'SeaCat', The Villanova University ASV AUVSI RoboBoat Competition 2013 Journal Paper

The Villanova University autonomous surface vehicle team will be competing again with SeaCat in the 6th Annual RoboBoat Competition. Designed from the ground up by Villanova engineering students, it relies on video, GPS, and compass sensors processed by custom algorithms running on a variety of controllers including Speedgoat Real-Time module and Arduino microcontroller.

The competition requires that SeaCat be able to maneuver independently through and around buoy channels, obstacles, and tasks without any human interaction. The tasks this year include speed and thrust tests, obstacle detection and avoidance, identifying targets, firing projectiles at targets, underwater object detection, and thermal imaging.

Introduction

Autonomous vehicles are a rapidly increasing field within the sciences. With their potential to function completely independent of human interaction, these vehicles offer unique solutions to many current problems facing society. Popular applications include search and rescue, law enforcement, and military – situations normally hazardous to human life, inaccessible, or extremely repetitive to humans. These can now be safely operated by robots.

SeaCat is an autonomous surface vehicle (ASV) specifically designed by students from Villanova University to compete in the annual AUVSI RoboBoat competition. The robotic boat is capable of navigating through buoy channels and completing an array of land and sea based tasks independently. Making its first debut at RoboBoat 2012, SeaCat has proven itself a dependable platform to be used for years to come.

Physical Design

Hull

In previous years, Villanova's ASVs were overweight and suffered greatly from pitch/roll instability due to poor hull design. This prevented accurate and repeatable movements from the boat - both important characteristics in the RoboBoat competition. It also meant that the team received weight limit penalties. As a result, last year the team completely redesigned and constructed a new twin catamaran-style hull for SeaCat. The twin hulls are made from custom hand-laid fiberglass, the frame is PVC piping, and the splash covers are Plexiglas. The new design provides a significantly lighter, weather resistant, more stable operating platform.

7

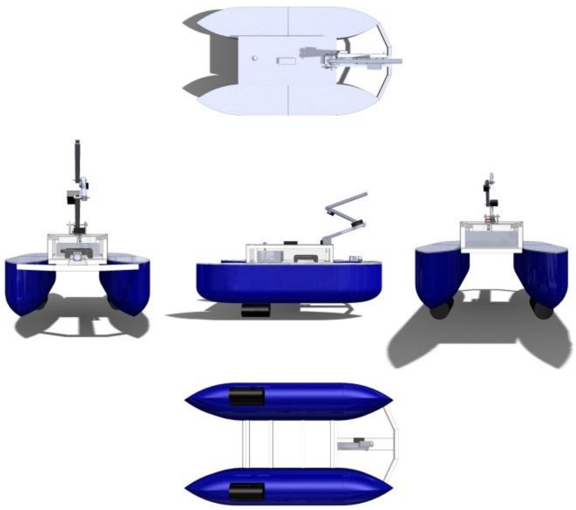

Figure 1: SeaCat's twin hulls provide excellent stability and prevent the boat from getting stuck on buoys

Power System

SeaCat is powered by two 12.8V LiFePO4 batteries wired in series to provide a total of 25.6V at 20Ah. Lithium Phosphate batteries offer several advantages over other more traditional battery cells. They are lighter, smaller, and can provide a relatively constant voltage throughout their charge. Three DC-DC power converters provide steady 5V and 12V options for all onboard electrical hardware. Under maximum current draw, SeaCat can run for an estimated 8 hours before needing to be recharged.

Actuators

Propulsion of the boat is handled entirely by two non-pivotal thrusters mounted ¾ of the way to the stern on either hull. Each thruster is wired to two motor controllers. The first controller receives analog signals from the onboard computer (autonomous mode). The second controller receives PWM signals from an RC receiver (manual mode) and is given overwrite priority. This design permits a user on shore to wirelessly switch the boat between autonomous and manual mode at any time via an RC remote – a critical feature for safety in autonomous vehicles. The controllers also permit differential control of the thrusters which gives SeaCat the ability to rotate 360 degrees in place.

