Old Dominion University ODS BlueFin Journal RoboBoat Competition

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***Abstract*—The goal of the 2015-16 Old Dominion Autonomous Surface Vehicle team is to outperform expectations at competition while gaining an understanding in the automation systems utilized. The team plans on taking the learning's from this year long project and building upon them throughout their engineering careers. Autonomous vehicles are no longer a far-fetched dream as they are nearing production and testing.**

The scope of the competition our team will be participating in contains multiple obstacles where the vehicle is required to not only avoid certain barriers but also obtain data wirelessly while holding a position. The vehicle can contain multiple sensors including ultrasonic, lidar, IMU, and cameras on board. These devices all gather data at various instances to later provided assistance in decision making done on the CPU. This CPU is paired up with microprocessor boards in the effort to gather the data mentioned above. While the vehicle is fully automated with little or no manual interference, the team will be equipped with a safety switch on land while the competition is in route.

The competition brings students from various countries and universities to one local event to showcase their ideas. The competition is held on our home turf, Virginia Beach, VA. This provides us, the Old Dominion Team, with an upper hand as we are not located far from the competition site. The past few teams have had great success in the past which we hope to achieve this year.

I. Introduction

The goal of the Old Dominion University Autonomous Surface Vehicle team is to build a vessel to compete in the 9th Autonomous Unmanned Vehicle Society International – Autonomous Surface Vessel competition (AUVSI-ASV) [1]. The vehicle must be able to navigate through the given course and complete mission tasks. Knowledge of vehicle control (which includes navigation, positioning, data fusion, and motion stabilization), obstacle detection and avoidance, system integration, wireless communication, manufacturing and payload management is essential to the design of the vehicle.

II. Key elements

Key elements for the autonomous surface vehicle include maneuverability, obstacle detection, and communication. The vehicle will navigate itself through the obstacle course using GPS coordinates. While it is going through the course, it should be scanning the area for objects in its path of motion. If it detects something, the vehicle's computer should be able to make a logical decision as to what it should do next. Ultrasonic sensors, LIDAR, and cameras will be key components in object detection and avoidance. Wireless communication is vital to success in the competition. Certain GPS Coordinates, gate codes, and other course information will be sent over the wireless network.

III. Paper Contents

A. Hull Design

The new hull design, shown in Figure 2, was designed to improve on the flaws of the old vessel. For the new vessel, a mono hull design was chosen instead of a Catamaran hull like the previous one. Having a mono hull reduces drag and maintains stability which is important as we maneuver through the course. In an effort to decrease weight, the steel material of the old design would be replaced by a lighter material. One of the aspects that we wanted to be featured was for the vehicle to have modularity. If need be, we would like to have the option to be able to remove any parts of the boat, work on them, and place them somewhere else. This will be helpful once we start testing and integrating the sensors, camera, and GPS components.

The new design will allow us to remove the top and put the electrical components and batteries inside. Having the electrical systems stored inside will protect it from any exposure to water. To solve the cooling issue the previous team had, we have an exhaust system that will take air in and then filter it out. There will also be two fans under the top to further cool down the computer systems.

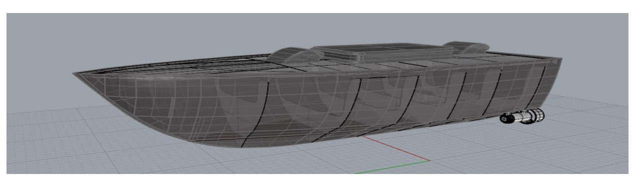

Fig 1. Rhino Hull Design Vehicle Design

B. Obstacle Detecction

Obstacle detection is important as the vehicle navigates through the course. The vehicle needs to be able to detect the buoys, docks, and gates. The vessel will be equipped with a Lidar sensor and ultrasonic proximity sensors to detect objects in its path. Lidar sensor technology measures distance by emitting a light beam and uses the reflected light to calculate the proximity of the object. The particular

LIDAR sensor model we are using is the LIDAR-Lite 2 Laser Rangefinder produced by PulsedLight [4]. It needs a 5V power source and has a low power consumption. This Lidar sensor can scan up to 40 meters in front of the sensor. We are using a Futaba S3004 Servo so that we can get a 180 degree scan of the area in front of the LIDAR instead of a linear scan. This LIDAR operates at measurement speeds of up to 500 readings per second allowing us to attain better resolution for our scanning applications.

