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Design, Analysis and Development of Autonomous Underwater vehicle

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Abstract*: Autonomous Underwater Vehicles (AUV) are slowly operated unmanned robots which Capable of propelling on pre-defined mission tracks independently under the water surface and are frequently used for oceanographic exploration, bathymetric surveys and defense applications. This AUV can perform underwater object recognition and obstacle avoidance with the use of appropriate sensors and devices. Vidyut is a miniature AUV developed at Sri Sairam Institute of Technology. The vehicle is equipped with six thrusters which allow for motion control in 6 Dof and has a non-conventional single hull heavy bottom hydrodynamic design. This paper discusses different aspects of the vehicle's unique design. The output of the Arduino Uno controller has been discussed for continuous depth and heading control.

***Keywords* : AUV, Arduino, Image processing, Vision system**

I. INTRODUCTION

India's extensive coastline and near-shore waters contain biological and mineralogical resources. The exploration focus has shifted to these unexplored areas. We are determined to be a part of this technological advancement in underwater technology for exploration and inspection. With the focus and vision to design and develop a full-fledged underwater vehicle which operates autonomously, which also specializes in exploration and inspection. Our teams of undergraduate students from multiple disciplines have cracked a first successful attempt to develop an AUV. It is our maiden attempt to take part in this competition and develop our AUV. Design and development of an AUV has copious challenges starting with water proofing, Static and hydrodynamic stability, propulsion, power consumption, control and navigation are other more significant problems. A blend of technologies like image processing, artificial intelligence, remote communication, embedded systems, electromagnetics and pneumatics are employed in the vehicle.

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The design of Vidyut can be grouped in three verticals mechanical, electrical and software. A fully assembled Vidyut Auv is shown in fig 1.

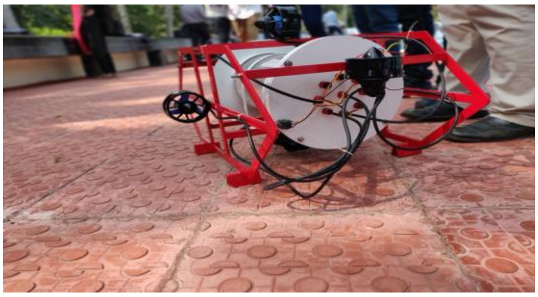


Fig 1. Vidyut AUV

II. MECHANICAL SET UP

Mechanical design module includes designing, prototyping and manufacturing of the various components of AUV. The Cad model of our Auv is in fig 2.

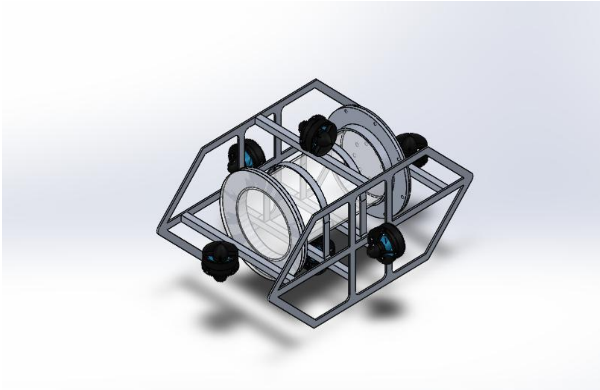


Fig 2. CAD Model of Vidyut.

The major components include pressure hulls, actuation for the various payloads and structural frame of AUV. Each of the sub modules is explained in detail in subsequent sections. AUV is designed to be positively buoyant to a certain extent.

A. Design of Pressure Hulls

Hulls provide a waterproof enclosure at atmospheric pressure for electronic payloads of the AUV. Generally, several factors influence the design of the hull.

- Static and dynamic stability of the vehicle.
- Modularity to allow upgradability in the design.
- Reduction of drag against velocity while in motion.
- Availability of sufficient space for the storage of batteries, electronics and other components. • Ease of manufacturing.

Laying emphasis on the above stated points, a cylindrical shaped hull has been incepted in the design because:

- It is a strong hydrostatic resistance structure.
- It has a good hydrodynamic form which helps in reducing the drag on the vehicle.
- It provides sufficient space for placement of electronics.

