URI Ram Boat 2013

University of Rhode Island Autonomous Vehicle Team

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1 Introduction

This is the fifth year that the University of Rhode Island has competed in the AUVSI RoboBoat competition. The robot's complexity has increased steadily over the years, and has gained sophistication in hardware, software and sensing systems. This report is organized to highlight the basic components of the URI RamBoat competition entry, first introducing legacy systems and then the recent changes made to this years robot. The URI teams experience in the RoboBoat competition has demonstrated that ambitious development and radical redesign comes with great risk, and this year we have worked hard testing our robot to ensure that its performance will reflect the work we put into it.

2 Hardware and electrical

2.1 Existing system

The structure of the ASV is based upon a *Hobie Float Cat 60* fishing platform. The Hobie hulls, connected with 1.25 aluminum tubing, provide a very stable platform for the Hobie polyethylene hulls. Two additional 1.25 aluminum tubes form the backbone of the ASV. Not only do these tubes provide easy mounting for hardware and payload but they also provide easy trim adjustment forward and aft. Mounted directly behind the hulls are twin tolling motors mounted directly to the aluminum backbone of the ASV.

In order to provide maneuverability and power, dual Sevylor 18lb thrust tolling motors were used. The motor controller that is used in the ASV is an IBC V2 Dual Speed Controller from RobotMarketplace.com. The motor controller is mounted in the electronics box. The controller takes RC signals or a signal from the mission computer and converts it to high–current pulse width modulation (PWM) that is capable of driving high amperage brushed motors. There are two hard kill controls on the motor system. First a red key on the side of the electronics box with kill battery power to the motor controller. Secondly, a RC controlled control will switch the motor control between the RC controller and the computer controlled signal generator.

A large watertight aluminum box is mounted aft of the centerline on the deck contains the RAMboat electronics. The aluminum of the box provides a large passive heat sink, and all the high power consumption electronics are mounted directly to it. Inside the box a flat piece of Lexan is mounted to the bottom to hold the battery packs and act as a platform for various stand offs and mounts for the equipment inside. The simplicity of a single box is favored as it allows easy access to all of the electronic and computer components of the vehicle, while still providing a secure and durable platform.

The passive heat sink provided by the aluminum box proved insufficient for the heat generated by the two 12W fit PCs, a 12W Wi–Fi router other electronics. The temperatures in July in Virginia Beach made

Figure 1: Ram Boat. Vision mounting system is attached to the front of the vehicle with camera and LIDAR. The aluminum cooling fin attached to the side of the vehicle is provides water cooling. No mission specific hardware is attached in this image.

the watertight box a veritable oven, and caused intermittent restarts of critical electronic systems. An open loop water-cooling system was installed to address this issue in 2012. An aluminum fin with copper tubing was installed to the outside of the box, and a pump was used to cycle water and cool the electronics.

2.2 New development

2.2.1 Camera mount

Ongoing development by the vision team to combine camera and LIDAR measurements into a single processed scene has made position calibration highly sensitive. The relative position of these two sensors and their relative angles need to be measured to high accuracy in order to line up their readings. A camera mount was developed that fixed the position of these two instruments relative to each other. The camera and LIDAR readings are manually lined up in a calibration procedure, which determines precisely the relative mounting position. The team is then free to position the entire mount in the best position for the buoy course task without having to re-calibrate these position values.

2.2.2 Power distribution board

The power distribution system of the boat has changed to a single power supply system from a two supply system. The major challenge of this design is that the robot's thrusters create large voltage transients which travel along the ground plane when the trust value changes quickly. These voltage transients are substantial, and turn off and on digital electronics. The advantage of a single power supply system is the boat requires fewer batteries, at the cost of only very slightly reduced runtime. The two motors are expected to consume approximately 300 W of power, while the digital ground only consumes 50 W of power. Adding the digital electronics to the motor battery therefore makes a minimal difference in the total power consumption of the system.

The basic challenge in creating a single power supply system is to create two isolated ground planes, one for motors and one for digital electronics. This isolation is simple with two power supply systems, where one power supply is used for motor ground and the other for digital. This same isolation was created using a Vicor 12 V isolating DC/DC converter, capable of providing 100 W of power with 80 % efficiency. Additionally passive voltage transient filters made of capacitors, inductors and TVS diodes were needed to completely isolate the two grounds. This system has worked through boat testing without any unexpected computer restarts, and has provided a marked improvement in battery use efficiency.

3 Computer and software

3.1 Existing systems

Ram boat 2013 uses 2 FitPC single-board computers, one for mission control and the other for image processing. A Netburner 5282 is used as an interface between the servos, motor-controllers, low-level digital systems and power switching on the vessel. These computers are connected via Ethernet, a 1–watt wireless bridge links RAMboat's network with the shore.

