GTSR ASV Victoria - 2011 AUVSI RoboBoats Competition

[Abstract] Georgia Tech Savannah Robotics' (GTSR) student ASV project began as an interdisciplinary project between mechanical, electrical, and computer engineering students. Our mission is to construct new vehicles using parts from previous GSTR vehicles. The ASV's Hull was constructed from fiberglass. The fiberglass catamaran is a prototype that was built alongside the development of a land-based platform. A basic differential drive system is created by mounting CrustCrawler thrusters on each hull. This year's design is focused on reducing the overall weight of the vehicle. The hulls now contain the bulk of the electronics including all three batteries. All code now runs exclusively on the CompactRIO which houses an FPGA chassis. Our wireless communication, GPS navigation, and laser range finding equipment is mounted on top of the vehicle. Remote deactivation of the vehicle is achieved using a wireless radio relay. The overall waterproofing of the vehicle has been upgraded to ensure the safety of the onboard electronics.

I. Introduction

THIS year marks GTSR's second consecutive entry into AUVSI's International RoboBoats competition. The goal this year was to continue to develop a marine vehicle for testing autonomous control algorithms, with eventual plans of developing a vehicle for AUVSI's AUV competition. Victoria is also planned for use in various experiments in cooperative and networked marine vehicle control systems. This includes a vital role in a joint effort with Louisiana State University to survey the effects of the oil spill on the Gulf Coast. The first goal was to create a vehicle using many of the existing systems from remotely operated vehicles (ROV's) that were developed for the 2009 and 2010 MATE International ROV Competitions. These systems include CrustCrawler Hi-Flow thrusters, National Instruments' CompactRIO and LabVIEW development environments. Axis network cameras, a Garmin GPS, a Sick LIDAR, a Microstrain Inertial Motion Unit (IMU), and a newly trimmed hull were added to these systems.

Figure 1 Victoria Remodeled

II. Vehicle Systems

Many systems are being used to accomplish the missions for the competition. The following section outlines these systems and how they are incorporated to become a complete vehicle.

A. Mechanical

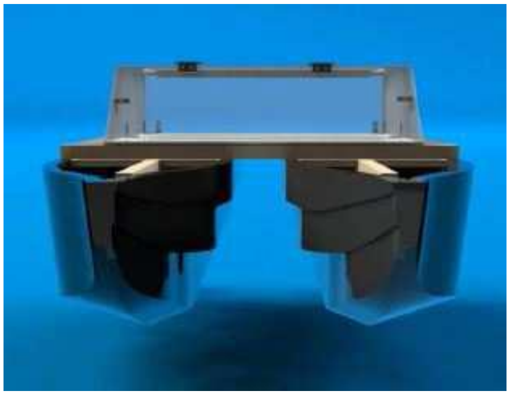

Figure 3 Original 3D Model

Figure 2 Banana Mold Design

Victoria has a catamaran style hull that provides a stable surface, as the boat maneuvers this helps keep all the sensors in a 2D plane. In figure 2, it is apparent that each hull is not symmetric. Instead, the inside of the hull resembles steps, while the outside of each hull is more planar. The twin hull catamaran design allows for a smoother ride, since the turbulence in the center of the boat is reduced. The optimized hull spacing can produce high load carrying capability and maintain optimum stability. The boat is made of three main parts that can be easily assembled or disassembled; they are the two hulls and the bridge that hold the system together. Victoria also has the same virtues as most current boats, a composite hull that provides high strength at a light weight. The fiberglass hull is made up of S-2 glass braided fabric sheets used with a super hard 4 to 1 Epoxy resin that is often used on surfboards or speed boats. The thickness of the hull is approximately 2mm. The thickness was achieved with 6-8 layers of fiberglass sheets. We used Epoxy because it provides a harder surface when compared to other resins, such as polyurethane. The weight ratio of the resin to fiberglass must be 50% for each material; therefore, an epoxy resin was the best choice. The final coat to the boat is Interlux VC, a performance Epoxy which produces a hard, slick, semi-gloss white finish with special additives to make wet sanding and burnishing easy if necessary in the future. This layer covers any porous parts of the fiberglass by sealing the whole surface of the boat with a slick coat that will reduce drag. To implement the designed fiberglass hulls a creative fabrication method was developed. A banana mold was used since fiberglass requires a mold for the resin and glass to set. The mold incorporates a rib and stringer method similar to what is used to make airplanes. There were 18 ribs made out of plywood, and cut to match the specified designed cross sectional area of the hulls. The first step to making the fiberglass was to block off one end of the mold. Since the same mold was used, we were able to make the body of the hulls exactly the same. The procedure can be seen in Figure 4. After each hull was made a frame was added, connecting the two hulls together, while serving as a house for electrical components that could not be contained within the hull. Weight distribution was a concern for the design. The propulsion system, power system, and electronic housing were arranged in a manner to keep the center of mass closest to the actual center of the boat. This is necessary to minimize pitching from acceleration and deceleration.