Ultrasonic proximity sensors will be utilized in order to get more detection of obstacles. Ultrasonic sensors emit signals and use the time the signals echo back to calculate the distance of objects. The model we will use is the Ultrasonic Ranging Module HC-SR04 sensors [5]. They have a range of sensing from 1 inch up to 13 feet which is ideal for the RoboBoat competition. The functions of these sensors are not affected by sunlight which is important due to the competition being held outdoors. Unlike the Lidar, these ultrasonic sensors are low cost and easily integratable with our system. In the picture below, the ultrasonic sensor is housed in a 3-D printed casing that was designed, printed, and delivered to us from our counter MET team.

C. *Vision*

A camera onboard serves as another efficient method to detect obstacles. Camera technology offers more than just detecting distance. It allows for the capability of detecting certain colors and shapes. This is useful in the automated docking mission task where the vehicle will have to dock at three different docks assigned by the hosts of the competition. The sequence will be determined by the hosts. These docks will each have their own sign with a different colored shape. The camera will be helpful in detecting these colors and shapes and dock in the correct sequence.

The vision system utilizes the OpenCV library and a Logitech C920 webcam. The program is written to be able to detect the shapes of the signs on the docks, buoys, and any other obstacle that may be assigned. This year's competition features an interoperability challenge where an AUV will have to take a picture of a display and identify what number it took a picture of. The vision system will be useful in completing this challenge. Having this camera on board will prove to be important also in giving us video monitoring or playback for testing purposes.

D. *Navigation*

Navigating successfully around the course is very vital for our vehicle. This can be the difference between staying on course or wandering off and failing a run. The GPS module we are utilizing is the same module the past team used which proved to be accurate. The module is known as a 3DR Ublox GPS with Compass. The technology in this GPS widget is famously used in quad copter systems worldwide and is perfect for the competition requirements [7]. While provided with coordinates throughout the entire course, we can utilize this data to efficiently stay on course and avoid wrong turns.

E. *Wireless Communication*

One of the most important tasks within the competition is communication with the judges to receive information while the vessel is underway. During specific tasks such as the buoy avoidance and the auto docking; the vessel will need to receive information from judges in order to know how to complete the task. During the testing and competition, the team would like to be able to see and look at the data that the vessel is processing. Communicating with the vessel that is a distance away creates a challenge when it comes to communication. In order to overcome this challenge our team has decided to utilize wireless communication. Wireless communication has become a major tool used all over the world for various challenges. There are many different tools and hardware that can be used for wireless communication. We are utilizing the Ubiquiti Bullet M2 Zero-Variable Outdoor airMax Radio.

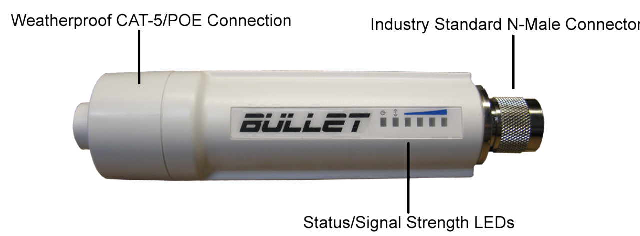

Fig 2. Ubiquiti Bullet M2 Zero-Variable Outdoor airMax Radio

Using one bullet on the vessel and one bullet on land will allow us to remotely monitor the computer on board and will also allow the computer on board to communicate with the judges servers to ask for and receive data. Since the distance that from land to the vessel will not ever be that great due to the size of the course these antenna should be sufficient in providing a strong and secure connection.

F. *Onboard Computer*

The onboard computer is composed of a couple different components. Our team has decided to go with the same motherboard as the previous year's team since they already had an extra one and that saves us money from our budget. The motherboard acts as the coordinator of the entire system, it handles communication between input/output devices, storage and the CPU. The motherboard we chose is an ASUS H971-PLUS [9]. This is a mini-ITX motherboard that is designed to provide all of the features of a regular sized motherboard with the fraction of the size. Size is very important since our vessel is only but so big and we need to optimize all of the space we can.

One of the most important components of the computer is the CPU or processor. This is the brain of the operation. Since we need our computer to make decisions as fast as possible within our budget; we decided to use an Intel Core i5-4690 processor [9]. This processor is quad-core allowing for faster and more decisions to be made simultaneously. This processor is on the lower end when it comes to power consumption at 85W. To support the speed and decision making of the CPU we will be outfitting the on board computer with 2x4GB HyperX Fury DDR3 memory [10]. Working along with the processor and motherboard the 8GB of memory should assist with the image processing, data processing, and communication between devices that the vessel will have to do in a timely manner in order to complete each task of the competition.

