Old Dominion University
Autonomous Surface Vehicle Team
2013-2014 AUVSI RoboBoat Competition

Ryan Snyder, Benjamin McKinley, Dr. Gene Hou, K. Almutairi, M. Almutairi, R. Blanchette, D. Burs,
A. Casson, J. Diloy, B. Garman, W. Howard, V. Lopez, A. Ortega, S. Quiatchon, and C. Shertzer
Frank Batten College of Engineering and Technology
Old Dominion University
Norfolk, VA 23509

Abstract For the 7th Annual International RoboBoat Competition (IRC) competition held in Virginia Beach by the Association for Unmanned Vehicle Systems International (AUVSI), an autonomous vehicle was designed and fabricated by the Old Dominion University (ODU) Autonomous Surface Vehicle (ASV) team of engineering students and faculty. With assistance from various methods and resources, ODU students and faculty were able to create a roboboat capable of navigating through multiple obstacles and meeting the prescribed requirements conveyed in the 2014 Final Rules. Equipment recycled from previous competitions, an improved computational platform, and various sensors types mounted to a newly fabricated pontoon inspired aluminum hull substantialize the ODU ASV team capability to attempt all competition challenges.

I. INTRODUCTION

For the past four years, ODU's ASV team has risen to meet AUVSI's objective of creating an opportunity for science, technology, engineering, and math students to relate classroom learning to the workforce in a controlled, challenging environment through the application of new and innovative technologies affecting the robotic community. This year's boat was fabricated in response to testing and analysis of data gathered from previous IRC boats in addition to information collected through research of modern technology, tools and principles.

ODU's ASV team is comprised of students from the Frank Batten College of Engineering and Technology, representing fields including mechanical, aerospace, electrical, computer, and modeling and simulations engineering. The primary faculty advisor for the team is Dr. Gene Hou of the Mechanical and Aerospace Engineering department.

A set of rules that have been modified and updated annually govern the IRCs, with hopes of confronting the growing demand for autonomous vehicles. Static trials and four challenges comprise the IRC: automated docking, underwater light identification, acoustic beacon, and obstacle avoidance. The first challenge is underwater light identification, requiring the boat be able to identify an

Figure 1. 2014 ODU ASV Boat

underwater colored LED light sequence. Obstacle avoidance, the second task, entails the boat is able to identify buoys of various colors and maneuver around each one. The third obstacle, automated docking, specifies the boat locate an image and autonomously dock at that location. Fourth is the acoustic beacon positioning challenge, which calls for the boat to detect and report color of the buoy emitting an acoustic ping. Upon completion of the four challenges, the rules suggest the boat return to the starting dock location.

ODU team members branched into two organizations for the ASV's creation, consisting of mechanical and intelligence systems. The intelligence group commands selection of sensors, hardware controllers, and processing computers. Software controls the electronics necessary for retrieving or sending sensory information used to make logical decisions in guiding the boat. The processing

computer is housed in a waterproof, plastic box painted white to lower surface emissivity, limiting the thermal radiation reaching the computer box. The box also contains most other electrical components wired through access holes to reach external components, including cameras, microphones, range finders, and motors.

The structure of the boat and mounting of the hardware relied upon the mechanical group. The ODU team had a new design for this year's competition consisting of two easily assembled aluminum pontoons alongside a rectangular frame. Designed by ODU students and fabricated at the Advanced Machine and Tooling INC. (AMT) in Virginia Beach, this yields a more rigid, more stable, and lighter platform than previous years' boats.

II. Autonomous Rover

A. Overview

B. Mechanical

1) Hull Design and Fabrication

Two demi-hulls were designed using Rhinoceros (McNeel & Associates, Seattle, Washington) Software. The initial design ratio of the separation of the demi-hulls divided by the length of them (S/L) was chosen to be .5. This lead to a designed length overall (LOA) of 53" and a separation (S) of 27", beam or width (B) of 8" and 8" in height. The demi-hulls were reinforced with bracers on the inside of the hull for strength. A bilge design or rounded hull was used to maximize the displacement. The demi-hulls were designed to be made of 1/8th inch 6061-T6 aluminum sheeting for its good machinability, weldability and corrosion resistance. The proposed new deck was then drawn in Rhinoceros Software using the dimensions 1.5"x1.5"x0.125" of 6061-T6 aluminum angle iron. The full weight of the new system was calculated based on the surface area calculation tool in the Rhinoceros Program along with the predictions for the individual system components. This weight was used to produce a Hydrostatics and Stability Report and a Holtrop Analysis Report in Orca 3D (DRS Technologies Inc., AMTC, Stevensville, Maryland) Software. From this analysis the