Figure 4 Fiberglass Procedure

A typical powered catamaran has two sources of propulsion, and Victoria is no exception. CrustCrawler High-Flow Thrusters, Model 600HF, are located at the stern under each hull. The orientation of the thrusters was chosen such that the vehicle could be modeled mathematically as a differential drive robotic system. The maximum power of the thrusters is 600 watts producing enough thrust to make Victoria a powerful vehicle. Previous measurements have rated Victoria at 50 pounds of thrust.

B. Electrical

The power system consists of two separate power supplies; one for propulsion and the other for sensors and devices. A set of 2 HR22-12 B&B batteries is used to provide 24 volts to the electronic speed controllers and CrustCrawler thrusters. These batteries were chosen for their high power to weight ratio, to reduce the overall vehicle weight. Besides the hulls, these batteries are the heaviest subsystem on Victoria. A 22.2, volt lithium polymer (Li-Po) battery powers the CompactRIO, Garmin GPS, Microstrain IMU, wireless router, and network cameras. An additional 25.9 volt Li-Po battery powers the LIDAR. Two VICOR DC/DC converters are used to obtain 12 and 5 volts for meeting the varying power requirements of the devices.


Figure 6 CrustCrawler Hi-Flow Thruster

Figure 5 HR22-12 B&B 12 Volt Battery

C. Sensor Network

Victoria's navigation system includes a Garmin 16x GPS receiver, Microstrain 3DM-GX1 Inertial Motion Unit (IMU), Sick LMS-291 Laser Range Finder (LIDAR), and two Ethernet cameras. Navigation is performed based on data received from one or more of the devices. The GPS, LIDAR, and IMU are connected to the CompactRIO via serial connections. The cameras are connected via a Linksys router. The GPS is an integrated waterproof antenna and receiver, providing WAAS-enabled GPS data at 1 Hz with an accuracy of 3 meters. The IMU contains 3 accelerometers, 3 gyros, and 3 magnetometers providing data at a rate of up to 100 Hz. The orientation provided by the IMU can be compared against GPS data to derive heading values. The LIDAR is a 75Hz, 180-degree scanning range finder used for object detection and avoidance. The data from the LIDAR in conjunction with the camera images is used for littoral navigation, shoreline detection, and mission state props.

The cameras chosen for the competition are Axis M1011 Ethernet cameras. The cameras can provide video at 30 frames per second (fps) with a resolution of 640x480, over Ethernet. They were chosen mainly for their compatibility with LabVIEW's Vision module.