Having finalized with the cylindrical hull shape, the following hull-thruster configurations were considered for the design of the AUV:

- Laminar Flow Design
- Single Hull, Multiple Thruster configuration
- Dual Hull, Multiple Thruster configuration
- Dual Hull Design with Azimuthal Thrusters

The advantages and disadvantages of each design were reviewed and finally, the Single hull, Multiple Thruster Design was selected considering the static stability, dynamic stability and maneuverability requirements of the vehicle.

B. Material for the Hull

The hull material must have corrosion resistance, high strength to weight ratio. Considering above factors, acrylic plastic is chosen as the material for the top hull of the AUV. The added advantage of acrylic is that it is transparent allowing monitoring of the electronic components inside.

C. Waterproofing Mechanism

Waterproofing is an important part of any water-related vehicles for the safety of electronics inside it. Face Seal Mechanism has been chosen for water sealing demand of the AUV. The end flange is incorporated with two grooves to accommodate two rubber O-rings which is attached permanent. Shown in Fig 3.

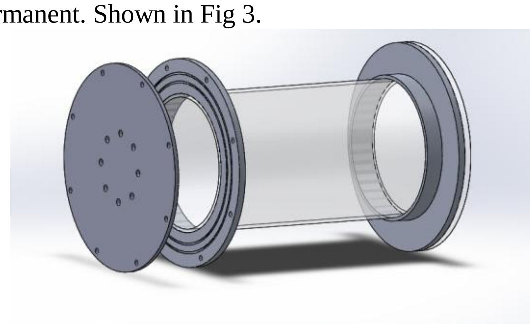


Fig 3. Face Seal Mechanism

D. Frame

The frame constitutes the supporting structure of the AUV on which the peripherals are mounted. The material chosen for the frame was thin aluminum 6061 alloy sheet because of corrosion resistance, machinability and high strength to weight ratio. Many designs of the frame have been developed and analyzed using the ANSYS software along with the main peripherals. The key factor for design of the frame is to reduce the drag in all the required directions of motion. In order to estimate the resistance in the forward direction, the inlet velocities chosen were 0.3 to 1 m/s for designed frame of the vehicle. The graph in figure 3 show the variation of drag force and power required in forward direction contributed by different versions of the vehicle.

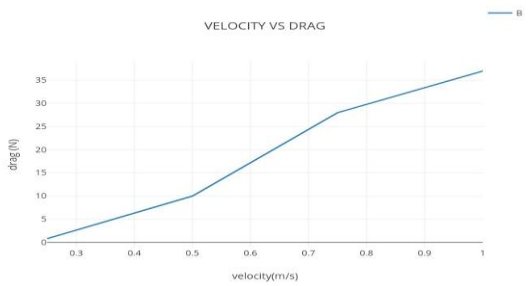


Fig 4. velocity vs Drag graph

The flow around the Auv is also studied and which gives clear idea of flow of water in and around our Auv. The fig 5. represents the image of flow around the vehicle.

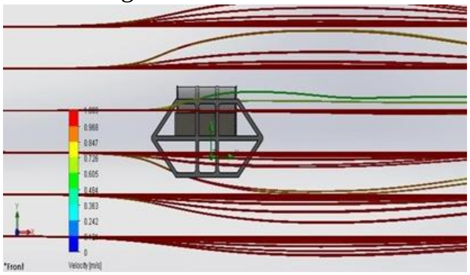


Fig 5 Flow around the vehicle

The static analysis of the structural frame is analysed using ANSYS, the various test conducted are the results are checked and verified. Fig 6 represents the stress on the frame, Fig 7 represents the deformation on the frame.