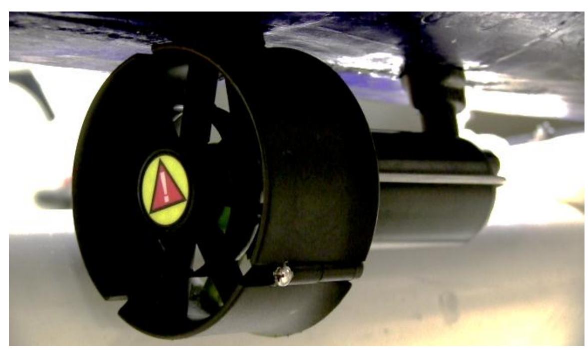

Figure 2: One of SeaCat's two stationary Seabotix BTD150 thrusters, which provide all of the boat's propulsion and steering.

A new three degree of freedom (DoF) robotic arm mounted on top of SeaCat's modular platform provides the boat with a full reach of 30" from center. The arm is powered by three bipolar stepper motors all of which receive signals from an Arduino Mega microcontroller. To maximize space on the boat, the arm can fold down its forward link and convert into a two DoF Nerf launcher. The Nerf launcher can hold a maximum of six projectiles, can fire accurately up to 25 ft., and is also controlled by the Arduino microcontroller.

SeaCat has a detachable land rover subsystem, initially housed within a water resistant garage on the stern of the boat. The garage door is powered by a servo and when activated, becomes a deployable ramp for the rover to access shore-based tasks. The rover itself is completely independent of SeaCat, having its own power supply, drive system, and microcontroller. It is equipped with ultrasonic and color sensors to maneuver its way around the competition dock. A stationary Velcro claw allows the rover to grab other Velcro objects.

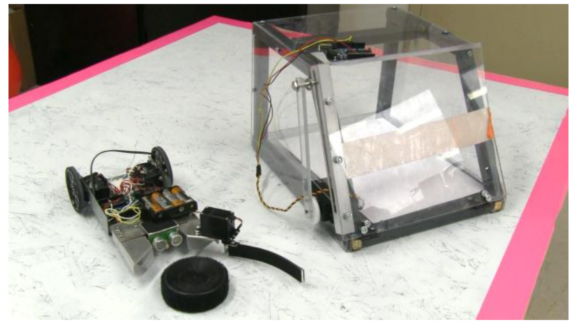

Figure 3: Land Rover Subsystem with Garage

Sensors

As a completely autonomous vehicle, SeaCat relies on the information it gathers from onboard sensors to make decisions. A Logitec Pro 9000 webcam is mounted on the bow and provides SeaCat with all necessary imaging data. The boat receives heading, pitch and roll data from the Honeywell HMR-3000 Compass module and the Garmin GPS provides latitude, longitude, and acceleration.

Computer and Software

The onboard computer is a Speedgoat Real-time module which runs Mathworks xPC Target. All programming is done via Mathworks' Simulink. The advantage of a real-time machine over conventional computers is that it can input and process data at a continuous dependable rate without lags and delays. This is optimal for autonomous systems which could fail if a vital command is cued up, delayed, or in some other way fails to activate on time.

Software Design

FSM

SeaCat uses a Finite State Machine (FSM) to progress through the various stages of the competition. The course gets split up into a series of states (essentially subtasks) which the boat will need to complete in order. A state will only activate when given the command to do so by the previous state and must be completed before a signal is sent. SeaCat sequentially progresses through the entire FSM until all states have been completed or the time runs out.

RPM, Heading, and Image

When activated, each state continuously outputs a desired heading, RPM, and processed video signal as seen in Figure 4. A PD closed loop feedback controller compares the desired heading angle with currently sampled heading values every 0.1 seconds and then outputs an appropriate voltage to be sent to the motor controller. RPM signals are scaled to an appropriate voltage for the motor controller to read and are then sent out. All processed video is streamed wirelessly through a router back to computers onshore and enable engineers to see what the boat sees in real time, making it possible to make changes to the code as quickly as possible.

