arduino uno is used to measure the pulse widths of these pulses and accordingly generate a PWM signal which drives the motor driver circuit
- **Motor Driver Circuit** : The arduino uno will send control signals to the motor driver which in turn will control the actuator i.e. pumps. The pumps will be operated at variable speed according to navigation control using PWM to allow more precise control over the rover

4.2 Hardware Design

Hardware design has three main components. They involve the power distribution circuit, the motor driver circuit and other peripheral device connections. A circuit as shown below was designed to reduce wire connections and also to simplify sensor interfacing. It includes the power distribution system, the motor driver circuits and sensor input slots for the Arduino Pro Mini.

4.2.1 Motor Driver Circuit

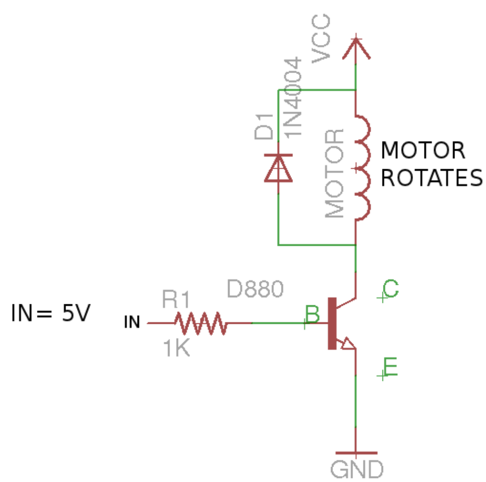


Fig 4.2 MOSFET schematic

Fig 4.2 shows the basic controlling of a motor using a MOSFET. We have used IRFZ544 MOSFETs to drive 3 bilge pumps. We did use standard motor driver circuits because the pumps needed to be controlled in only one direction, unlike the standard motor usage where we need bidirectional control. As the bilge pumps cannot propel water backwards, we used 3 pumps, 2 at the back for differential propulsion and 1 at the front for braking. To drive the MOSFETs, we need to control the voltage formed at the Gate w.r.t. Source which is done by the Arduino Microcontroller. Proportionately, the Drain current will flow through the bilge pump as required

4.2.2 Power Distribution Circuit

The 12V Lipo battery is connected to a General Purpose Board on which different circuits of the system are soldered. The voltage is stepped down for powering the sensors and the microcontroller board, using a LM2596 buck converter which step downs the voltage from 12V to 5V. The circuit is soldered on a General Purpose Board.

4.2.2.1 Solar Panel

Calculations for Solar Panel and Battery

Operating Voltage of System =12V Current Consumption = 10AH

Power Consumption = 120W/hour

Per day power consumption = 360 WHr (Considering 3 trials per day)

Battery Ampere Hour Rating = 360W / 12V = 30A.

Battery of 12V 30A is needed

Charging time = 6 hours, 360/6 = 60Wh, 60/0.6 = 100W

Solar Panel of 12v 100W would be suitable for high efficiency

4.2.3 Peripheral Devices

The peripheral devices include the RPI 3b, Navio 2, Arduino Pro Mini, Arduino Uno and sensors. The following subsection go through the process of setting them up.

Attaching Navio2 to a Raspberry Pi

- Install spacers to the top side of Raspberry Pi and fix them with screws from the bottom.
- Connect extension header to the 40-pin gpio port.
- Attach Navio2 to the extension header.
- Fix Navio2 using screws

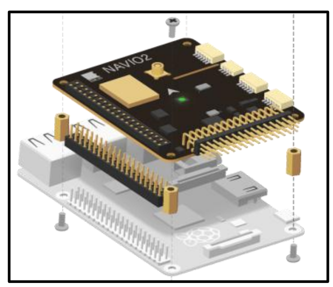


Fig 4.3 Navio2 Setup

4.2.3.1 Making Wired Connections

After Navio2 is mounted on RPI we have to proceed and attach other peripherals and wires for communication and sensors. The connection diagram is as follows :-