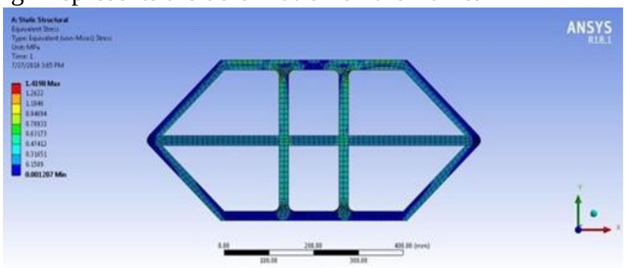


Fig 6 stress analysis

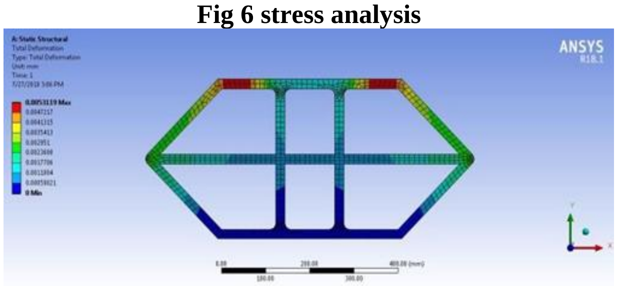


Fig 7 Deformation on the frame

E. Thruster Configuration

The vehicle uses 6 T200 Blue Robotics thrusters for achieving control in 6 degrees of freedom. On either side of the frame, two thrusters are placed which gives independent surge and yaw motion control in the steering plane. In the diving plane, a for and an aft thruster are mounted axially upwards to provide control over Heave and Pitch. The other two thrusters placed symmetrically on either side of the line joining the CG and CB of the vehicle facilitate sway motion. The heavy bottom design of the AUV eliminates Roll motion. This thruster configuration is sufficient for effective manoeuvrability of the vehicle.

Fig 8 represents the thruster configuration of the Auv.

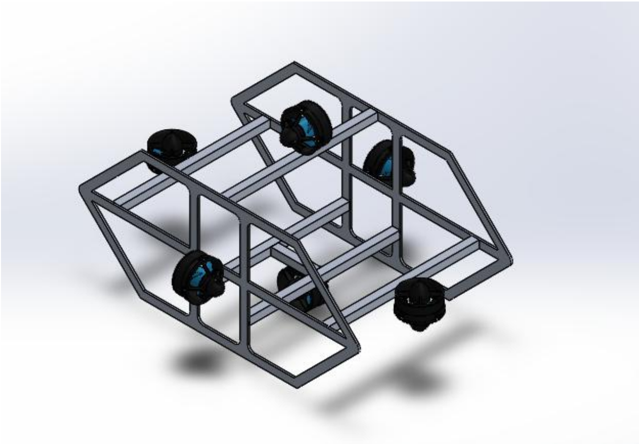


Fig 8 Thruster configuration

III. ELECTRONICS

The Electrical system consists of Li-Po battery, kill Switch, Microcontrollers, Cameras, Inertial Measurement Unit (IMU), Motherboard, Thruster control, Sensors and other devices are used. This helps in the control and navigation. Hardware was designed with restrictions to power management system and other tools. The flow chart of the system is given below. Fig 10 represents the circuit of our Auv.

A. Microcontroller

The microcontroller used is Arduino Uno which operates at 5V. The Arduino has 14 digital input & output pins, 6 analog inputs, a 16 MHz quartz crystal. It includes all necessary to support the microcontroller. It also has a reset button attached with it. It has a USB connection, ISCP header and power jack. 2 Arduinos are used one for the sensors and other for controlling the thrusters and servo motor. It is used to send and receive information to the motherboard.

B. Sensors

The IMU in our AUV is 9DOF Razor IMU. This incorporates three sensors - MEMS triple-axis gyro, accelerometer, magnetometer - to provide 9 Dof of inertial measurement and their corresponding outputs are processed by an on-board ATmega328. The 9DOF Razor can therefore be utilized as a very efficient control mechanism for AUVs, UAVs and image processing systems. IMUs are used to determine the accurate position of the vehicle. The temperature sensor used is LM35.This sensor is used for the safety purpose. In this the input is taken and passed through the microcontroller. Here it monitors the temperature inside the hull. It is connected to the analog pin of microcontroller and continuous readings are taken. The Bar02 depth sensor has Ultra-High Resolution and accuracy up to 10m Depth. The MS5837-02BA sensor which is present helps this device can measure up to 10-meter depth with 0.16mm resolution. This sensor is used to measure the depth and helps in the dropping mechanism.
Fig 9 represents the SOS Leak, Before any major damage can occur, the SOS Leak Sensor is able to quickly and accurately detect water flow into a poorly sealed water resistant container. The LED lights up and shows the indication as the SOS Leak Sensor is powered.