Each of the computer components is not necessarily meant to be operated off of battery power so providing power to the computer components creates a challenge in itself. Since the boat will be operating on 3 4S LiPo batteries that will provide unregulated power, our team has decided to use an automotive power supply that is intended to supply power for automotive computers. The M4-ATX-HV is an ATX standard power supply that accepts any DC input between 6 and 34 volts [11]. Since the power supply is normally used in automotive applications, it has a built in feature to power down the computer cleanly in situations where the battery is drained or the battery is rapid disconnected.

Storing and accessing all of the data that will be necessary for the vessel will be also be important. The computer will need an operating system and multiple programs that will be necessary in order to function. All of this will be stored on a 128GB Samsung 850 Pro SSD [12]. Solid state drives are one of the fastest storage solutions available today for computers and they provide that speed with low power consumption.

G. Data Integration

In order to get all of our data integrated into the onboard computer we are using the Robot Operating System (ROS). In order to work on ROS are onboard computing is running the linux-based operating system Ubuntu. With ROS we are able to create different nodes for the variety of sensors that will be used on our autonomous surface vehicle. The nodes for the ultrasonic sensors, GPS, lidar, camera, and wireless communication will be established as publisher nodes so that they can publish data to the master node which will be a subscriber. The subscriber node will be able to take in all of the data from the nodes that it is subscribed to. Once all the data is collected the master node will be making the decisions on the matter of obstacle detection or which one of the sensors will take priority over others to be able to go through the competition successfully.

III. Evaluation

A. Results

As our team is a few months out from competition, our progress over the past two semesters have brought our talents and hobbies together to result in the hull we display below. We have a minor set of modifications and additions to complete before we land at competition in July. In the sections below, we highlight our great accomplishments along with learnings and data to showcase our progress.

B. Hull Construction

The boat we are currently working with was donated to us from an old team here at Old Dominion University. We have maintained the design we initially had while working and constructing the boat. Due to budget and time constraints, we were unable to our initial boat design fabricated, but were fortunate enough to have a similar designed boat to work with. Below is a picture of the boat at its most current state.

Fig 1. Current Hull State

We started with an empty hull that required and needed some cosmetic work. This cosmetic work was done by the MAE team, who were able to reseal and repaint the entire body. Before any cosmetic work was done, the image below indicates our vessel.

Fig 2. Hull State Before Restoration

Cosmetic work was required as we were unsure where previous cracks and deformities may have existed. Below we have included an image that was taken at the end of the cosmetic stage.

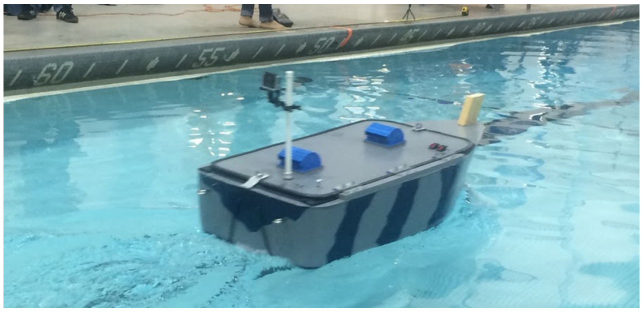

Fig 3. Hull State After Restoration

Once the hull was prepared for us, we the ECE team were able to begin implementing our design and start mounting various modules. We began by understanding the size restrictions inside the hull to plot our on board computer. This was very vital as the previous team had great difficulties with the computer layout. We were able to also get started on the hood design, as this would be a very important and would include the control switches, fans, and wireless routers. We have included a picture below that documents the planning state of our hull.

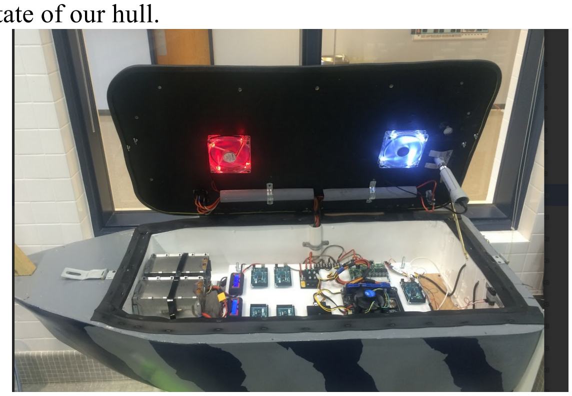

Fig 4. Interior of Hull During Planning State

C. Propulsion

For the vessel to navigate the course successfully, we had a dual propulsion system integrated to provide the necessary power. These thrusters are manufactured by Blue Robotics who sell marine components for rc size vessels and have developed a line of thrusters specialized for our need. The T200 model is a brushless electric motor that is made from high strength material, and pre-fitted with a electronic speed controller that we were able to tie into our system effortlessly. The esc's, one for each thruster, were ran side by side into our Arduino board that is solely responsible for taking in data based upon signals we declared necessary. As effortless as this process was, understanding the turn radius of the vessel at exact signals required extensive testing.

