SRM ASV - Poseidon

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***Abstract*—This paper details the process of building the hardware and software of Poseidon, an autonomous surface vehicle and an autonomous underwater vehicle, designed by SRM ASV, a group of 11 students from SRM Institute of Science and Technology, India. It also discusses hurdles the team has faced during the development process and the modifications made to the team structure to overcome them. The vehicle Poseidon has been built for the purpose of participating in AUVSI Foundation's 11th International RoboBoat competition at Reed Canal Park, South Daytona, Fl, USA. Being the second time SRM ASV is participating in the competition, emphasis has been placed on the completion of hardware and the integration of software for the construction of a stable platform capable of supporting further research and development.**

I. Introduction

SRM ASV is a research group from SRM Institute of Science and Technology and is currently the only team from India participating in the AUVSI Foundation's 11th International RoboBoat Competition. The team currently consists of 11 members from various engineering disciplines, working under five domains - Mechanical, Electronics, Coding and Integration, Computer Vision and Corporate Relations. Established in April of 2014, the team has grown from a 5-member group, largely self-funded to being sponsored by multiple companies and becoming the official representative from SRM Institute of Science and Technology for the competition. The team is participating with the primary intent of producing a working platform that can be modified and developed with ease. To achieve this, the team has built Poseidon, the third and final iteration of a hull that has had a year of prototyping and design changes. For the interoperability challenge, the team has built a quadrotor capable of deployment from Poseidon. The multirotor was fabricated upon the frame of Bullfrog.[3], a waterproof multirotor.

The remainder of this paper is organised to explain the design strategy is Section II. Section III details the system design. Conclusion is provided in Section IV

II. Design Strategy

When begun in April 2014, the team operated with emphasis given to functioning within the domains, sans a view of the state of progress overall. This voluntary tunnel-vision soon led to a mismatch in work timelines that quickly led the team members to abandon working in separate groups and work together. Domain soon became a convenient word to recruit people with broad interests. Design became a collaborative process, with constant inputs

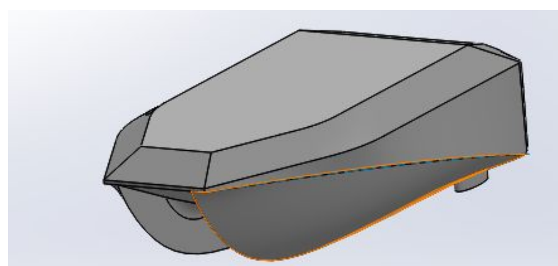


Fig .1 Render Of Poseidon

from each domain to every other. A near-instant improvement Fig. 1: Render of Poseidon with this new mode of project management were the insights into the working of other domains. Knowledge-sharing within the team streamlined the flow of work and offered a chance to move outside one's department and experiment with unfamiliar technology. The team's design strategy varied in the first few months, until it eventually coalesced to its present form. The final modus operandi can be distilled to the following series of steps. The first step involved the domain heads deciding the type of platform that is optimal for testing. Platform refers to the configuration of the Poseidon, i.e., monohull, or multihull. On deciding the configuration, the type of hull is chosen. As sensors require a stable platform with least amount of noise, displacement hulls were chosen to be the main class of hulls to be used. Planing hulls usually introduce noise when the hull rises above the water and when it settles back down. The coding and electronics domain decide the number and type of sensors that go on board. The power supply for these sensors and the control electronics would be decided by the electronics domain and their dimensions estimated. These dimensions are used by the mechanical team to decide placement and get an approximate idea on the dimensions of the hull. Placement of the sensors is decided based on separate requirements from the electronics team. Simultaneously, the mechanical team chooses the material to be used to construct the hull. Once the initial requirements are finalized, the hull is modelled using SolidWorks. The model is tested virtually using ANSYS Workbench CFX Student Edition and Static Structural modules for drag and structural rigidity. The electronics boards are prototyped on Proteus or Multisim and SRM ASV - SRM Institute Science and Technology tested before soldering is begun. Poseidon is a platform that was originally designed with the capability of deploying a UAV (Unmanned Aerial Vehicle).

III. System Design

1. Control Systems

The software designed for accomplishing the Mission Tasks have been built on Robot Operating System(ROS), which is a robotics meta operating system that is used to accomplish the system integration of the entire system of the Poseidon. ROS is used mainly for active and passive message-passing mechanisms, transport reliability, multi-nodal structure and multi-threading processing. Robot Operating System is used in our design to include the sensors to be interfaced with the System in such a way that they provide continuous outputs to be broadcasted to any ROS nodes. ROS also ensures maximum code reusability and eliminates the need to develop the system networking from scratch by providing interfaces independent of the language that they are developed in. The entire system can be divided into four major parts:

Navigation Module: The navigation module of the system provides the system the necessary softwares required for accurately transitioning the Poseidon from one defined point to another in the frame of the robot. The navigation module consists of 4 systems:

Sensor Interfaces from the Inertial Measurement Unit(IMU) and Global Positioning System(GPS), combined together to form the localisation of the Poseidon in 6 degrees of freedom.