Fig.9 SOS Leak sensor

C. Thrusters

The T200 is a more powerful version of the T100 Thruster. The T200 is shown in fig.10 which is made of injection moulded plastic with high-strength, UV resistant polycarbonate. The windings of the motor are screened and sealed through an epoxy coating and use plastic bearings instead of steel bearings in saline water to produce high-performance. All other components are made of either aluminum or high quality, un-corrodable stainless steel. The propeller and nozzle provide efficient, powerful thrust while active water-cooling keeps the motor cool. The thruster is easy to use just connect the three motor wires to any brushless electronic speed controller.

Fig.10 T-200 Thrusters

D. Motherboard:

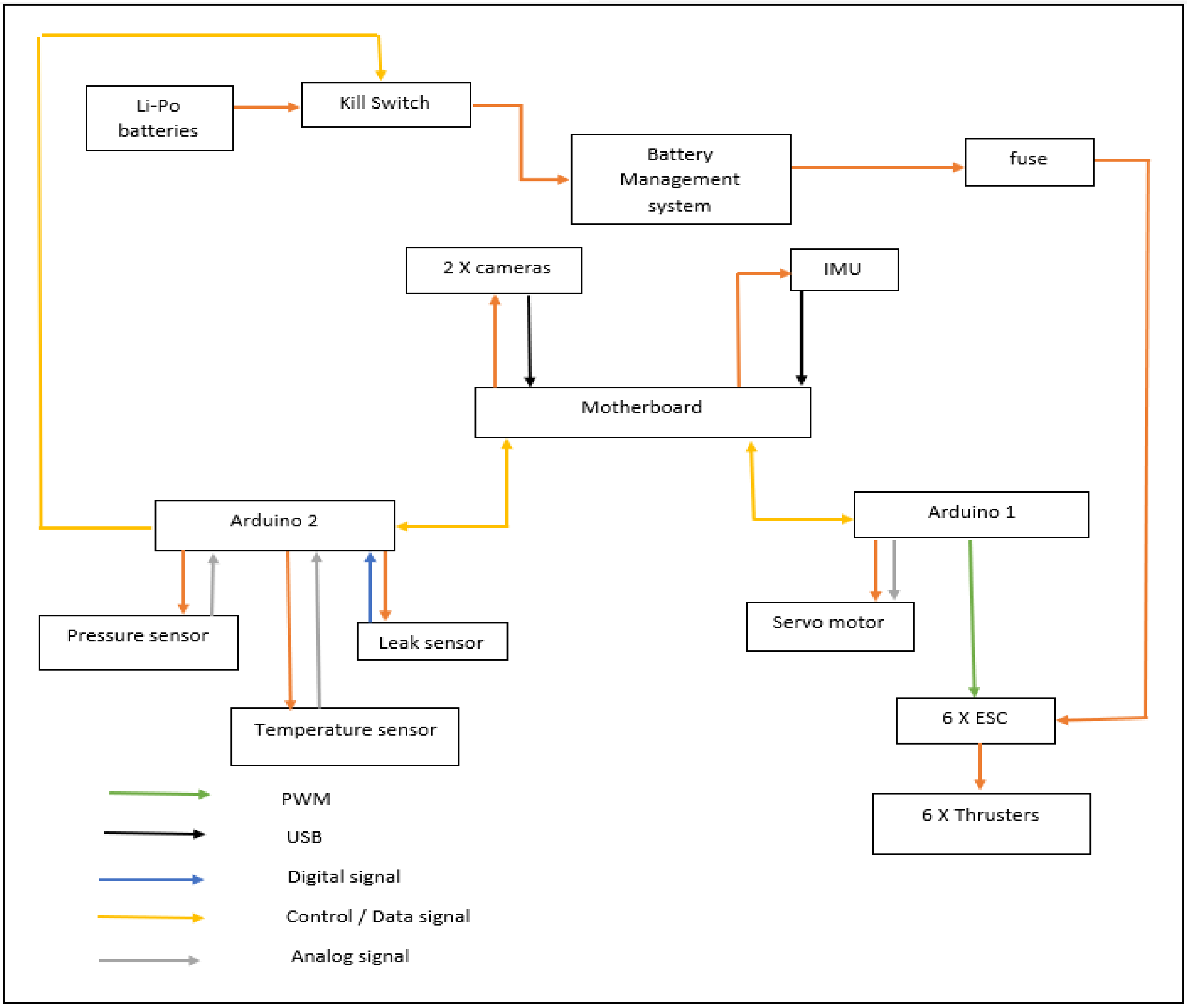
Motherboard is the basic block of the module. It is the hardware which communicates almost with every component. It is the hardware where almost all components are connected. It is the soul block for the entire module. Our Auv is equipped with Intel NUC i3-5TH Gen UCFF Processor which is shown in figure 11 and it also powered with DDR3L-1333/1600 1.35V ram and A-data SSD memory drive.