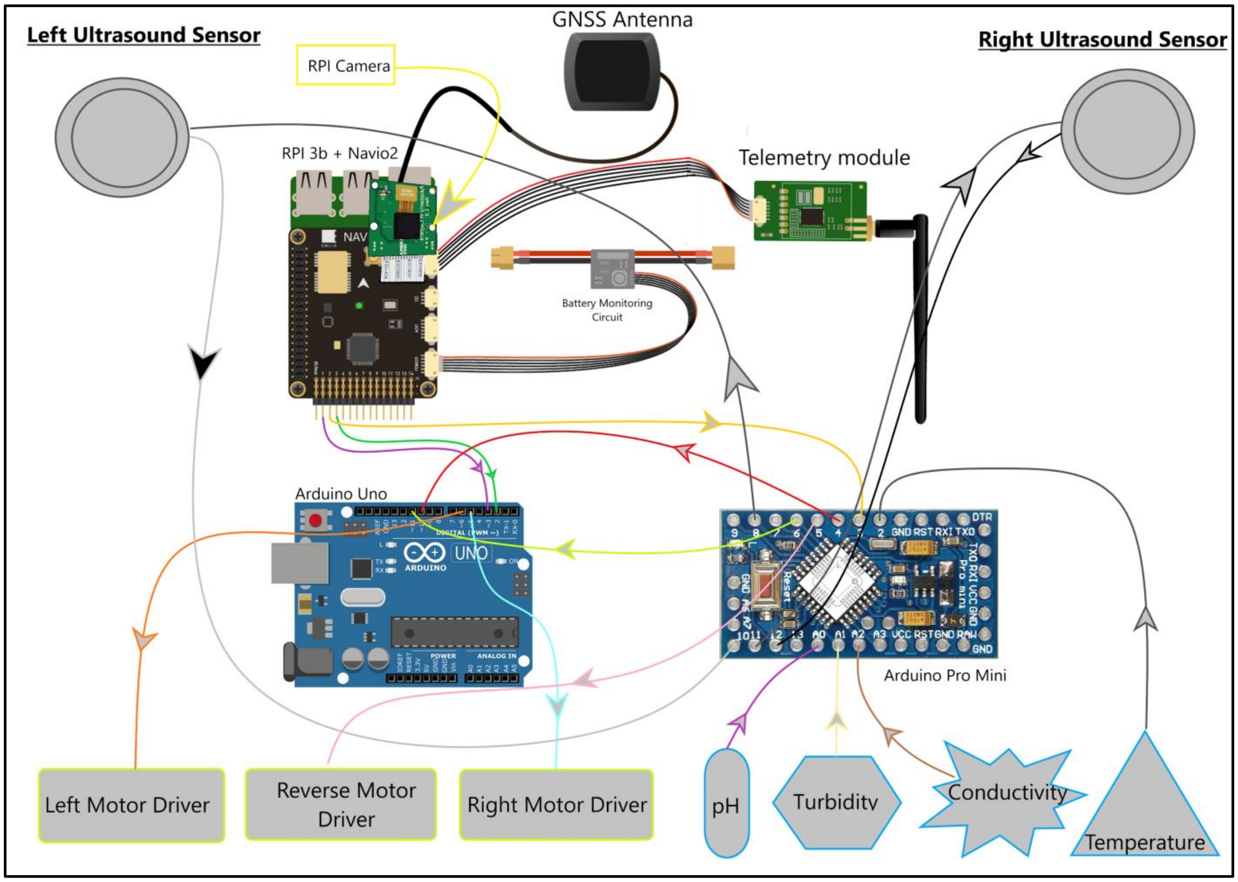


Fig 4.4 Peripheral Connection Diagram

In Fig 4.4 the power connections haven't been illustrated and are to be made for each sensor. Each board also has a common ground connection. The Arduino Pro Mini is also connected to the RPI through an UART to USB converter to communicate sensor data to the RPI. At the Ground Control Station the receiver of the radio telemetry module is connected using an USB connection. When the rover is to be deployed in manual mode a local wifi network is created to control the rover from the web interface.

4.3 Software Implementation

As seen in Fig 4.1 there are three blocks which have a software component. They are :

I. Raspberry Pi 3B
II. Arduino Pro Mini
III. Arduino Uno

The three are related to one another as shown in Fig 4.1. The underlying technology stack is explained in the following sections.

4.3.1 Raspberry Pi 3B

The RPI is used as autopilot with Navio2, as a server for the web interface and as central hub for all sensor data.

- An open source preconfigured raspbian stretch image is provided by the developers of Navio2. The image has the necessary drivers for communicating with an ardupilot ground control station using MAVLink protocol. The image is configured for an ardupilot rover during the initial setup. The calibration of IMU. PID coefficients and other settings are configured using Mission Planner, which is an open source Ground Control Station
- The web interface is hosted using a Flask application written in python. The design of the website is done using HTML5 and CSS. Javascript is used for dealing with dynamic page elements
- Major APIs used are Just Gauge for representation of sensor data and Google Maps API for displaying real time location of the rover
- SQLite is used for storing sensor data received from Arduino Pro Mini and GPS data from Navio2
- Matplotlib library in python is used for generating plots of sensor data which are then displayed on the website

- Motion service is used on RPI to host live video stream on port 8080 of the RPI which is also displayed on the website
- Socket programming is used in the flask server for updating the location of the rover in real time.The screenshots of the various web pages are as follows :-

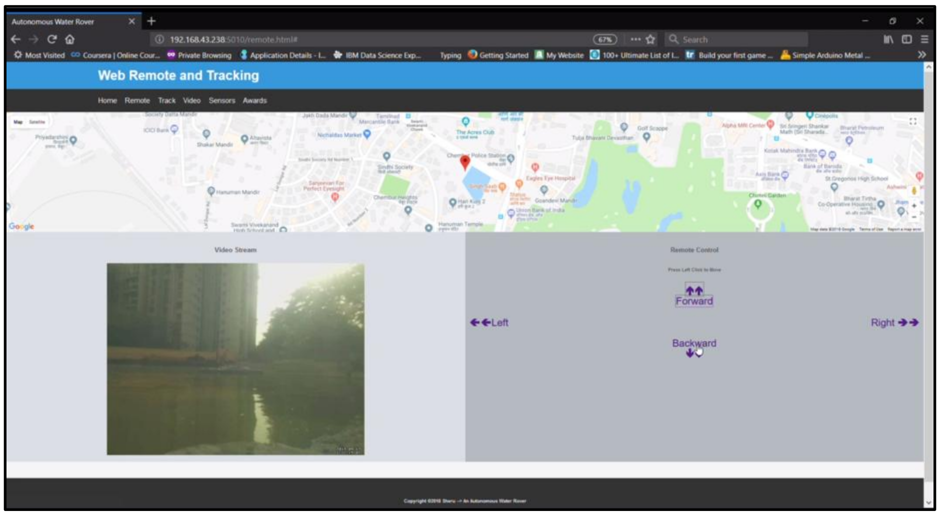


Fig 4.5 Remote Control Web Interface

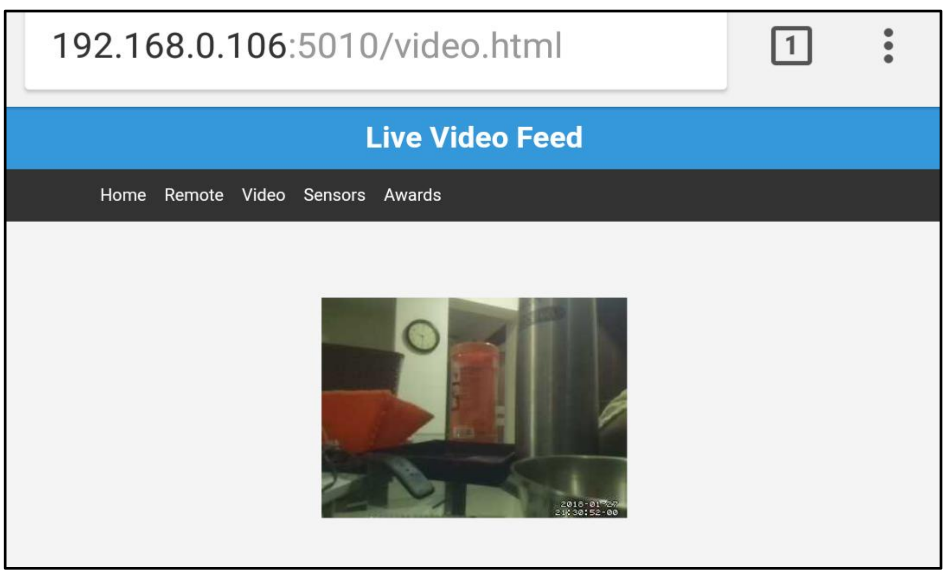


Fig 4.6 Live Video Stream (First Person View of AWR)

