Stevens Institute of Technology: Autonomous Surface Vehicle

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Figure 1: The completed SIT ASV

ABSTRACT

The Stevens Institute of Technology Autonomous Surface Vehicle incorporates 'semisubmersible' wrapped foam pontoons for flotation, HD cameras for vision analysis, and custom LabVIEW programming which allows for autonomy with a front panel allowing for quick adjustment of parameters to account for environmental changes. All aspect of the vehicle haven implemented and tested in complete compliance for competing in AUSVI's Fifth Annual RoboBoat Competition.

1. INTRODUCTION

The Stevens Institute of Technology submission into the Fifth Annual RoboBoat Competition was designed, built, and tested with the goal of completing all of the tasks in the "Five Card Draw" themed competition. This year's entry has several significant modifications over the Stevens ASV entry from last year including computer system upgrades, completely redesigning the image filtering and decision making, as well as task based subsystems.

Our vehicle was redesigned from the ground up with custom fabricated foam wrapped hulls. As a replacement to last year's fiberglass hulls, the new hulls provide a greater freeboard distance and increased in water stability. Other components such as an aluminum frame, and task mechanisms have been designed and built in order to interface with the new hull system. The team has also completely overhauled the computer system and software, creating entirely new LabVIEW VI's to provide autonomy for all competition tasks loosely based on the "building blocks" of last year's submission. Several successful water tests over the past five months have proved essential in debugging and modifying the vehicle. The Stevens Institute of Technology ASV team is very proud to present this vehicle at AUVSI's RoboBoat 2012 Competition.

2. HULLS

2.1 Design

Early on during this project our team investigated alternative hull designs for the vessel with the assistance of our team's naval engineer. The hulls on last year's vessel only displaced enough water, given the weight of the entire vehicle, to provide only a one inch gap between the waterline and top of the hull (freeboard). At a very minimum the team wanted least 2 inches of freeboard on the hulls to prevent the vessel from sinking or otherwise capsizing.

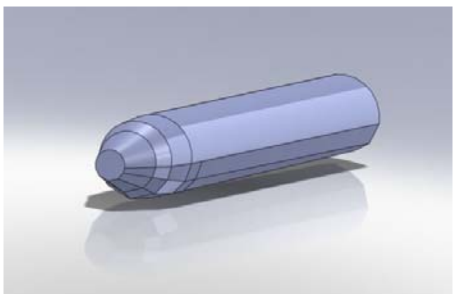

Figure 2: Prototype Pontoon Hull

The concept for the current design included inflatable nylon construction, much like a zodiac boat. Due to the fact that these pontoons were not constructed from rigid materials, it would be difficult if not impossible to construct the many faceted faces employed on this proposed design and have them hold their shape. This being the case, the group modified the design and removed the facets to form a smooth cylinder. This cylinder maintains the same buoyancy as the original proposed design.

2.2 Fabrication

To combat the potential problem of a catastrophic puncture causing rapid deflation of the pontoon and the sinking of the vessel, the group further modified the design of the pontoons to include an inner foam core. This was achieved by using pool noodles which were initially bound in a tough water resistant tape, arranged in a configuration that would preserve the original dimensions of the pontoons.

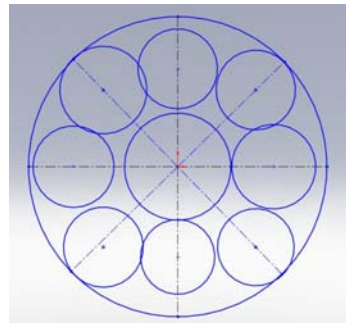

Figure 3: Noodle Arrangement

The bound noodle pontoons were then sent to Switlik Parachute Corporation to be bound in a commercial waterproof material with all seams sewn and or heat sealed to prevent water from entering the pontoons and increasing their weight. A cone was sewn to the front of the pontoon in order to taper the front of the pontoon improving the ability to 'cut' through the water improving drag performance. The Switlik Parachute Corporation specializes in inflatable safety equipment for aviation, marine, and government applications

2.3 Mounting System

Due to the non-rigid nature of the new hulls, a mounting system comprised sleeves sown down the length of each pontoon, bars through those sleeves, and brackets to secure the bars to the frame were designed and fabricated.