When working to understand the boat's ability to navigate the necessary path, our team developed numerous test cases to test and understand the effects of various signals. In order to test each possible case, we created an array of possible routes based upon the various speed control signals which are displayed below. Our speed controllers worked on a simple scale, 1500 microseconds being idle, 1100 microseconds resulting in full reverse, and 1900 microseconds outputting a full forward speed. With a scale of 800 microseconds, we equally divided the values among the various test cases. As shown below, the green values show idle signals that are being sent, and the yellow show a reverse signal to provide a sharper turn.

Once we programmed the test cases onto the onboard computer, a vital trip to the Old Dominion University Pool was needed to test and document each result. Our main goal was to understand the time and turn radius each sequence generated which we measured as shown below.

Using the starting and stopping position of the vessel in reference to the walls of the pool gave us a starting and stopping location. Also using the same point on the board (the bow shown by the yellow circle) will give us a total distance traveled and time taken to get there. These trials resulted in the table shown below. The distances were recorded in inches, and the times were automatically calculated from the program that initiated each trial.

This Appendix is taken from the IEEE Transactions template on the IEEE website, and should be followed for citing references (http://www.ieee.org/web/publications/authors/transjnl/index.html).

Basic format for books:

[1] J. K. Author, "Title of chapter in the book," in *Title of His Published Book, x*th ed. City of Publisher, Country if not

[2] USA: Abbrev. of Publisher, year, ch. *x*, sec. *x*, pp. *xxx–xxx.*

Examples:

[3] G. O. Young, "Synthetic structure of industrial plastics," in *Plastics,* 2nd ed., vol. 3, J. Peters, Ed. New York: McGraw-Hill, 1964, pp. 15–64.

[4] W.-K. Chen, *Linear Networks and Systems*. Belmont, CA: Wadsworth, 1993, pp. 123–135.

Basic format for periodicals:

[5] J. K. Author, "Name of paper," *Abbrev. Title of Periodical*, vol. *x,* no. *x,* pp. *xxx-xxx,* Abbrev. Month, year.

Examples:

[6] J. U. Duncombe, "Infrared navigation—Part I: An assessment of feasibility," IEEE *Trans. Electron Devices*, vol. ED-11, no. 1, pp. 34–39, Jan. 1959.

[7] E. P. Wigner, "Theory of traveling-wave optical laser," *Phys. Rev.*, vol. 134, pp. A635–A646, Dec. 1965.

[8] E. H. Miller, "A note on reflector arrays," *IEEE Trans. Antennas Propagat.*, to be published.

Basic format for reports:

[9] J. K. Author, "Title of report," Abbrev. Name of Co., City of Co., Abbrev. State, Rep. *xxx*, year.

Examples:

[10] E. E. Reber, R. L. Michell, and C. J. Carter, "Oxygen absorption in the earth's atmosphere," Aerospace Corp., Los Angeles, CA, Tech. Rep. TR-0200 (4230-46)-3, Nov. 1988.

[11] J. H. Davis and J. R. Cogdell, "Calibration program for the 16-foot antenna," Elect. Eng. Res. Lab., Univ. Texas, Austin, Tech. Memo. NGL-006-69-3, Nov. 15, 1987.

Basic format for handbooks:

[12] Name of Manual/Handbook, *x* ed., Abbrev. Name of Co., City of Co., Abbrev. State, year, pp. *xxx-xxx.*

Examples:

[13] *Transmission Systems for Communications*, 3rd ed., Western Electric Co., Winston-Salem, NC, 1985, pp. 44–60.

[14] *Motorola Semiconductor Data Manual*, Motorola Semiconductor Products Inc., Phoenix, AZ, 1989.