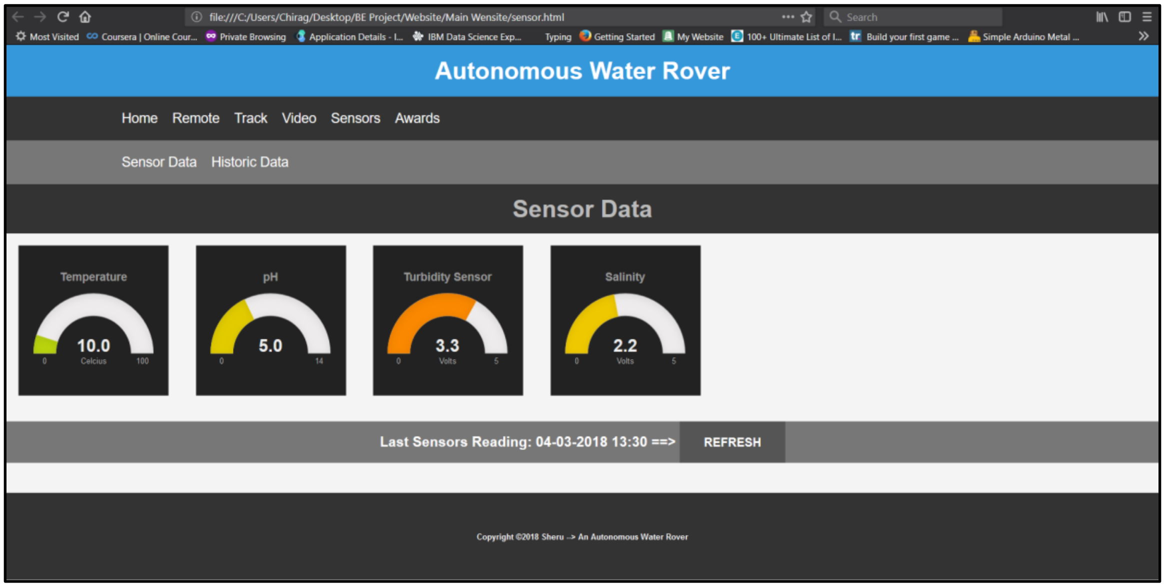


Fig 4.7 Latest Sensor Reading Visualization

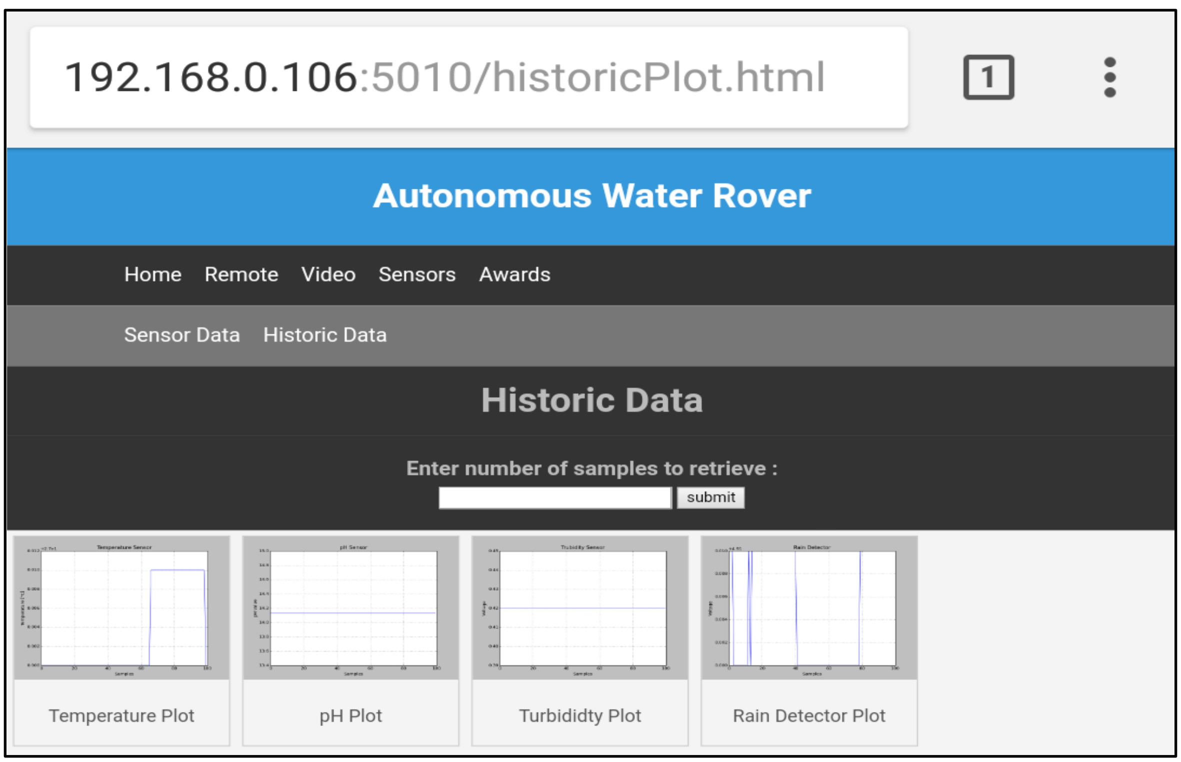


Fig 4.8 Historic Sensor data Visualization

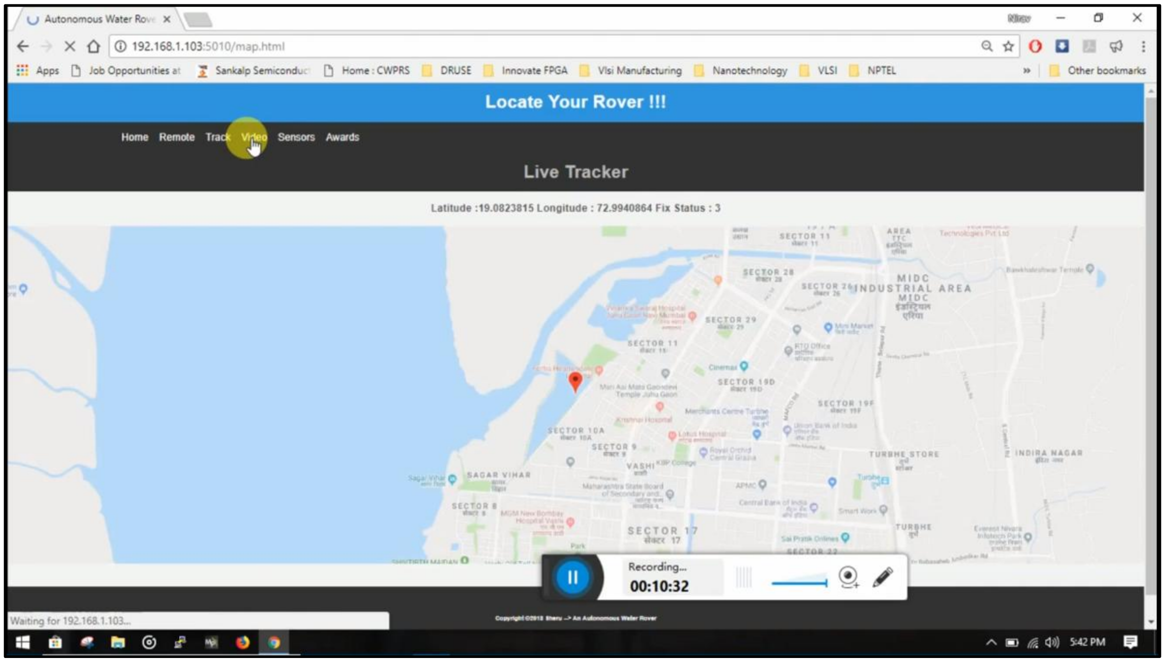


Fig 4.9 Location Tracker in the Web interface

4.3.2 Arduino Pro Mini

This device used as a sensor node which not only interprets sensor data but also does some preprocessing and forwards the data to the RPI for further processing. The main functions implemented on this device are :-

- Reading the digital values of the analog signals from pH, turbidity and conductivity sensor through the ADC. Also, every final reading is the average of 40 readings in order to reduce outliers in sensor readings. The sensor reading is then sent to the RPI as per the frequency decided by the user. One reading is usually sent every eight seconds
- Temperature sensor readings are read by using the one wire protocol which is implemented in the sensor
- Distance sensor readings are computed by triggering the sensors and then reading the pulse width of the output signal at the echo pin of the sensor. After computing the distance the sensors change the state of two digital pins which is then read by the Arduino Uno to control the heading of the rover

- The external interrupt pin is used to measure the pulse width of the output signal from tha Navio2 board. The pulse width is then used to compute the duty cycle of the PWM signal which is given as input to the motor driver controlling the reverse pump

4.3.3 Arduino Uno

This device is used as a signal converter as commercially available modules for the same are expensive. The functions implemented on this board are :-

- It is used as a signal converter which measures the pulse width of pulses from the Navio2 board using the external interrupt pins present on the microcontroller. The pulse width is then used to compute the duty cycle of the PWM signals which are given as input to the motor drivers controlling the right and left pumps