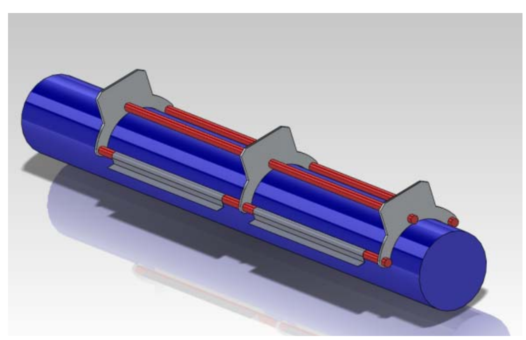

Figure 4: Pontoon Hull Mounting System

3. FRAME

As the vehicle's skeletal structure, the team built a new frame comprised of a double beam structure to oppose flexural and torsional stresses. The double beam creates a highly rigid frame thus more evenly distributing load and maximizing space for mounting of task mechanisms and other components.

The new frame design has the dimensions of 66 inches in length and 32 inches wide, which are the same dimensions as the previous frame. It is also made of lightweight 1" x 1" 6061 Aluminum rods and estimated to have the weight of roughly 11.37 pounds.

Figure 5: Assembled Hull and Frame

4. ELECTRICAL SYSTEM

The majority of the ASV's electrical system is by and large unchanged from last year's entry. However the most noticeable addition is two ballistic lithium ferrous batteries. Analogous to last year's lead acid batteries, the lithium ferrous batteries wired in series provide enough power to run the entire vehicle at only a third of the weight.

5. COMPUTER SYSTEM

Our ASV is equipped with a fully functional computer which interfaces through LabVIEW to microcontrollers and other USB devices such as the GPS, USB compass, and HD cameras. This year, the operating system, hard drive, and RAM were upgraded to Windows 7, 64GB solid-state, and 8GB, respectively, to ensure the central OS compatibility with all components and that the computer has decent specifications.

In order to be able to update and control the vessel from a laptop that is not physically connected to the machine, it was necessary to set up an ad hoc wireless network connection between the vessel's on board computer and an outside laptop. This enabled remote desktop capabilities without having to connect a display, mouse and keyboard to the onboard computer in the event that quick changes need to be made, especially during the competition when time is limited.

LabVIEW was once again chosen as the primary development environment for the ASV. Due to its easy-to-use graphical programming interface, it allowed for rapid development even by team members with little programming experience. LabVIEW has been designed with projects such as this one in mind and includes many libraries and add-ons that are specifically developed for use with hardware equipment for robotics, including machine vision.

6. TASK SUB-SYSTEMS

This section will highlight how the vehicle will attack each challenge station in the competition.

6.1 Speed Gate

The method used to complete this task in last year's competition was simple. Last year the ASV was lined up with the two gates and ran at 80% maximum thrust for a predetermined time. This method proved successful but had a few obvious flaws. The most obvious flaw would have occurred if the boat was misaligned.

To ensure that the ASV remains on a straight course the group developed a Proportional Integral Derivative (PID) controller in LabVIEW. The code first acquires the raw heading from the

OceanServer OS5000-US digital USB compass (see Figure 6) while the PID controller will automatically adjusts the rudder values in response to the difference between the desired heading and the actual heading. The maximum tolerance for this heading difference was determined; through the use of simple trigonometry at around 2°. If the boat is unable to maintain the centerline between the two sets of speed gates runs the risk of bumping into one of the speed gate navigation buoys or not making it through.

Figure 6: USB Digital Compass

6.2 Channel Navigation

Our vehicle utilizes LabVIEW's Vision suite to acquire, filter and collect data from images. The images obtained were from an "off-the-shelf" high definition web camera. This method proved to be quite effective however there were some problems discovered early on by the group.

The first problem was that the filters used last year only separated out object by color and minimum area. This was insufficient because of objects or glares that may have areas within the range of buoy tolerance, as a result such interference would not be filtered out. The second problem was the method used for determining which object that data was gathered from.

This year's image processing and filtration system was further refined to combat the issue of interference from glare and undesired objects. To ensure more noise is screened out, the team added a diameter filter and a fill modifier, both LabVIEW provided functions that use user defined input values. The diameter filter allows for objects that are too thin or too wide to be removed, thus allowing for the removal of narrow or wide objects with on screen areas similar to those of the buoys. The fill modifier acts to fill in any tiny gaps within desired objects. With these modifications to the filtration system the group has improved upon the previous team's channel navigation image filtering and logic.

6.2 Hot Suite Task

The IR sensor is attached to two servo motors, giving it two degrees of freedom so that it can be manipulated up and down as well as left and right to get the most accurate reading possible without movement of the entire ASV. A second USB camera is also mounted to this assembly and is used to take a photograph of the "hot suite" for suite detection.