Fig.11 Intel NUC

E. Battery

The battery used is Li-Po battery of 2 units. The first unit is for the auxiliary units such as sensors, Intel NUC, Arduino, servo motor, etc. The battery used for auxiliary is 52oomAH 11.1V Li-Po battery. The second unit consists of 11.1 V 16000mAH Li-Po battery which supplies the power to all 6 thrusters in the model.

The battery gives a 25C in discharge and a BMS (Battery Management System) is Used to monitor the battery discharging. The discharging of the Li-Po is done using an incandescent light and reduced to 0V before charging for the safety of the equipment.



This Switch permits turning a circuit on and off within a watertight enclosure without having to open it. Handling up to 5A of current and 120V, you'll be able to use it to directly operate low power circuits or move with a microcontroller to produce input for the operation of our vehicle. It is connected to relay which cuts of the supply for the protection of the

IV. IMAGE PROCESSING AND MISSION PLANNING

A.Software Analysis:

The system is divided into several modules. It is mainly classified into 2 systems. The Middle-ware and the Mission Planner. electrical and electronics components inside.

1.Middle-ware: The middle-ware acts as a medium to collect different kinds of sensor data. This converts the analogue signals into digital signals and feeds the data to the required modules. It can also respond to digital signals from Arduino and send signal to the mission planner.

2.Mission Planner: The most important module in the system is the Mission planner. It has a Linux-stack which has many software frameworks for several operations. The architecture is based on Model-View-Controller (MVC pattern).

B.Control Module

Control module is invoked by the mission planner, when required to change orientation and position and orientation of the AUV based on the operation being performed and input is from vision, depth and other sensor modules AUV orientation is controlled through a continuous data collected from an IMU sensor that runs concurrent with the task planner by the mission controller. It is mainly based on the pitch movement and therefore controller regulates the depth, horizontal and vertical movement of the AUV.In ROS (robot operating system), the mission control algorithm is coded. This ROS module has demonstrated its performance, its processor intensity and its ease of deployment. Using the IMU, sight modules, and depth sensors, the AUV retains its stable equilibrium. The below fig.13 shows the complete flowchart of our system.

C.Software & Machine Mission

The software team is responsible for mission planning, machine vision and developing several software tools to enhance the debugging and operability of the vehicle.

The vision module is developed using the OPENCV module in python. The OpenCV module is a python wrapper for the original OpenCV C ++_implementation. OpenCV makes use of NUMPY, which is a highly standardized library for numerical calculations. OpenCV mainly focuses on the image processing. Image processing source is from cameras that are attached in the AUV. OpenCV module detects the images and the processor commands the thrusters according to the path.