- It reads the state of two digital pins on the Arduino Pro Mini. These pins indicate the presence of an obstacle if any, to the Arduino Uno

Raspberry Pi 3b
1. Flask ---> Server (Python)
2. HTML, Javascript, CSS ---> Web Interface
3. Database --> Sqlite3 using python
4. Communication with arduino -->python
5. GPS and RC pulses ---> Python
6. Motion --> Live video streaming
7. Ardupilot --> Autonomous Navigation

Arduino Pro Mini
1. Sensor data Acquisition and filtering
2. Control reverse motor
3. Communication with RPI
4. Indicating obstacles to Arduino Uno

Arduino Uno
1. Control forward pumps according to Navio o/p obstacle data

Fig 4.10 Tasks of controllers

4.4 Ground Control Station

Mission Planner a full-featured ground station application for the ArduPilot open source autopilot project is used. It is compatible with Planes, Copters and Rovers but we are using it in the Rover mode. It is compatible with Windows only. Mission Planner can be used as a configuration utility or as a dynamic control supplement for an autonomous vehicle. Few actions that can be accomplished using Mission Planner are :-

- Load the firmware on the Navio2 board
- Setup, configure, and tune the AWR for optimum performance
- Plan, save and load autonomous missions into the autopilot with simple point-and-click way-point entry on Google or other maps
- Download and analyze mission logs created by autopilot
- Interface with a PC flight simulator to create a full hardware-in-the-loop UAV simulator
- With radio telemetry hardware we can :
    - Monitor our vehicle's status while in operation
    - Record telemetry logs which contain much more information the the on-board autopilot logs
    - View and analyze the telemetry logs

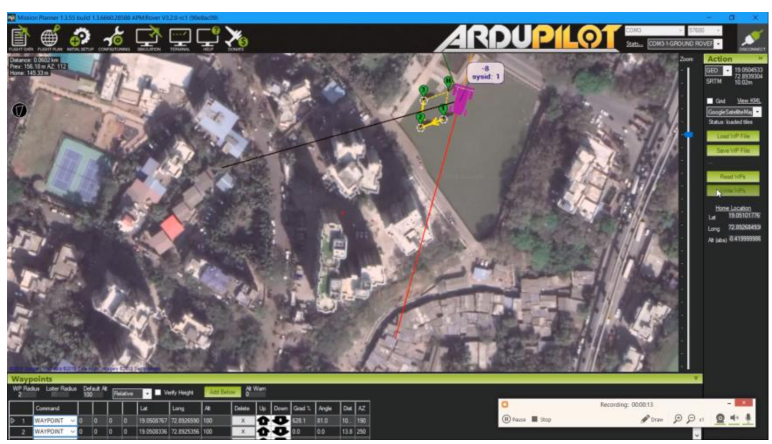


Fig 4.11 GCS waypoint Planning Interface

4.5 Under Water Image Processing using Wavelet Fusion

Taking reference from IEEE paper "Underwater Image Enhancement by Wavelet Based Fusion" a model has been implemented to enhance an underwater video captured during the testing of "Autonomous Water Rover".