Basic format for books (when available online):

[15] Author. (year, month day). *Title.* (edition) [Type of medium]. *volume (issue).* Available: site/path/file

Example:

[16] J. Jones. (1991, May 10). *Networks.* (2nd ed.) [Online]. Available: http://www.atm.com

Basic format for journals (when available online):

[17] Author. (year, month). Title. *Journal.* [Type of medium]. *volume (issue),* pages. Available: site/path/file

Example:

[18] R. J. Vidmar. (1992, Aug.). On the use of atmospheric plasmas as electromagnetic reflectors. *IEEE Trans. Plasma Sci.* [Online]. *21(3),* pp. 876–880. Available: http://www.halcyon.com/pub/journals/21ps03-vidmar

Basic format for papers presented at conferences (when available online):

[19] Author. (year, month). Title. Presented at Conference title. [Type of Medium]. Available: site/path/file

Example:

[20] PROCESS Corp., MA. Intranets: Internet technologies deployed behind the firewall for corporate productivity. Presented at INET96 Annual Meeting. [Online]. Available: http://home.process.com/Intranets/wp2.htp

Basic format for reports and handbooks (when available online):

[21] Author. (year, month). Title. Company. City, State or Country. [Type of Medium].Available: site/path/file

Example:

[22] S. L. Talleen. (1996, Apr.). The Intranet Architecture: Managing information in the new paradigm. Amdahl Corp., CA. [Online]. Available: http://www.amdahl.com/doc/products/bsg/intra/infra/html

Basic format for computer programs and electronic documents (when available online): ISO recommends that capitalization follow the accepted practice for the language or script in which the information is given.

Example:

[23] A. Harriman. (1993, June). Compendium of genealogical software. *Humanist.* [Online]. Available e-mail: HUMANIST@NYVM.ORG Message: get GENEALOGY REPORT

Basic format for patents (when available online):

[24] Name of the invention, by inventor's name. (year, month day). *Patent Number* [Type of medium]. Available: site/path/file

Example:

[25] Musical toothbrush with adjustable neck and mirror, by L.M.R. Brooks. (1992, May 19). *Patent D 326 189* [Online]. Available: NEXIS Library: LEXPAT File: DESIGN

Basic format for conference proceedings (published):

[26] J. K. Author, "Title of paper," in *Abbreviated Name of Conf.*, City of Conf., Abbrev. State (if given), year, pp. *xxxxxx.*

Example:

[27] D. B. Payne and J. R. Stern, "Wavelength-switched pas- sively coupled single-mode optical network," in *Proc. IOOC-ECOC,* 1985, pp. 585–590.

Example for papers presented at conferences (unpublished):

[28] D. Ebehard and E. Voges, "Digital single sideband detection for interferometric sensors," presented at the 2nd Int. Conf. Optical Fiber Sensors, Stuttgart, Germany, Jan. 2-5, 1984.

Basic format for patents:

[29] J. K. Author, "Title of patent," U.S. Patent *x xxx xxx*, Abbrev. Month, day, year.

Example:

[30] G. Brandli and M. Dick, "Alternating current fed power supply," U.S. Patent 4 084 217, Nov. 4, 1978.

Basic format for theses (M.S.) and dissertations (Ph.D.):

[31] J. K. Author, "Title of thesis," M.S. thesis, Abbrev. Dept., Abbrev. Univ., City of Univ., Abbrev. State, year.

[32] J. K. Author, "Title of dissertation," Ph.D. dissertation, Abbrev. Dept., Abbrev. Univ., City of Univ., Abbrev. State, year.

Examples:

[33] J. O. Williams, "Narrow-band analyzer," Ph.D. dissertation, Dept. Elect. Eng., Harvard Univ., Cambridge, MA, 1993.

[34] N. Kawasaki, "Parametric study of thermal and chemical nonequilibrium nozzle flow," M.S. thesis, Dept. Electron. Eng., Osaka Univ., Osaka, Japan, 1993.

Basic format for the most common types of unpublished references:

[35] J. K. Author, private communication, Abbrev. Month, year.

[36] J. K. Author, "Title of paper," unpublished.

[37] J. K. Author, "Title of paper," to be published.

Examples:

[38] A. Harrison, private communication, May 1995.

[39] B. Smith, "An approach to graphs of linear forms," unpublished.

[40] A. Brahms, "Representation error for real numbers in binary computer arithmetic," IEEE Computer Group Repository, Paper R-67-85.

Basic format for standards:

[41] *Title of Standard*, Standard number, date.

Examples:

[42] IEEE Criteria for Class IE Electric Systems, IEEE Standard 308, 1969.

[43] Letter Symbols for Quantities, ANSI Standard Y10.5-1968.