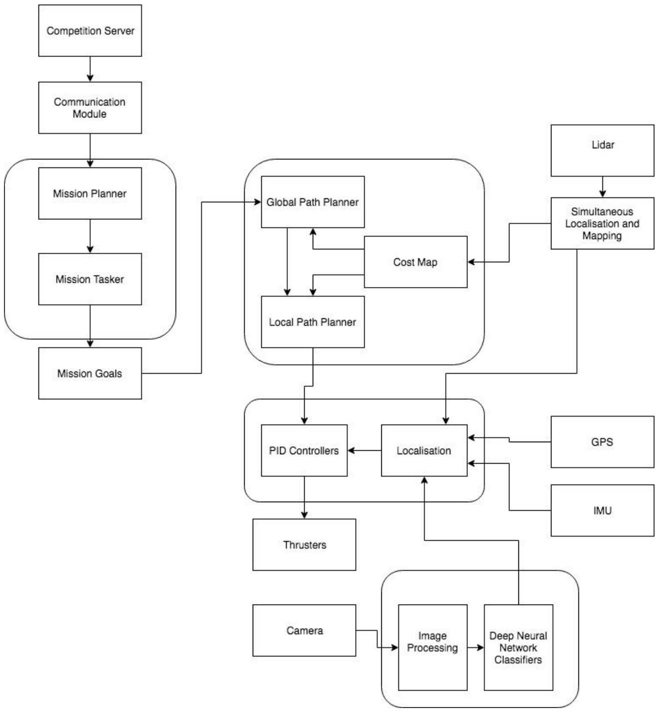
The Lidar Interface of LMS101, along with Simultaneous Localisation and Mapping(SLAM) to form the localisation of the Poseidon in 2 degrees of freedom

The Trajectory generation algorithms, which are used to sample trajectories and evaluate them for their feasibility with respect to the waypoints and collision avoidance with the obstacles and dynamics of the ASV.

Non-Linear Control System for tracking the trajectory while ensuring the commands are passed as speeds of the motors.

Tasker Module: This module of the system deals with the specific mission tasks, algorithms and software used to finish each task utilizing the Navigation Module. This module ensures that the requirements for fulfilling each task works with greatest accuracy and optimal time[1].

Communications Module: This module deals with the requirements of the communication of the Poseidon with the base station and the competition server by using HTTP GET and POST requests with the competition server that provides us with the further information.



2.Computer Vision

The image processing on-board is done using 3 cameras using image stitching to obtain a panoramic view of the front 180 degrees of the Poseidon. The video feed from the cameras in real time is fed to a classifier after pre processing by the various feature extractors used. We are using a self trained model for the classification trained on Mobilenet[2] to obtain a better realtime frame rate. The classifier gives the dimensions and the position of the objects detected to the main driver module which then fuses it with the LIDAR data to have a much precise prediction of the objects being detected. The CUDA toolkit from NVIDIA and an NVIDIA GPU help us to run the whole system independent of ROS so as to provide a less populated CPU for the Control Computing of the controller of the Poseidon.

3. Mechanical Design

It's always been the foremost concern for the mechanical domain to design the efficient structure that has the capability to navigate through the water with least amount of energy expended but also have the strength to handle the stresses that usually a naval vessel is subjected to. Team also had to design an UAV but due to lack of time it was decided to buy the standard waterproof frame from hobby stores and make it buoyant enough to float for sometime on waters. A separate platform was created on top of the Poseidon lid which consists an array of IR light beacons that could be read by the camera mounted on the base quadcopter.

Hull Design and Construction

The hull was designed on SolidWorks 2016 CAD modelling Software and analysed on Ansys Fluent Workbench. The final results extracted from the analysis include the overall drag force (Fd) and the coefficient of Drag (Cd) and Lift (Cl). The analysis has been done assuming that there will be no pitching and rolling imbalance. The assumption speeds up the analysis process as it required less computation power and provided the elemental consistency in all the models. The tradeoff is that the theoretical value might be different from the actual value if the Poseidon orientation changes if the Poseidon pitches up above the water.

The design process follows the extreme right(starboard) to left (port) and surface to solid modelling strategy. Firstly a 3D wireframe of a single hull was made using 3D sketches with help the points marked at measured distance on 3D sketch planes. Although it was a labor intensive job at first but it provides a better control over the curves that gives the shape to the hull. The surface loft and surface fill feature was used to generate the surface along the closed curved boundaries. The bulged part of the hull was the important surface of the hull which actually rides completely below the waterline and was given proper attention at the time of design process. In the first iteration, this profile was proved to have the maximum amount of drag and was highly inefficient because it wasted most of the energy of thrusters to push the water aside and couldn't kept the centre of gravity and centre of buoyancy in a straight line that resulted in pitching down the nose of the Poseidon.

