Floating Point IV Surface Vehicle

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Abstract

This paper explains the function and changes made to the Floating Point IV platform, which is the entry of the Robotics Association at Embry-Riddle (RAER) into AUVSI's international Roboboat competition. This year the team divided into two subgroups consisting of software and hardware in order to prepare the boat to complete all the necessary tasks at this year's competition. Concerning hardware Floating Point IV retains the proven hull design that competed in the 2016 competition, but improves wiring by having wires labeled and secured to the deck of the boat to prevent wires getting coiled, the boat also includes a removable drawer system that makes connectors for router, and computer are easily accessible. However, the system software on Floating Point IV is completely different from any previous ERAU entry into the Roboboat competition. The software architecture utilizes custom-built communication framework, Minion Core, which is similar in function to ROS, but design for use in LabVIEW. This architecture has enabled the development of an entirely new perception system, based on a Velodyne High Res Lidar, a Hemisphere GPS, and visible camera.

I. Introduction

The Robotics Association at Embry Riddle Aeronautical University designed Floating Point IV, an Autonomous Surface Vehicle (ASV), to participate in the 2017 International Roboboat competition in Daytona Beach. The contents of this paper will discuss the processes and strategies the team used to prepare the ASV. This paper will highlight how the unique challenges of the 2017 competition affected the final design of Floating Point IV. Floating Point is generally design for accessibility, easy maintenance, and implements a new to RoboBoat software architecture, which has previously been proven on the ERAU RobotX Challenge Vehicle Minion.

II. Roboboat Challenges

The design of the ASV and the Autonomous Aerial Vehicle are both important to complete specific tasks to gain points. A short list below describes said challenges and how they affect design of the ASV:

1. Autonomous Navigation: Demonstrate basic autonomous control and sensing abilities.
    a. The ASV must have reliable Lidar and GPS sensor to identify the buoy locations. It is also necessary to use cameras to identify buoy color.
2. Speed Challenge: Demonstrate the quality of path planning and naval engineering of the vehicle.
    a. ASV should map surroundings in order to navigate intelligently. Vehicle must also be highly maneuverable.
3. Find the Path: Demonstrate complex path planning in a crowded area.
    a. The ASV must have identification and path planning software that enables these behaviors.
4. Automated Docking: Demonstrate the ability to launch an aerial drone and combine information from multiple sensor systems to make a decision in autonomous mode.
    a. The USV must have hydrophones to be able to detect and filter out desired frequencies. The aerial drone must communicate to the ASV and determine the location that it must land.
5. Follow the Leader: Demonstrate dynamic target identification and precise navigation.
    a. The ASV needs Lidar, Camera, and GPS in order to identify its location, as well as the location of the object the Vehicle is tracking. Vehicle must be fast and have robust controllers to follow the moving target.
6. Return to Home: The Autonomous surface vehicle must navigate back to its starting point.
    a. The ASV needs to store the starting waypoint as its desired location.

Fig 1: Floating Point IV

III. Vehicle Design

A. Design Strategy and Considerations

The Floating Point IV platform is simple, effective and modular. The hull is comprised entirely of wood with two layers of fiberglass for reinforcement along with two coats of waterproof paint. The boat has a flat deck in the back that is adaptable to new challenges. This allows for changing the entire deck plate to adapt to the competition challenges. For instance, the competition deck utilizes a landing pad for a UAV, but the team also developed a launch and recovery deck for the UUV used in last year's competition. The hollow hull houses the computer and electronic components and becomes easily accessible by removing the deck plate.

The software architecture enables the development of modules to perform specific platform tasks, such as path planning, control, perception and vision. These modules are tied together using a communication architecture developed by members of RAER, known as Minion Core, and originally developed for use in the 2016 Maritime RobotX Challenge. Minion core utilizes a set of independent modules running as state processes. This allows the code to run various parts all at once without conflict. To ensure code robustness, Minion Core also allows simulating sensor data by replaying logged data files, which mirror the internal messaging produced by the sensor modules. Additionally, all code is ultimately deploying as compiled code.