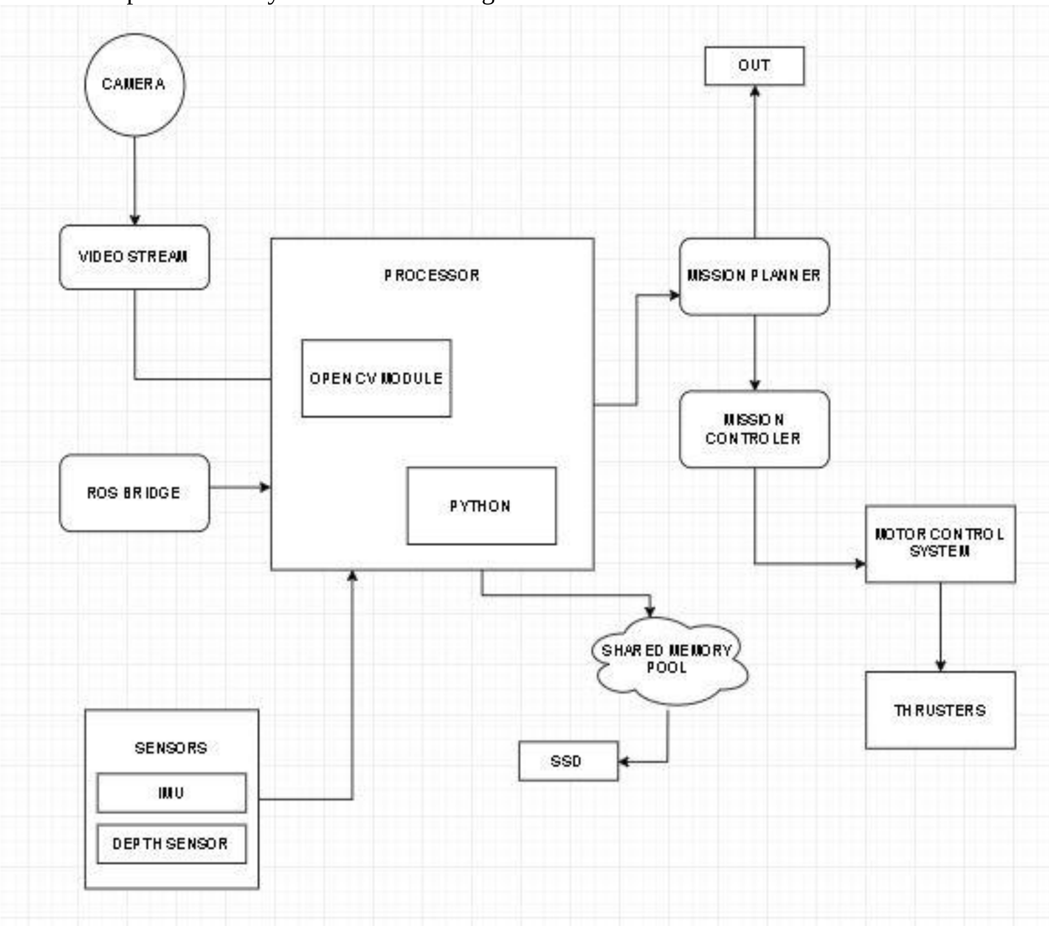


Fig 13. Overview of our system

D.Vision of Auv

The vision of AUV is integrated with camera the serves the vision for it. Images tend to be very degraded as the AUV goes underwater. Since, as the depth increases the amount of light on objects decreases and light distribution becomes non-uniform. To overcome this issue, the input images are converted to HSV colour space. After the AUV is sent in the water, it first detects the floor-mat path and moves according to the image detected by the floor facing camera and buoy is detected and it travels according to the command given to it using python ROS module. It further reaches the next stage and detects the gate using front facing_camera and validates it and enters the gate with the programmed speed and velocity valued.

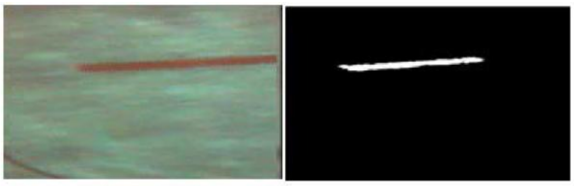


Fig 14: Floor-mat detected and converted.

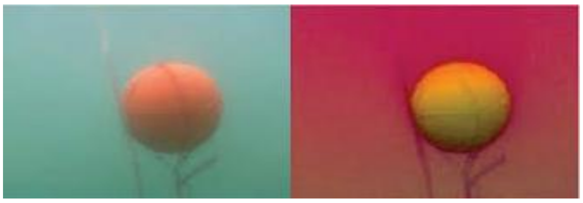


Fig 15: Buoy image while detection.

Fig 16: Buoy image after conversion.

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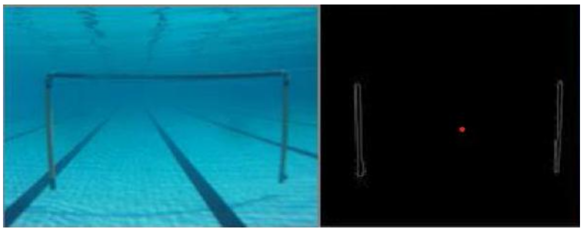

Fig 17: Gate validation image detected and converted.

The above figures 14,15,16,17 represents the outputs of the image processing and shows the objects when detected and processed object images.

E. Software Frameworks

Many python's software module frameworks are used to coordinate the overall working of the system.