The flow of the process is as follows :-

Step 1: Import image

Step 2: Contrast Adjustment using CLAHE

Step 3: Colour Correction using histogram stretching of V in HSV

Step 4: Wavelet Fusion of images from step 2 and 3 using

- 2 level decomposition
- A db2 wavelet
- 'max' rule for approximate coefficients and 'min' rule for detail coefficients

Step 5: Get enhanced image

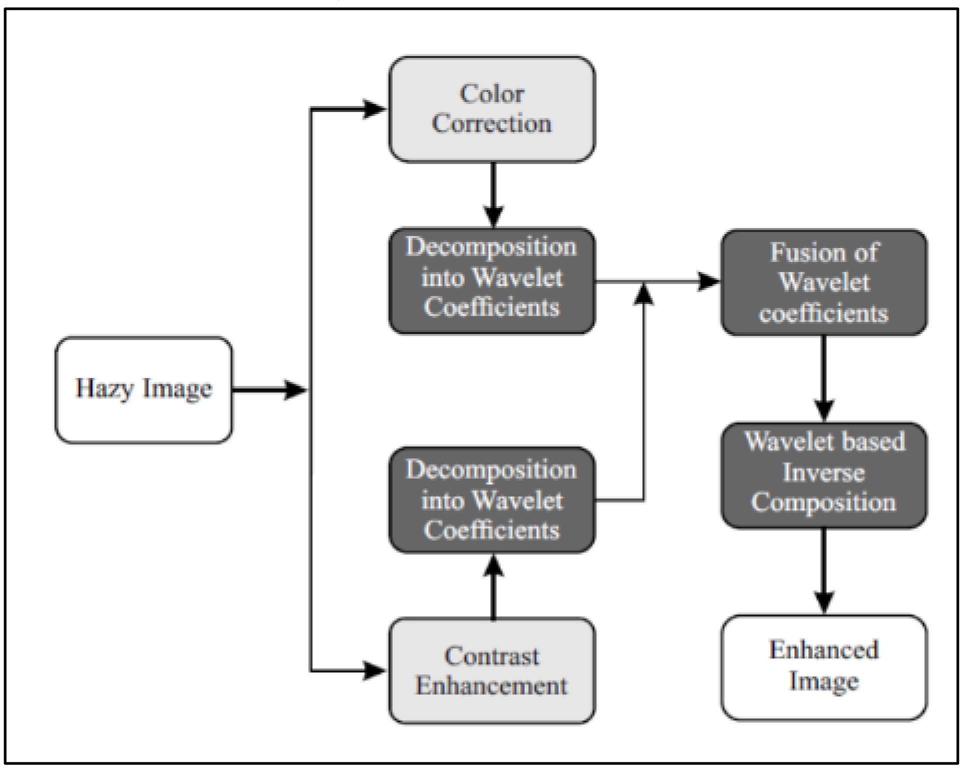


Fig 4.12 Underwater Image enhancement algorithm

Results

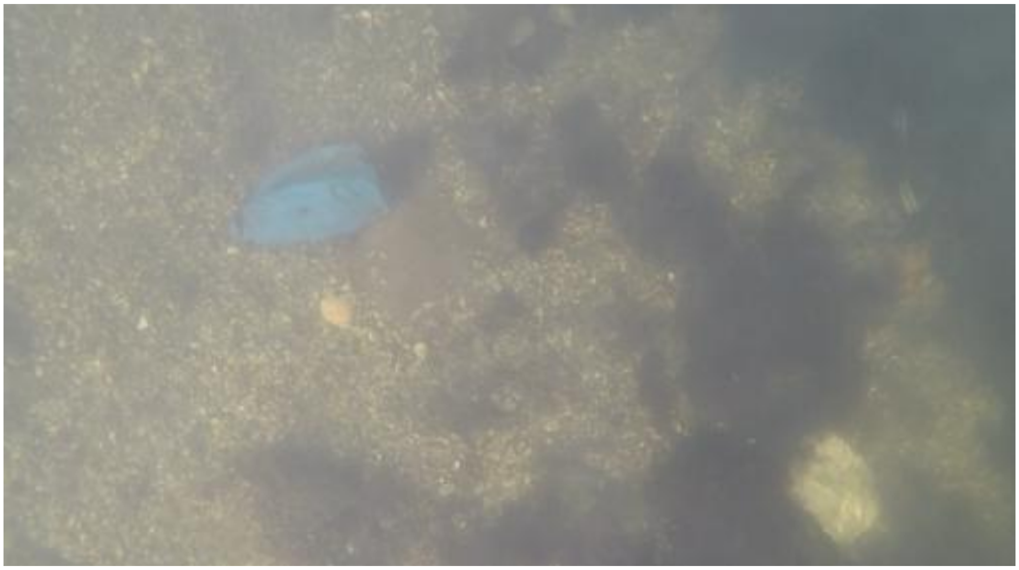


Fig 4.13 Original Image

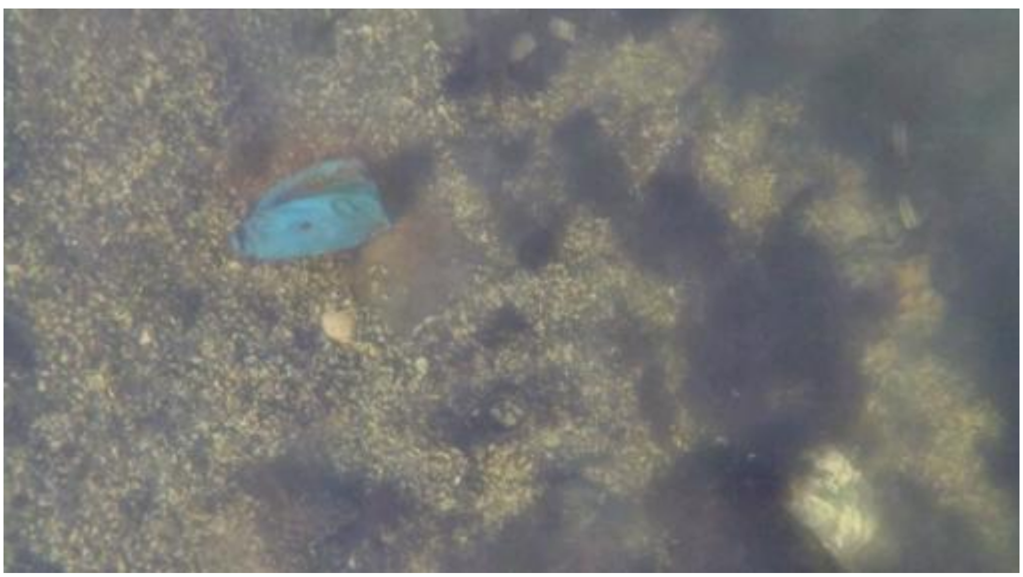


Fig 4.14 Enhanced Image

4.6 Pricing Model

The prototyping cost of the model can be divided into two parts :

1. Autonomous Water Rover
2. Sensors for data acquisition

Table 4.1 : Retail Costing for Autonomous Water Rover

Sr. No.	Component	Price
1	Mechanical Components	₹6,500
2	Hardware Components	₹16,500
3	Solar Panel and Circuitry	₹3,500
	Total :-	₹26,500

The above total cost of ₹ 26,500 is absolute for every user and is the base price to get a fully functional Autonomous Water Rover. As the rover can be used for various applications, depending on the application the sensors can be selected according to the need of the user.

We aim to build the model which is convenient for every use case .i.e. To provide the user the option to choose the sensors either from a list of sensors available or to enable him/her to incorporate their existing sensors onto the rover with minor modifications in the mechanical and software architecture of the AWSR.

Table 4.2 Retail Costing for Sensors on the AWSR:

Sr. No.	Sensor	Price
1	Echosounder	₹11,000 /-
2	pH	₹4,000 /-
3	Turbidity	₹1,500 /-
4	Temperature	₹165 /-

5	Conductivity	₹200 /-
6	Underwater Imaging Camera	₹30,000 /-

Hence, as per the needs of the user the user can customise the sensors needed for the mission.

4.7 Target Market

- AWSR can provide water quality data to the recipient government or non-government bodies for keeping a track on the fluctuations in water parameters viz. pH, temperature, salinity, dissolved oxygen.
- AWSR can also provide indigenous solution for fish tracking in freshwater bodies and in fish farming to aid fish dependent communities.