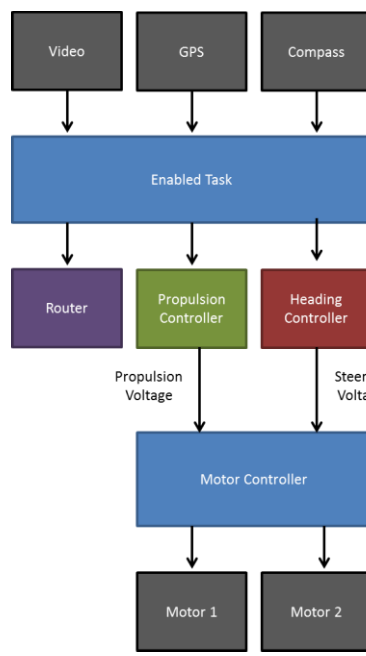

Figure 4: Diagram of SeaCat Logic

Video Navigation

SeaCat analyzes the video for targets (such as buoys, or hoops) by first filtering the image by color. As the boat operates outdoors, the lighting conditions are not controllable. This means that the brightness of the image could increase or decrease day to day, or even frame to frame, particularly on a partly cloudy day. To isolate color independent of brightness, the filter uses the Hue, Saturation, Value colorspace. This colorspace has a separate channel for color (hue) from the brightness of the image (value). The video image gets passed through a filter which selects HSV values within a desired range to isolate targets by color, regardless of the brightness.

Once the video has been filtered, the code searches for blobs with a specified shape and identifies the largest. The location of the centroid is then located, and a bounding box is placed around it. This process can be seen in Figure 5 for a green buoy. The bounding box centroids of the largest blobs from each color segmentation are used in calculating a desired heading angle to send to the controllers.

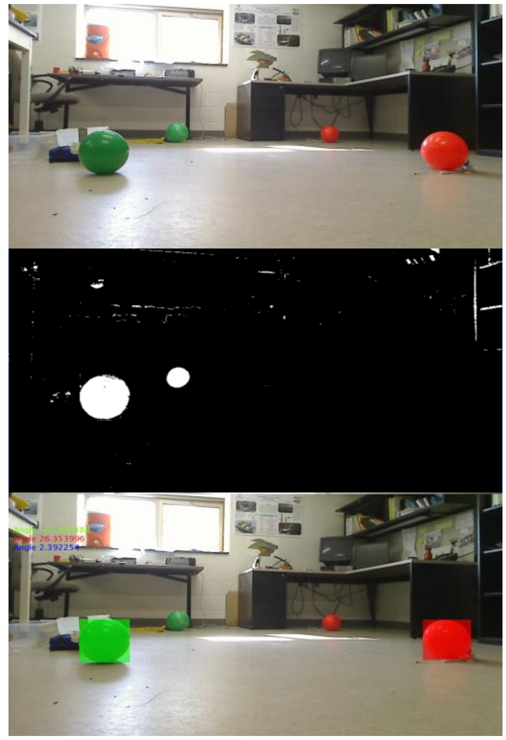

Figure 5: An example of green buoy detection via HSV filtering and blob analysis

Conclusion

SeaCat has logged in countless hours on the water and has proven itself to be a stable and dependable operating platform for the 2013 RoboBoat Competition. It was designed and constructed from the ground up exclusively by Villanova students. It has undergone several modifications from last year, including a new robotic arm, land rover, and Nerf launcher. Villanova's ASV Team is excited to participate again this year and looks forward to the challenges which the RoboBoat competition will bring.

Team Members

Current Members

Students

Anderson Lebbad - MSME ‘14

Alex Poultney - BSME ‘14

Edward Zhu - BSME ‘15

Dylan DeGaetano - BSME ‘15

Advisors

Dr. C Nataraj

Previously Contributing Members

Students

Joseph Denny – BSME ‘13

Nick DiLeo – BSME ‘13

Ryan Holihan – BSME ‘12

Shahriar Khan – MSEE ‘13

Lester McMackin – BSME ‘13

Mike Weber – BSCPE ‘13

Advisors

Dr. Helen Loeb

Dr. DongBin Lee

Dr. Garrett Clayton

Ralph Sullivan – MSME ‘12

Acknowledgements

Mr. Chris Townsend

Dr. Garret Clayton

Office of Naval Research (ONR)

Avi Nehemiah