The automated program works by running an Arduino program which begins a sweeping pattern with the two servos. At first, it will take an initial reading and picture. While at each position the sensor takes a reading and passes the voltage valued obtained in LabVIEW. If the value is greater than the previous, it will store it and take a new picture. At the end of the sweep, the latest picture taken is processed by LabVIEW to determine its suite based off of color and pre-defined images of each suite. Lastly, the GPS coordinates are logged and then, combined with the determined suite, a message is sent over TCP to the judge's IP and Port number.

6.3 Cheater's Hand

Rather than enabling the water stream, sweeping back and forth hoping to hit the target, the vehicle will use logic similar to our channel navigation to locate and steer towards the cheater's card. Knowing the angle of the water stream and a vertical distance from the water stream to the middle of the blue box, a distance from the target was calculated using simple trigonometry and an algorithm reading the perceived size of the box based on the number of pixels can keep the vessel an exact distance from the target. Weighing only 4lbs, the wash-down pump being used interfaces with the 12 volt relays on the ASV in order to provide a steady stream of water.

6.4 Poker Chip

Similar to Stevens' entry into last year's competition, this year the team has once again chosen to use our Lynxmotion robot in conjunction with a new deployment mechanism.

In order to deploy the robot onto the ramp, a slider mechanism uses two drawer sliders, typical of those found in kitchen cabinetry, are mounted to a platform where the robot will sit atop of an anti-slip surface. Using a four-bar arm set in motion by a high torque DC motor, the slider mechanism can extend and retracted to the proper length so that the Lynxmotion robot can drive from the ASV onto the poker chip ramp.

As for capturing the poker chip, the robot will be tethered to the ASV using a USB cable over which camera and motor control information will be processed with the main computer. Utilizing a similar, however altered, navigation routine to drive towards the black poker chip, once touching the chip glue rat traps affixed to the robot will allow for its steps to be retraced on the way back to the mother ship ASV.

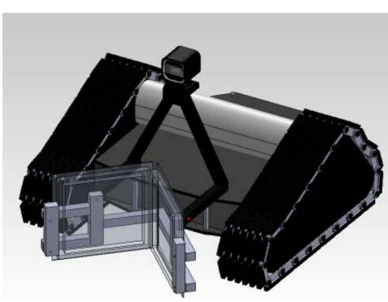

Figure 7: Lynxmotion Robot

6.5 Jackpot

Another of the tasks this year is to find a submerged buoy and then press a button that is found nearby above water. For the task we have designed a box to contain an off the shelf Hummingbird fish finder (see Figure 8) and a web camera to collect the sonar data by viewing the screen. The back lighting of the fish finder is sufficient for the camera to detect the various images. The logic behind this task is similar to that of the channel navigation in which certain shapes and areas will be detected. The camera pointed at the screen of the fish finder will pick up objects. From here the buoy will be distinguished from the rest of the information. Once this is done, the boat will adjust its left and right motion to correctly hit the jackpot button.

Figure 8: Hummingbird Fish-Finder

6.6 Card Exchange

For our boat, we have determined that the score benefits of the robotic manipulation are outweighed by the added bulk and complexity required to perform this task. Since it is required that our boat be able to hold the five cards at one time, the card exchange plate has been built. This plate is created out of expanded PVC, with 5 steel plates attached to the cards, to allow for the magnetic cards to stay in place.

7. Testing

Over the course of the past five months our team was conducted extensive testing in the Davidson Lab towing tank, the aquatic center pool, and at a pond about 45 minutes from Stevens. The primary focus of these tests included speedgate/compass navigation, and channel navigation. By getting the vehicle in the water, especially in a similar outdoor environment, our team was able to work out issues that would have proved costly at the competition.

Figure 9: ASV in the Davidson Lab towing tank

8. Conclusions

The Stevens Institute of Technology Autonomous Surface Vehicle Team has submitted their vehicle into AUSVI's Fifth Annual RoboBoat Competition. Our team has redesigned our hulls and frame to increase our freeboard. The replacement of lead acid batteries with lithium ferrous has significantly decreased our vehicle's weight while maintaining power requirements. The design, build, and testing new task based mechanisms serves as the hardware base to complete these tasks. The greatly improved vision acquisition, filtering, and processing algorithms in LabVIEW as used in channel navigation and object recognition for the other tasks will prove to be well-built in many competitions to come.