- In ports, the channel depth monitoring is essential for preventing grounding of ships. AWSR can be used to monitor the channel depths and provide seasonal data to dredging department.
- AWSR can assist the naval bodies by providing above water as well as underwater surveillance; while the rover is equipped with an echo sounder for depth mapping, it can also provide underwater video feed upto a depth of 5 m for hydrography mapping.
- AWSR can also aid the defence forces in emergency relief operations where emergency supplies are to be transported to stranded individuals in cases of floods and other natural calamities.

Chapter 5 : Implementation for deployment in real world

This chapter explains step by step procedure of working and also showcases the sensor data accumulated

Step 1: Customising of the Rover

At this stage the user will have the flexibility to select the features of the water rover that the user needs to enable/disable. For instance in the application of surveying sea bed underwater camera, light source for flash, echosounder will be necessary.

Step 2: Deciding the Route of the Rover

The user will mark the checkpoints on a map with the order in which the areas have to traversed. This will be made possible by the computer application called mission planner for ardupilot compatible boards. A snapshot of the UI is as shown to right.

Fig 5.1 Mapping of checkpoints

Step 3: Programming the Rover

The user will program the ardupilot board i.e. the Navio2 mounted on the Raspberry Pi 3b through the mission planner software. Once the programming is done the rover can be deployed in the water body which has to be monitored. The point of deployment can be chosen according to the closest checkpoint.

Step 4 : Remote Control of the Rover

The user can give commands to the Rpi through the active telemetry radio which connects Ground Control Station and the Autonomous Water Surveillance Rover. New routes or evacuation signals can be sent through this link.

Step 5 : Data Acquisition and Visualization

The data gathered by the AWR is to the Ground Control Station and visualized using various data processing softwares such as R, python etc. This visualization will be made available to the user in real time, ensuring that time sensitive applications like emergency relief, surveillance and are not hindered.