Figure 7 Sensor Devices

D. Computer/Software

Georgia Tech Savannah continues to use National Instruments' LabVIEW and the CompactRIO embedded computing system for its robotics applications. The ease of interfacing hardware and software, the power of its vision software, and the availability of the hardware make this our top choice for a software interface. A major change from last year is the location of the computing. Last year a quad-core laptop with 4 GBytes of RAM running Windows 7 served as the mission computer, doing all the computing. This year the computing will be done on the CompactRIO except for a few vision processing algorithms. The FPGA module in the CompactRIO is used for interfacing with the thrusters, the mission apparatus, and the water cannon. The serial module on the CompactRIO allows for multiple interfaces which are used for communicating with the GPS, LIDAR, and IMU.

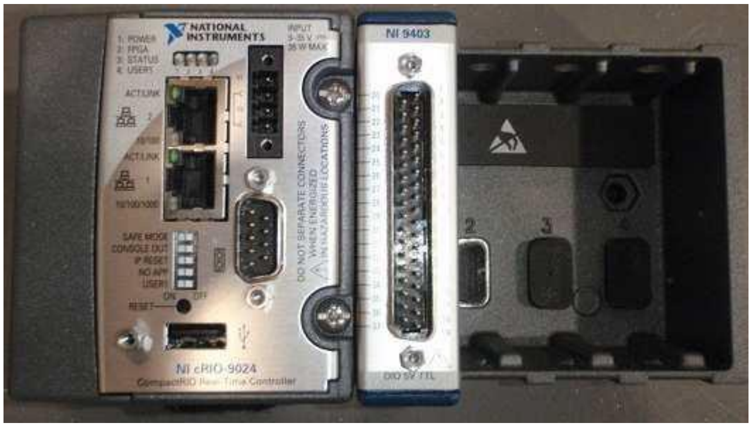

Figure 8 National Instruments CompactRIO with 4 bay chassis

The mission computer utilizes a state machine to move Victoria through the competition course. Each state consists of a small task which uses at least one of the sensors as input. The remote control state is an exception as it requires no sensor input and is driven completely based on joystick commands. All controllers were designed to be proportional (at least), making the vehicle robust and smooth in its movements. An example of this can be found in the state which navigates to a GPS location. This control uses the current and previous GPS coordinates to determine the vehicle's heading and proportionally adjust the vehicle to the heading necessary to reach the desired GPS location. A full state-machine diagram for the competition missions can be found in Appendix A. One of the many issues encountered during the coding/testing design process was related to reading the GPS data at a rate of less than 1 Hz. This problem was identified over time and fixed.

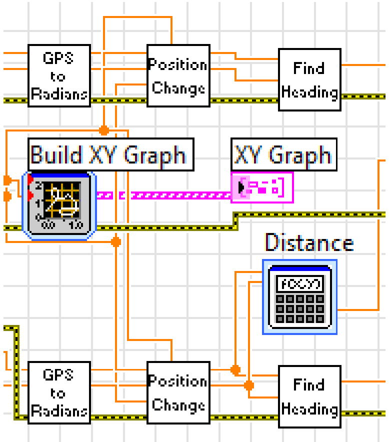

Figure 9 Example LabVIEW Code

LabVIEW is a graphical programming environment, which uses icons and wires to build software code based on diagrams that resemble a flow chart. It supports multiple operating systems and targets, which facilitate easy integration with an extensive amount of hardware devices. Pre-built drivers for the GPS, LIDAR, and IMU can be downloaded reducing the time required to interface with these devices. The LabVIEW Vision module is also used to support image processing functions.

The LabVIEW Vision Development Module is a tool that can be used in machine vision and image processing applications. This module includes NI Vision Assistant and the underlying vision functions of IMAQ Vision. Using the same flow chart style as the LabVIEW graphical programming environment, users can quickly create vision algorithms from over 200 image processing functions. Upon completion of the vision algorithm, Vision Assistant generates the LabVIEW code as a function. It allows testing of the algorithm with inputs from cameras, video files or pictures, making adjustments quick and simple. One of the process functions is color recognition. Color matching is accomplished by dividing the image into hue, saturation, and intensity planes, and specifying acceptable values of each one. In order to make the vision system work in various lighting conditions, the saturation and intensity ranges are kept very large, with only the hue range being reduced to the desired amount.