B. Hull Design

Floating Point IV features a trimaran design and is based on the United States Navy's USS Independence (LCS 2). It is lightweight and spacious, yet robust and faster than many other hull designs seen in the Roboboat competition. The boat is composed of wood which is coated in 2 layers of fiberglass to ensure strength, rigidity and water proofing of the platform. The boat is also covered in two layers of water proof paint with lacquer. The top of the platform has three mounting areas for the GPS, LiDAR and Camera. The rear deck is 25 inches by 25 inches to fit different decks for challenges such as UAV or AUV. Under the platform are two fins that hold the thrusters as well as two areas for the hydrophones.

Floating Point IV is designed to be hydrodynamic and aesthetically pleasing. Laser cut wood and smoothly sanded sides minimizes drag while reducing the complexity of manufacturing. Due to old paint being worn away by water, the color scheme was changed from the blue and white color to a military gray with digital camo stripe.

To ensure Floating Point IV would not develop problems concerning leaks or decay in the wood. As stated before a new coat of paint was applied to the boat, but prior to applying the paint, the boat was thoroughly sanded, and lacquered. These steps were taken because; over time, wood soaks up water. If the wood on the boat were to soak up enough water, it would leave cracks in the hull. To prevent this problem from occurring the platform has also been fiber glassed. The E-Stop has also been placed in a new area, which is easier to access.

C. Electrical System

The main function of the boat's electrical system is transferring information from one part of the ASV to another. Arrangement of wires can affect how quickly a team can solve communication or power issues. In the previous 2016 competition, the team's performance was affected because of an unrecognized wire that was misplaced, which prevented communication from the main computer to the boat. Adjustments made to improve the wiring include premade wiring schematics, accessible system for the router and computer and a neater electronics area.

One major problem the platform had with electronics is the cramped electronics access door. This made it very difficult to access the computer and when updates or modifications such as soldering in new wires were necessary it required the entire platform to be moved. The new solution to this problem is to implement an access drawer in which the computers could slide out from their compartments to ensure ease of access. The inside of the platform has also been refurbished with a new coat of paint and cleaner wiring in order to reduce margin for error and make it aesthetically pleasing.

III. Vehicle Hardware

A. *Propulsion*

Having both speed and control over the vessel is important for the team to be able to make smooth turns around buoys, and propel the boat through the speed gates at higher speeds. The motors that will be used at this year's competition are Blue Robotics T200 thrusters with external ESC. These thrusters give the boat 11.2lbf of foward thrust each, which will help the team maintain desirable speeds for events such as the Speed Gate Challenge.

Fig 2: Blue Robotics T200 thruster

The Blue Robotics thrusters are brushless electric motors, purpose-built for use in the ocean. These thrusters are composed of high-strength, UV resistant polycarbonate injection molded plastic and contain high-performance plastic bearings as a substitute for steel bearings, which corrode and rust in saltwater as well as an efficient and powerful propeller and nozzle. This is a big benefit for the platform because it sends a variety of locations in which the team can test.

The T200 are easy to use and are compatible with various coding platforms including Arduino and Raspberry Pi. The T200 thrusters produce 11.2 lb. forward at 16V of power and 9.0 lb. reverse at 16V. Moving left and right is done through torque vectoring also known as differential thrust. One thruster provides forward thrust and the other reverses to provide a torque which moves the Platform left or right.