Fig 5.2 Conductivity

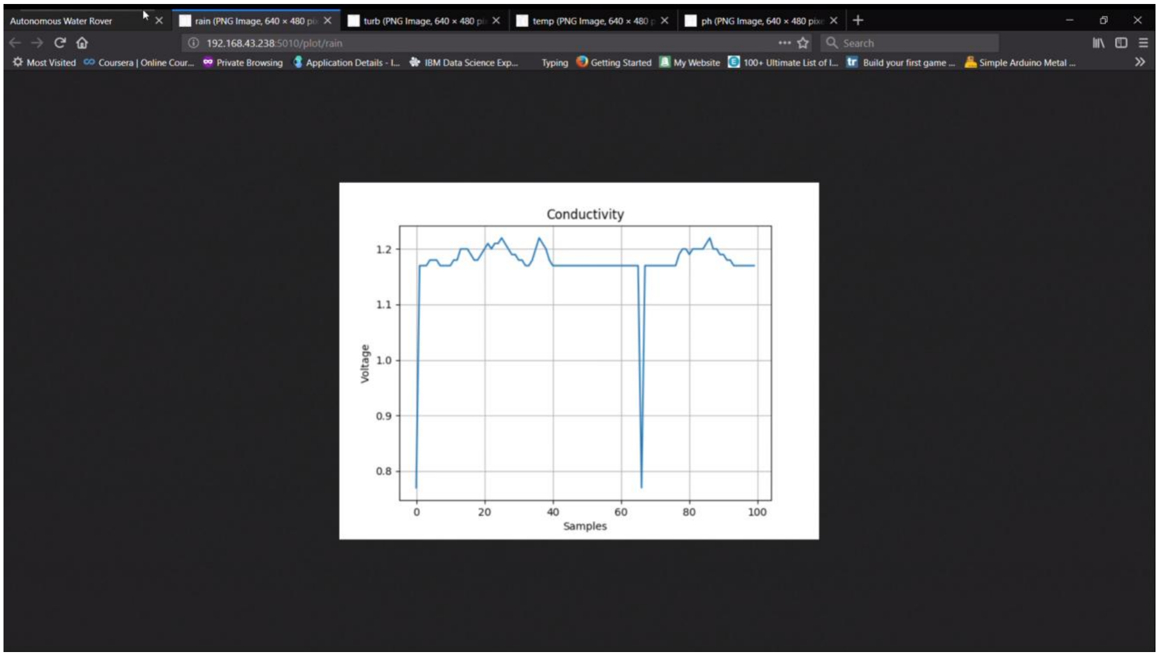


Fig 5.3 Turbidity

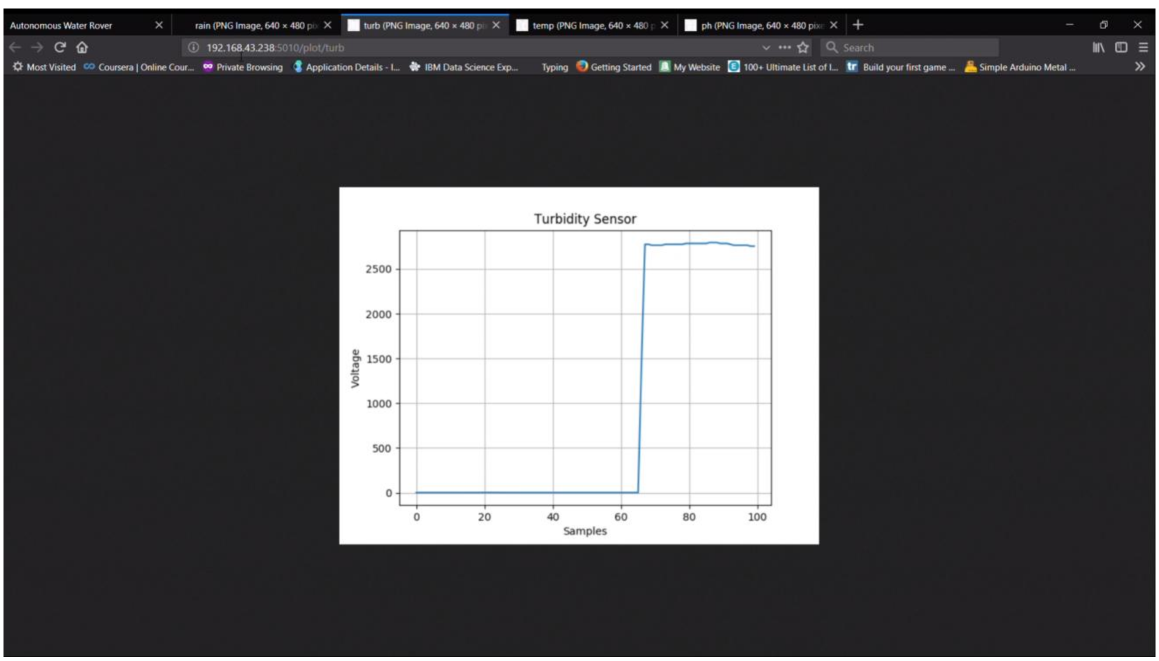


Fig 5.4 pH

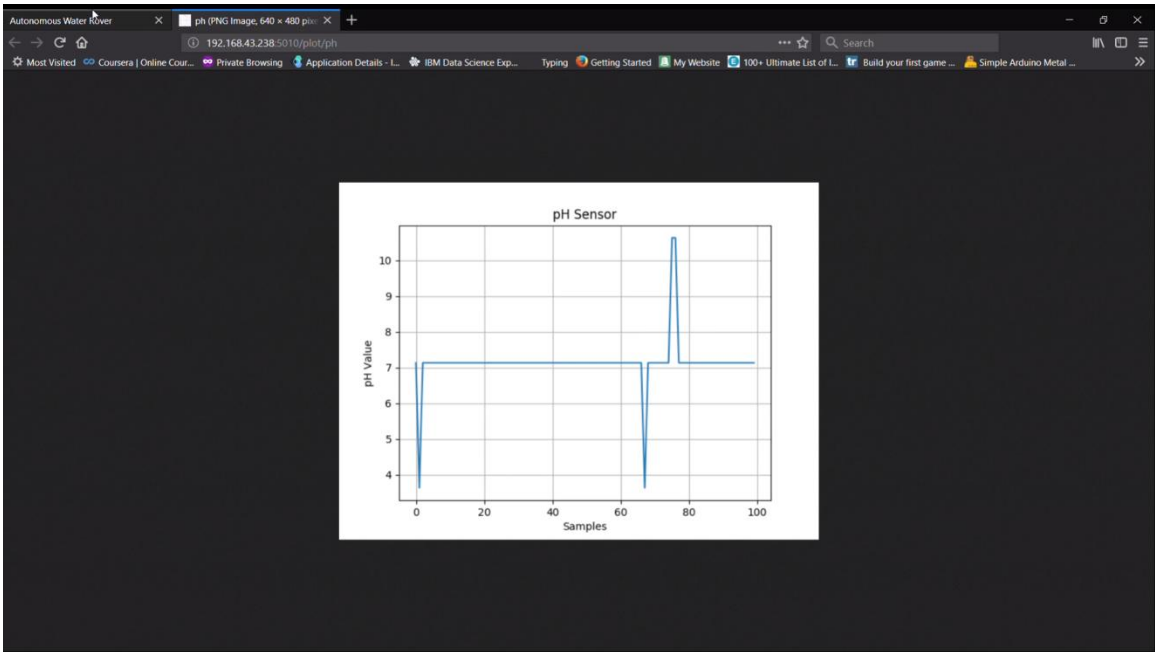
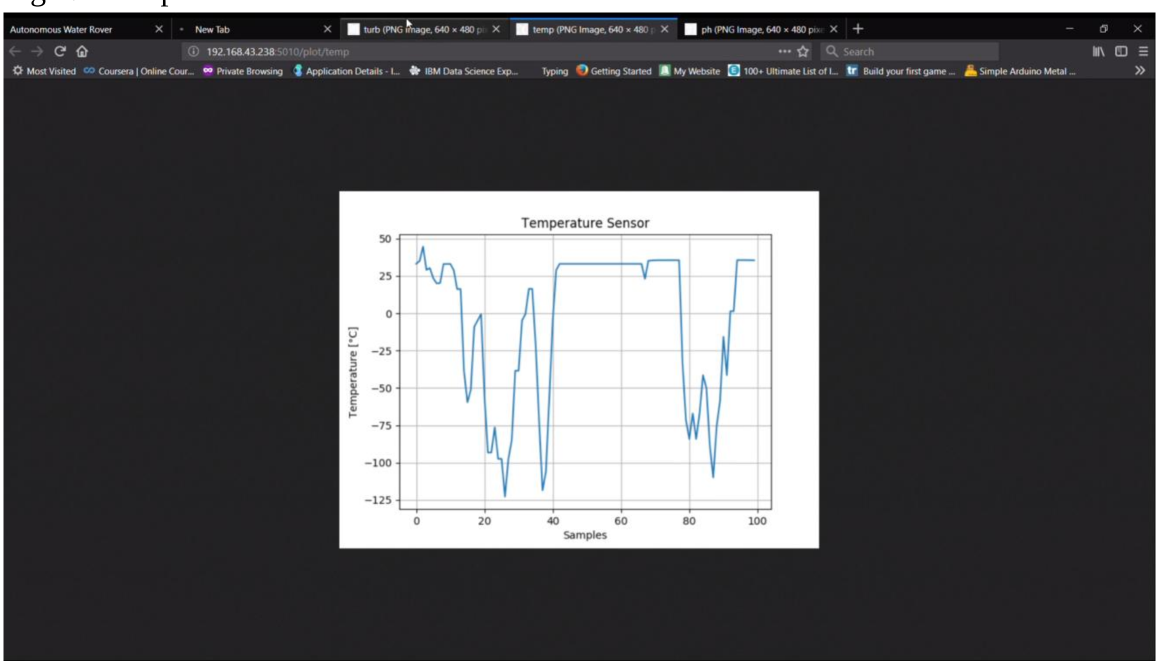


Fig 5.5 Temperature



Chapter 6 : Conclusion

This chapter explains our project's capabilities and tells us the scope of implementation in real scenarios

We tested our Autonomous Water Rover at multiple locations,first at Mini Seashore, Vashi, Navi Mumbai, then at Teen Talav, Chembur and also at Neelkanth Housing Society, Vidyavihar East for testing and modification purposes. While testing in the swimming pool, we were assured of it's capability of traversing water bodies using differential propulsion and manual control.

Autonomous mode of our rover was tested at Mini Seashore as the water pond was very much similar to the conditions of a lake. Als0 the area was larger, GPS coordinates assigned could be accurately interpreted by the rover. The sensors' data was collected and displayed live on the dedicated webpage. Front and Underwater videos were displayed live on the website and phone. SONAR accurately determined the depth of Mini Seashore.

Targeted Users:

1. Municipal Corporations
2. Dredging Industry
3. Flood Disaster Relief Teams
4. Fishing Industry