E. Mission Apparatus

Each mission requires a specific apparatus. The apparatus includes a water cannon, an IR temperature sensor, one designated network camera, and a manipulator specifically designed to land an amphibious retrieval vehicle and push the waterfall button. These apparatus, along with the camera and LIDAR data give us a great chance at attempting and completing all of the mission tasks.

The Amphibious Retrieval Vehicle (ARV) will be attached to the manipulator via a rail system that is driven by a motor to deploy and retrieve the vehicle. The ARV consists of a hinged compartment with an opening that allows for the land treasure (tennis ball) to stick to Velcro loops that line the inner compartment. The image scans taken from the mission camera will inform the vehicle when the treasure has been captured. The red emergency stop button used to turn off the waterfall will be recognized via the mission cameras by its color and shape. The ARV will also have a flat front face which will allow for the vehicle to hit the stop button.

Figure 7 Omega IR Temperature Sensor

III. Mission Plan

This year, to aid in the channel navigation we will be using a LIDAR system. We plan to use the cameras and LIDAR to identify the buoys, bisect the distance between them, and determine a path accordingly via GPS waypoints. This same system will be used to navigate back through the channel after completing all the missions.

For the air challenge, an IR temperature sensor mounted next to our mission camera will measure the surface temperature of the different panels. The cameras will identify and classify the shape and a message will be sent via an alternate wireless network with the symbol, GPS coordinate and temperature of the target.

In the fire challenge a water pump will activate when the target is seen via the cameras and will send a stream of water to the target. The pump itself was salvaged from last year's vehicle but the search algorithm was modified to look for the square target.

During the water and earth challenges the manipulator on the ARV will be used to retrieve the ball as well as turn off the waterfall. With the vehicle only semi-waterproof, a longer manipulator is needed to ensure the non-waterproof components are not damaged. The amphibious landing will entail the vehicle docking on the ramp and a rail system deploying the retrieval vehicle. The retrieval vehicle will consist of the rail system, an opening to enclose the land treasure, and a recessed area to ensure it will not fall in the water.

IV. Future Work

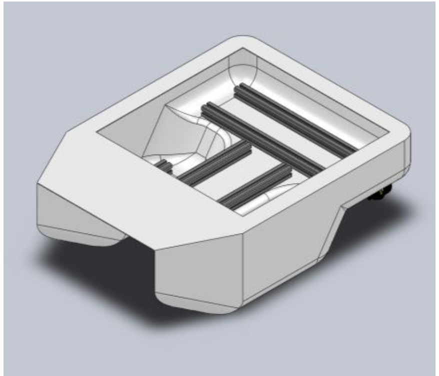
Figure 11 GTSR ASV Victoria III

Future work for Victoria will be focused on improving the GPS navigation system to allow easier programming of GPS paths with a Google Maps interface. Additional sensors and improved data filtering will allow Victoria to be used in many environmental survey applications as well as serving as a platform to test research topics ranging from battery usage to curve tracking algorithms. The ASV is also planned for use in other graduate-level research including chemical field profiling experiments, networked control system development, testing with our ROVs and our YSI EcoMapper, and tracking underwater vehicles.

The hull is also scheduled for an overhaul based on what we have learned in the last two years of developing and testing Victoria. These overhauls include such design upgrades as: protected thruster mounting locations, inner track system to increase the ease of mounting components with respect to the center of mass, and a completely waterproof inner body.