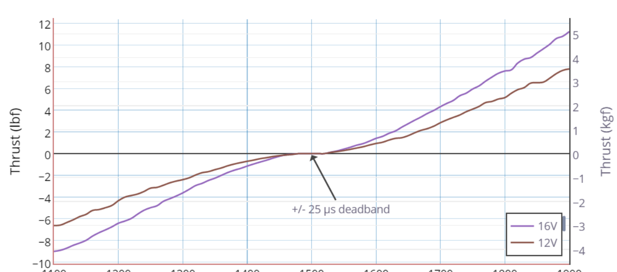
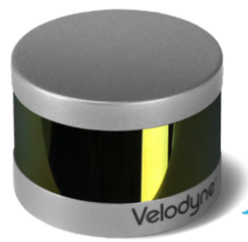


Fig 3: Thrust vs. PWM signal input

B. *Sensor Array, Computing, and Communications*

The Floating point system contains cutting edge sensors that allow the AUV to complete all the required tasks successfully for the competition. These sensors include the Velodyne High Res Laser range finder, GPS, Teledyne Hydrophones, Sparton GEDC6 IMU and basic webcam cameras and finally a custom ASUS motherboard with Intel Core i7 processor with a PCB.



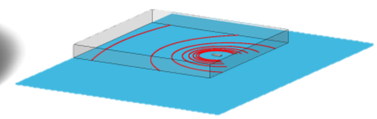


Fig4:Hi-Res lidar fig5: velodyne pattern

The puck Hi-Res LiDAR rotates 10 times each second capturing 300,000 points per second with a 360° horizontal and ± 10° field of view. This allows the AUV to have a map of the environment and help significantly with obstacle avoidance and navigation. The above illustrations, Figures 4 and 5, show the Velodyne, and the pattern it will follow

Fig 5:Hemisphere A101

The Hemisphere A101 Smart Antenna GPS is an affordable and portable system that offers professional-level accuracy. The GPS provides 60 cm accuracy 90% of the times as well as fast output rates of 20 times a second, which provide excellent visual guidance. The hemisphere GPS provides the AUV with accurate positioning which gives the team an advantage in navigating the course and locating various targets.

Fig 6:Teledyne TC4013

The AUV also contains Teledyne TC4013 hydrophones has a frequency range of 1Hz to 180 KHz with a 700m depth. The hydrophones give us the ability to locate and receive the pinger frequency for the pinger challenge.

The Sparton GEDC6 IMU is the altitude heading reference system and gives the boat its position relative to the horizon. This system allows for precision with navigation and maneuverability.

Communication from the ground station and the platform is done using an Ubiquiti M5 Rocket multi-antenna, which speaks to the Ubiquiti M5 Bullet inside the platform. The antenna communicates at 5.8 GHz with the ground station in order to avoid signal loss and interference. The system is also capable of long range RC which allows the platform to be manually controlled at any time. The platform also includes both a remote and on board E-stop systems. The platform has a commercial E-stop button, which immediately stops power flow to the thrusters. The remote E-stop located on the RC controller bypasses all software systems in order to cut power flow to the thrusters.

IV. Vehicle Software

Floating Point IV utilizes individual independent modules of software that only listen to the data message needed, and then tag outgoing data for consumption by other modules. There are separate modules for environment perception, obstacle avoidance, path planning and navigation. All the modules run in the background and the data from these modules is managed by the Objective Tracker to indicate the order of the tasks Floating Point performs during competition. Each software module is compiled as an independent executable and run on the onboard computer, which allows for the reset of individual modules without impacting the performance of the other standalone modules.

Floating Point IV creates a persistent map of its surroundings using the data points provided by the Lidar. This is performed by the Mapper module which extracts objects from raw data points. The Path Planner module uses state information from the Mapper Module (global data), and the vehicle state (local data) to compute the shortest distance and time path to the required waypoint while avoiding any obstacle. The objective tracker keeps track of the tasks the ASV performs, and automatically triggers a transition of tasks when the object the boat must interact with has been detected. For example, after starting the speed gate, it searches for the finish gate, locates it, and after driving through it, triggers a transition to the next task. Floating Point IV incorporates a sophisticated and efficient algorithm for image processing, which is used for both Docking and interoperability challenge. This vision module takes the acquired images, creates a region of interest (ROI) based on the Lidar knowledge of where the object is located and then applies a background removal technique to isolate the buoy in the ROI. The use of ROIs allows the subsequent processing to be faster since the image size and complexity has been significantly reduced. Further thresholding is applied (defined by the user, depending on the color assigned by the judges) to detect the correct colored shape when docking. Finally, Geometric Matching is performed on the isolated shapes to match the correct shape as assigned by the judges. A bounding box is then applied to the original image, and the ASV performs heading control to the centroid of the bounding box for docking. The process is tested to be accurate 90% of the time, and since the program repeatedly performs the same functions, an average is taken to finalize the location of the desired dock while eliminating incorrect detection.