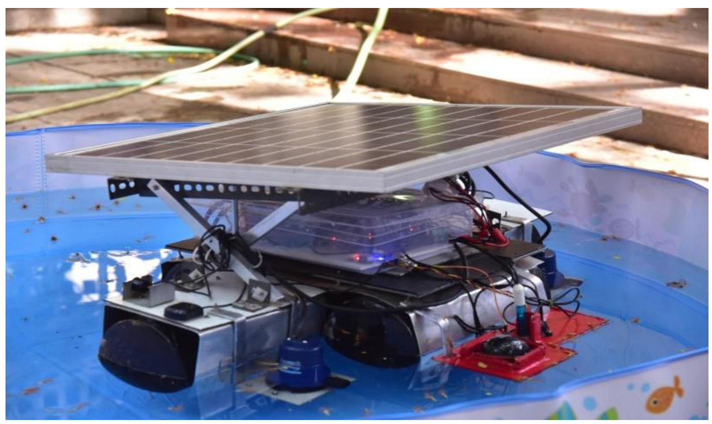


Fig 6.1 Autonomous Water Rover

Chapter 7 : Future Objectives

This chapter explains our project's future undertaking and objective with respect to multiple facets

We successfully built a prototype and achieved realistic results when tested in mini ponds across Mumbai. As lakes are water sources for city needs and come under Municipal Corporation & Forest Department's jurisdiction, we didn't get access to them for testing. However, the ultimate goal is to implement such a Rover in lakes across the world for continuous monitoring of lakes. From the technical perspective, following areas need improvement:

1. Mechanical structure can be designed as a Catamaran structure for higher mobility
2. More efficient design incorporating Solar Panel
3. Provide a simpler interface than website for controlling, for eg, mobile app
4. Electronics housing can be improved
5. Data Analytics for the monitoring the health of the water body

Apart from the improvements in the current prototype, different applications can be achieved more precisely if the rover is an Underwater Autonomous Rover, like

1. Depth mapping using SONAR
2. Underwater survey using Camera
3. Multiple defence applications

Fig 7.1 AWR in Mini Seashore

Bibiography

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