Froude number, a dimensionless number used in resistance calculations came out to be 4.99; this was used to find the total speed of the full size vessel with certain design parameters as size and weight. The equation for the Froude number is $V \div \sqrt{L_{wl} \, g}$ .. where V is velocity, Lwl is length waterline, and g is gravity. Also the Hydrostatic & Stability Report along with the Holtrop Analysis Report allowed for iterations in the original design so that the vessel would sit at a more suitable height in the water and create less draft. After the iterations and hydrostatic waterline were drawn into Rhinoceros the drawings were finalized.

2) Computer Housing

The central processing unit (CPU) is housed in the electrical box on the top of the boat. This box was chosen for many reasons. Last year, ODU team had a box that was made of pelican 1520 case and weighed for 15 pounds. This affected the central gravity of the entire boat wherever the electrical box was placed and resulted in the instability of the boat. To solve this problem last year the team added extra pontoons to the middle of the boat, which increased drag and decreased its ability to turn. The electrical box that is used this year is made of plastic, which weighs for 3 pounds that has less effect on the central gravity of the boat. Furthermore, this box has a larger volume that provides more space to add more hardware if needed.

3) Sensor Mount

To mount the sensors on the boat, ODU team members had to detect the best locations that the sensors can perform best and have an ultimate collection of data of the surroundings. Three ping sensors are mounted in the front of the boat's frame. The first sensor is directed straight forward from the center of the boat and the other two ping sensors are directed at 45 degree angles to the right and to the left. The color and sound sensors are located in the very bottom of the boat next to the pontoons. They are mounted in pairs of one sound sensor beside one color sensor. Color and sound sensors are demountable and installable in order to avoid their damage while moving the boat.

C. Electrical

1) Hardware

The boat's autonomous navigation logic relies upon using a direct drive propulsion system re-using two 18lb thrust, Watersnake trolling motors. ODU's vehicle utilizes standard high voltage speed controllers to control each trolling motor individually, using distance and camera sensor data to autonomously navigate on the water.

The boat's autonomous navigation logic relies upon using a direct drive propulsion system re-using two 18lb thrust, Watersnake trolling motors. ODU's vehicle utilizes standard high voltage speed controllers to control each motor individually, using distance and camera sensor data to navigate autonomously on the water.

For communication with on-shore computers and servers

a bullet antenna is used, which increases the computer's broadcasting range.

Manual control of the vehicle is done using a Futaba remote controller, allowing us to control each one of the motors separately in both forward and reverse directions. The controller has multiple other buttons that allow us to configure the control of other features if necessary, and the controller itself has more than enough broadcasting range for controlling the boat within eyesight. Extra toggle switches on the side are used to switch on or off the autonomous mode or to switch on or off the motors.

2) Software

For the 2013 AUVSI IRC, the team had several conflicting issues caused by poorly integrated software preventing the initiation of many tasks the boat was capable of performing. The team sought to avoid similar problems for the 2014 IRC by creating modularized code, allowing bugs to more easily be traced and fixed in the software code. The software on the boat is built in a variety of languages, all compiled separately and run with the main program built in C++, which calls and controls each program separately.

3) Computer (CPU)

For the computer system, the CPU, a small form factor is used that is Foxconn h67s atx motherboard. Also, a smaller processing hardware like the UDOO, which is a quad-core ARM processor single board computer is considered to be used. It was realized though that the benefits gained from decreasing the size and weight of the processing hardware was not beneficial after considering the extra time needed for software development alongside the decrease in graphics processing power.
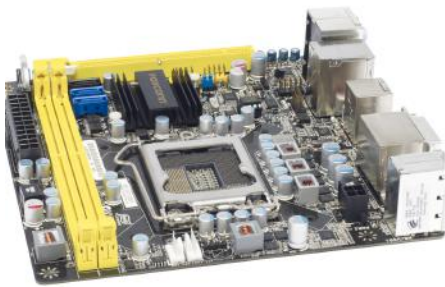
4) Hardware Controllers

In order to communicate with all external hardware there are three Arduinos which have been programmed to receive commands from the computer in order to get all the sensor data and to control the propulsion system. The preference for using Arduinos is because they are user-friendly programmable microcontrollers that do not require extensive knowledge of electrical or computer systems.