V. Challenges addressed by Floating Point IV Software

During previous competitions, the team has faced some issues with software including communication problems, cluttered code, vision problems and lack of hydrophone progress. This year the team focused on solutions for the software and divided into four main parts including, a new communication module, mission planner, vision and hydrophone code.

The Minion Core messaging protocol is a publisher subscriber system developed by the Embry-Riddle RobotX team to easily facilitate the development and integration of new software modules into the communications network. Its function is similar to Robot Operating System (ROS), but Minion Core is developed to run in LabVIEW. This new software modification allows code to transfer from one platform to the other over network.

Objective Tracker facilitates the code and controls all the separate modules. One problem the team encountered at competition was difficulty understanding the code and finding various parts because it was hard to read and understand. This gave way to various problems such as errors and slow progress on the boat. In order to solve this problem, the team implemented Minion Core, which is much simpler and cleaner. The team also examined the Mission Planner software, organized, and removed unnecessary parts.

One problem the team faced in the past was vision problems with the boat software being unable to locate black buoys. The LiDAR is used for obstacle avoidance and because it uses infrared lasers the black buoys absorb the infrared lasers leaving the LiDAR unable to detect any black buoys. In order to solve this issue, the team designed a separate code using the camera to detect the black buoys.

Fig7:Green buoy

The illustration Figure 7 shows how this process works. The ASV locates the buoy by identifying background colors, from the objects edges. The program then proceeds to remove the images

Fig 8:Green buoy Identified

background images, leaving only the buoy and its shadow. Once the color and shape is identified the shape relays that information to the mission planner so it can see the obstacle. The code was designed by recording the black buoys in various lighting conditions and creating an algorithm that compares the live view with previous images of the buoys.

The Teledyne TC4013 hydrophones on the boat acquire reliable and precise data from the pingers. Array placements and signal processing are the two ways the team ensured accurate data information. The array uses a triangular array; The positions of the array are placed 1.855cm away from each other. The placements are made in order to calculate the specific distance away and angle due to the length of time it takes a specific frequency to reach the sensor. The software of the hydrophone data uses a combination of both LabVIEW and MatLab in order to receive specific frequencies and filter out unnecessary noise, that may not be necessary to the data. The boat uses a Fast Fourier transform(FFT) to process information, because it is least likely to intercept unnecessary data from noise.

VI. Unmanned Aerial Vehicle (UAV)

The Unmanned Aerial Vehicle is the Mariner waterproof quadcopter. It is capable of operating in all weather conditions due to its highly durable thermoplastic waterproof frame. The Mariner gives us an advantage because it can land and take off in water minimizing the risk for water damage with a normal quadcopter. The quadcopter has been retrofitted with a raspberry pi computer to allow for autonomous capabilities. It is also manually controllable at any time and features a controllable E-Stop along with return to home ability.

VII. Conclusion

Floating Point IV, designed and manufactured by Embry-Riddle Robotics Association, has improved software as well as a refurbished platform to successfully complete all tasks at the 2017 Roboboat competition. The Floating Point IV incorporates a professional looking vessel that is modular and spacious.

VIII. Acknowledgments

The Roboboat team would like to acknowledge all the advisors and faculty, Christopher J. Hockley, David J. Thompson, Dr. Charles Reinholtz, Dr. Eric J. Coyle, Dr. Patrick Currier, James Hendrickson, Jefferson S. Romney, Marco A. Schoener, Stephen P. Cronin, Timothy A. Zuercher, who were each able to contribute time to assist the team and futher progress. We would not have been successful without your contributions.

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