A proper guiding curve was given to to this surface and lofted using surface boundary loft feature. After all the surfaces of the single hull were lofted to complete the hollow enclosure, they were knitted to create a one solid piece. The middle section was half extruded from the extreme right planar surface of the hull then the entire solid model was mirrored about the central plane to get the complete structure of the Poseidon. The middle section was kept enough broad to provide the sufficient space for electronics

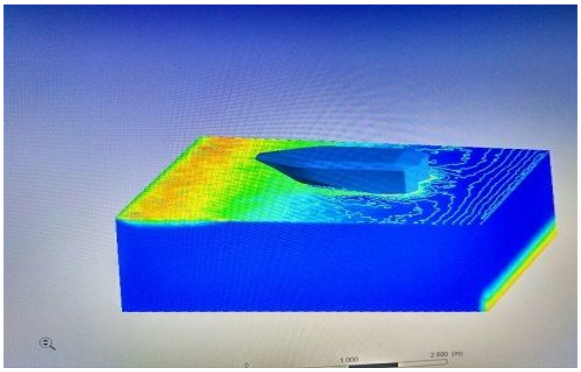


Fig 3 CFD analysis of Poseidon in ANSYS Fluent

To provide more clarity in the design iteration process drag values were calculated for various iterations of the hull as shown in the figure 3.

The analysis was conducted under following conditions

Weight of the hull = 20 kgs

Velocity of Flow (Inlet outlet)= 3 m/s

Fluid Used = Air & Water at 303 K

Fluid Density = 997 kg/m3

Turbulence = 5%

Model Setup = Volume of fraction

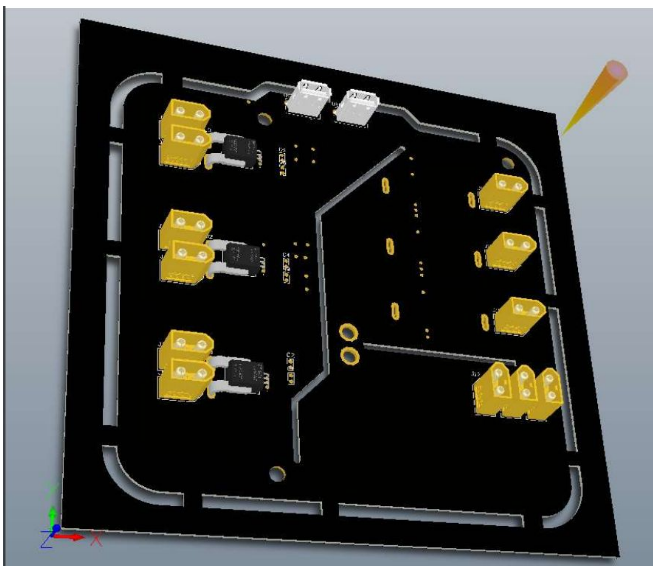
The analysis was conducted under transient flow conditions including gravity effect. The analysis model was chosen to be Volume of fraction with two fluid phases namely air and water. The desired waterline was assumed to 10 cm above from the bottom most point of the hull. Air was chosen to be fluidic medium for the part riding above the waterline and water for the part riding below the waterline along with scalable wall function. The boundary conditions were given accordingly. The model was iteration was 1000 steps with the time step of 0.001 seconds.

The wetted areas for the above iterations fall very close to each other. This condition allows us to compare them using the calculated drag coefficients. It is evident that there is a marked decrease in the drag coefficient from the initial to the final hull. The introduction of complex curves into the design eliminated 56% of the drag force exerted on the hull for the same wetted area. Note that although the area might be comparable, the water lines are not. The waterline for the catamaran hull is higher than that of the last year's trimaran hull due to the bulged surface in the front (which is common in HYSUCAT designs).

Iteration	Drag Force(N)	Wetted Area (m)	Drag Coefficient
1	120	0.7	0.038094
2	120	0.8	0.0333
3	110	0.8	0.0305
4	105	0.6	0.0407

4. Electronics design

The power to all the subsystems and the thrusters is crucial and so dedicated power distribution boards have been designed to serve power to the same. Each Blue robotics T200 Thruster draws about 22A of current at 16V max and keeping the same in mind PCB have been designed to draw 30A of current each. ACS non contact type current sensors have been placed at every power input to the thrusters which constantly monitor the current being drawn by the thruster so as to log everything in an event of a fault or over current. Fuses are also used at every point as an added layer of overcurrent protection. Led fuse blown indicators are given for easy monitoring of the board. The main controller board requires a ripple free power source requiring about 20W of power. The LIDAR requires about 40W of power and is supplied by the power distribution board. A buck and a boost Converter is provided to provide multiple voltage levels to the subsystems of the Poseidon.



IV. EXPERIMENTAL RESULTS

The boat is tested multiple times for the PID to be tuned until near perfect results were obtained. The boat had been made to pass through 4 buoys recreating the autonomous navigation challenge in a nearby water body. The obstacle avoidance was tested using ROS Gazebo and has been tuned to pass through it smoothly. An autonomous flight using Pixhawk and Dronekit on Raspberry Pi is tested to track and reach waypoints.

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VI. REFERENCES

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