The Arduinos receive sensor data and relay it to the CPU when the CPU asks for the data, which the CPU then uses to develop the vehicles navigation logic. This logic data is then passed through another Arduino, which uses the logic to control a motor speed controller in order to control the direction of the boat.

5) Sensors

The boat is equipped with several different sensors in order to attempt all the competition challenges. There are four TCS2300 sensors for detecting color and four sensors for detecting sound. Using four of color and sound sensor pairs in underwater containers is to navigate towards the highest sensitivity values of each type of sensor.

A 66 channel GPS receiver is used for GPS waypoint navigation. This GPS is capable of guiding the boat within close enough proximity of the tasks that other sensors can provide finer adjustments needed for challenges.

For above water color and object identification, the OpenCV libraries are used with a Logitech c920 webcam. This webcam seems more resistive to reflections and glares than most other webcams of similar price point. The Logitech c920 also provides a very detailed image of decent clarity at mid-range distances.

Object detection is achieved by using three Ultrasonic Range Finders - XL-Maxsonar EZ0, or ping sensors. These sensors are small and easy to use and mount to the boat. Ping sensors guarantee a delicate reading in short distances from 0 to 765 cm (0 to 25.1 ft) with 1 cm resolution. The range of powering these sensors can be between 3.3 and 5VDC.

III. CONCLUSION

The ODU ASV team built the 2014 competition boat upon an aluminum frame, yielding many advantages. The decrease in time required to modify equipment and secure sensors to the ASV is a major asset while attempting the competition tasks. Various components from the previous year's boat were recycled into the assembly of the current boat to reduce cost and to maximize the fluency of the navigation code. One critical component recycled from the previous boat is the propellers, allowing shared software calibration for effortless implementation with respective speed controllers for drive accuracy assurance and vessel stability. Other recycled components of the 2014 boat include electrical components for existing software compatibility, limiting time required to rework hardware layout modify code. By recycling these components and making modification of the boat easier, the time allotted for assessing and reacting to new challenges of the 2014 competition was maximized providing confidence in the ODU ASV team's ability to successfully attempt to complete all of the 7th annual AUVSI Roboboat competition challenges.

REFERENCES (EXAMPLES – NEED EDITS)

[1] G. O. Young, "Synthetic structure of industrial plastics (Book style with paper title and editor)," in *Plastics*, 2nd ed. vol. 3, J. Peters, Ed. New York: McGraw-Hill, 1964, pp. 15–64.

[2] W.-K. Chen, *Linear Networks and Systems* (Book style)*.* Belmont, CA: Wadsworth, 1993, pp. 123–135.

[3] H. Poor, *An Introduction to Signal Detection and Estimation*. New York: Springer-Verlag, 1985, ch. 4.

[4] B. Smith, "An approach to graphs of linear forms (Unpublished work style)," unpublished.

[5] E. H. Miller, "A note on reflector arrays (Periodical style—Accepted for publication)," *IEEE Trans. Antennas Propagat.*, to be published.

[6] J. Wang, "Fundamentals of erbium-doped fiber amplifiers arrays (Periodical style—Submitted for publication)," *IEEE J. Quantum Electron.*, submitted for publication.

[7] C. J. Kaufman, Rocky Mountain Research Lab., Boulder, CO, private communication, May 1995.

First A. Author (M'76–SM'81–F'87) and the other authors may include biographies at the end of regular papers. Biographies are often not included in conference-related papers. This author became a Member (M) of IEEE in 1976, a Senior Member (SM) in 1981, and a Fellow (F) in 1987. The first paragraph may contain a place and/or date of birth (list place, then date). Next, the author's educational background is listed. The degrees should be listed with type of degree in what field, which institution, city, state, and country, and year degree was earned. The author's major field of study should be lower-cased.