V. Team Specifics

A. Advisors

Dr. Fumin Zhang, Assistant Professor, Electrical and Computer Engineering Department
Brandon Groff, GTSR Alumni, Harvard Business School

B. Sponsors

Office of Naval Research (ONR)
National Science Foundation (NSF)
National Instruments (NI)
Microstrain Inc.
Crust Crawler
Vicor Power

C. Members

Name	**Email**	**Major**	**Level**	**Primary Task**
Valerie Bazie	vbazie3@gatech.edu	ECE	Undergraduate	GPS/IMU Controller
Steven Bradshaw	sbradshaw6@mail.gatech.edu	ECE	Masters	Mission Apparatus/Hull Design
Will Crick	wcrick3@gatech.edu	ECE	Undergraduate	LIDAR/ Camera System
Lisa Hicks	lhicks7@mail.gatech.edu	MATH	Undergraduate	Navigation Algorithms/Controller Design
Sean Maxon	sean.maxon@gatech.edu	ECE	Undergraduate	LIDAR/Camera System
T.J. Melanson	tj@tjmelanson.com		High School Intern	Mission Apparatus
Shayok Mukhopadhyay	shayok@gatech.edu	ECE	PhD	Mission Apparatus/Controller Design
Klimka Szwaykowska	klimka@gatech.edu	ECE	PhD	Controller Design

VI. Vehicle Photos

Figure 9 GTSR ASV Victoria 2010

Figure 8 GTSR ASV Victoria II 2011

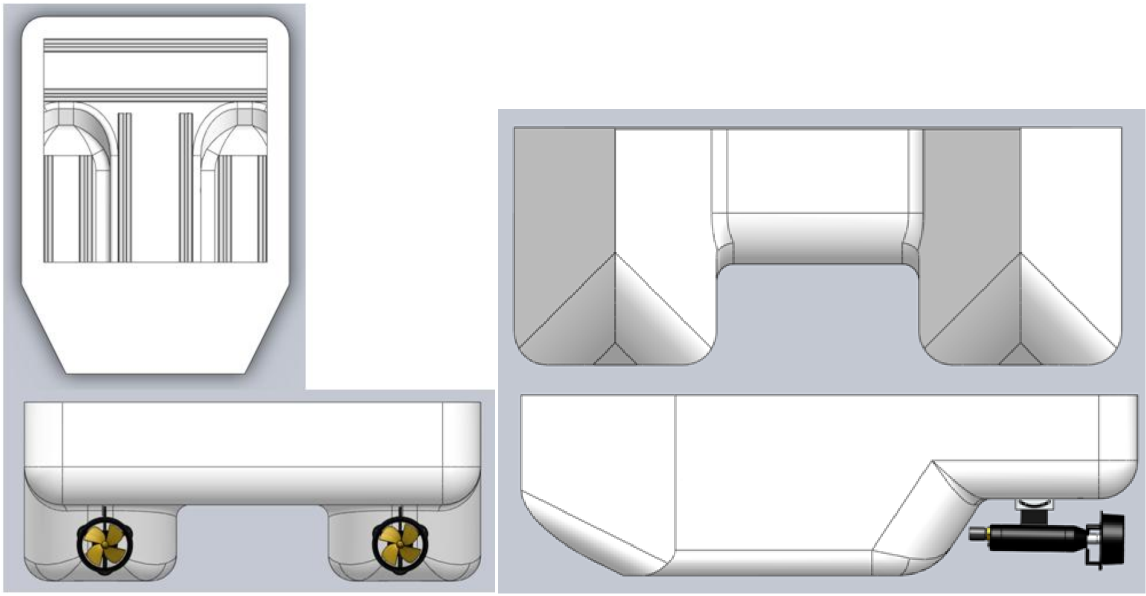

Figure 14 GTSR ASV Victoria III 2012

Acknowledgments

We would like to thank SeaCon for giving us discounts on their great watertight connectors, and CrustCrawler for their powerful thrusters. Also we would like to thank AUVSI for hosting this competition, which gives us a great opportunity to apply what we have learned in the classroom. Castle Creations for the high voltage electronic speed controllers. Vicor for the high efficiency DC regulators. National Instruments for the expandable compactRIO system. The mentors for dedicating the time and effort to provide us with useful advice. Georgia Tech Savannah for the facilities to house and work on the ASV.

Appendix

Figure A.1 Mission Computer State Machine