1.OpenCV: used for image processing. It is a library built on top of C and C ++.

2.Python 3.7: Python supports modules and packages that enable software modularity and reuse of code. For all major platforms, the Python interpreter and the comprehensive standard library are available in source or binary format free of charge and can be distributed freely.3.Gazebo: It is a simulator used to simulate a population of robots. Using input data, we can test the_algorithms and check the proper functioning of all systems by simulating them in gazebo. It is faster and best suited for ROS systems.

F. Mission Planner

This is responsible for choosing the best job which yields the best results by using the Dijkstra's algorithm. After completion or failure of each processes, the mission planner generates a new process by using the same algorithm. This is done repeatedly for the proper working of the AUV.

V. CONCLUSION

This paper presents the design and development of the AUV Vidyut to accomplish various superficial water tasks. This explains in detail the concept and rationale behind the mechanical design, the integrated and power systems design, the algorithms and computer mechanisms for control, image processing techniques and the computational processes involved in Pinger localization. Vidyut is currently under development phase. Before the vehicle was assembled, there was extensive testing of the mechanical systems and testing of the electrical systems on the table.

REFERENCES

1. W.H. Wang, R.C. Engelaar, X.Q. Chen and J.G. Chase, The State-of-Art of Underwater Vehicles Theories and Applications.
2. P.D. Deshpande, M.N. Sangekar, B. Kalyan, M.Chitre, S. Shahabudeen, V. Pallayil, K.T. Beng, Design and Development of AUVs for cooperative missions.
3. L. A. Gonzalez, Design Modelling and Control of an Autonomous Underwater Vehicle, Honours Thesis (2019).
4. D.R. Blidberg, The Development of Autonomous Underwater Vehicles (AUV); A brief Summary by Autonomous .
5. National Institute of Oceanography (NIO) AUV MAYA Technology.
6. M. Drtil, Electronics and Sensor Design of an Autonomous Underwater Vehicle.
7. R. K. Sinha, Aayush Jha, Faheem Ahmad, Vivek Mishra, Prateek Murgai, Vatsal Rustagi, Raj Kumar Saini, Akshay Jain. "Design and Development of a Littoral AUV for Underwater Target Localization and Homing Using Vision and SONAR Module", ISRN Robotics, 2013
8. V. Upadhyay, S. Gupta, A.C. Dubey, M.J. Rao et al "Design and motion control of Autonomous Underwater Vehicle, Amogh", 2015 IEEE Underwater Technology (UT), 2015.
9. "Proceedings of the 10th National Technical Seminar on Underwater System Technology 2018", Springer Science and Business Media LLC, 2019.
10. www.bluerobotics.com

AUTHORS PROFILE

S M Abishek student at Department of Mechanical Engineering, Sri Sai Ram Institute of Technology, Chennai, Tamil Nadu, India. He is a proud member of SAE India and IEI. He has worked in various robotics application projects and done a wide range of research in that field. Also he has a good experience in manufacturing engineering works which involves working in automated systems and robotic systems. He has been a design engineer in SAE BAJA competition and captain for SAVe 2019 an Auv competition held at NIOT.

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Mathesh.B, student of Department of Electric and Electronics Engineering, Sri Sai Ram Institute of Technology, Chennai, Tamil Nadu, India. I am a proud member of IEA and IEDC. I have done various works in electric drives and systems. Also has a wide research experience in batter management systems and lipo batteries.

Sairam.T, student of Department of Computer Science Engineering, Sri Sai Ram Institute of Technology, Chennai, Tamil Nadu, a Web developer and a blockchain enthusiast. He did coding and building new products. He has done many projects during my college like "TeachBot", "MediBlock", "GameCorner", etc. He actively participates in many hackathons and won a few. He tend to keep myself busy with various works at the same time, this taught me to manage my projects and its workflows more efficiently. JavaScript being my forte, He also learned a fair amount of Java and python. He also worked on computer vision technology while He was in a team to build AUV - VIDYUT 1.0

Rajkumar P student at Department of Electronics and Communication Engineering, Sri Sai Ram Institute of Technology, Chennai, Tamil Nadu, India. He is an ISTE and IEC member. He has done research works on meta-materials and EM absorbers. He participated in several Hackathon,talkathon,orations,etc. He was electronics team lead in SAVe 2019 competition held at NIOT.