3.2 Middleware

Last year a new software architecture was designed and implemented. Key goals for the new architecture included scalability, maintainability, and modularity. In particular, the mission software was split into a number of small, independent processes communicating over set of well–defined Lightweight Communications and Marshalling (LCM) structures. Individual processes are responsible for a single task, such as reading a specific sensor, computing a new set of motor thrusts, or searching images for buoys. The resulting architecture consists of a number of small programs rather than a single, large, extremely complex multi threaded program. This allows team members to be divided and work on specific tasks without having to worry much about what other members are doing.

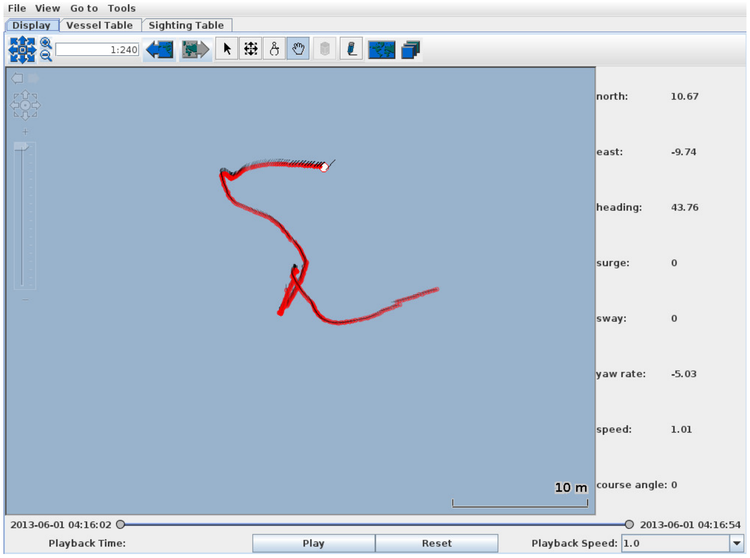
This year, the development of a LCM based system continued, emphasizing use of utilities including log creation, log playback, and message-sniffing. Additional support utilities and libraries were provided using libbot and its process manager. These logging and debugging capabilities allowed for the optimal use of test time, with pond tests becoming primarily data gathering exercises. This, combined with the inherently modular design of LCM allowed team members to use development time very efficiently.

3.3 New Development

3.3.1 Graphical User Interface

One of the most useful tools for a team is to be able to see what your vehicle sees. For this reason, new tools were developed this year to visualize the RamBoat in action. The software plots the track of the vehicle in real time or from LCM log files while showing buoys detected and the state of the vehicle. This visual feedback allows quick diagnostics during testing which is vital during crunch time.

Figure 2 shows the boat track and state along with controls for zooming and navigating the map. Plotting was done using OpenMaps in Java. The GUI allows the user to select a time slice to view as well as play back that interval at different speeds. Maps of the terrain can be added for even nicer plots, provided that there is a high resolution available.



north: 10.67
east: -9.74
heading: 43.76
surge: 0
sway: 0
yaw rate: -5.03
speed: 1.01
course angle: 0

2013-06-01 04:16:02
2013-06-01 04:16:54
Playback Time:
Playback Speed: 1.0

Figure 2: Boat visualization GUI. Boat position is indicated with red dot, and heading is black arrow. Boat state information is displayed on right hand side.

3.3.2 New Camera

The Microsoft HD–5000 webcams were not designed for use as a vision camera. They were designed to be cheap webcams that ”worked” automatically. This caused problems for us because it turns out that the driver for the camera would automatically adjust the exposure time as well as changing the frame rate automatically depending on that exposure time. The camera would also automatically try to adjust the white balance, which did not result in a consistent color balance. Thirdly, the camera had an autofocus. This was the largest challenge because it meant that the images would not be able to be used for 3D reconstruction accurately if the focus constantly changed. We were able to find a utility to override the webcam's settings with manual settings but it never quite worked because the manual exposure time was non–functional. We ended up deciding on getting an IDS UI–1640LE camera, and it has served us well since.

3.3.3 Buoy detection

The main type of buoy detection is done with an image processing based approach, using OpenCV. Images from the camera are first converted to HSV color space. This allows us to obtain ”True” color classifications via the Hue value, as well as obtain information on the ”Saturation” of color, and brightness, referred to as Value. An OpenCV function is used to detect circles in images, based on changes in pixel values. To provide this function with a good image to find circles on, we take the Saturation and Value channels, and combine them, taking the maximum value of the two as the pixel value. This is because overexposed parts of the image, usually caused by specular highlights, will cause the saturation value to drop to 0. Specular highlights are white, and white corresponds to a saturation value of 0, causing a spot of low saturation in an otherwise saturated area of the image. By taking the maximum of Saturation and Value, when the pixel is white this means that the low saturation will be corrected. This resulting image has high value in areas that have strong color, and low value in areas with weak color, appearing gray or tarnished. Our findings was that the water nominally had low saturation while buoys had high saturation due to their strong color, so this provided and excellent image for processing.

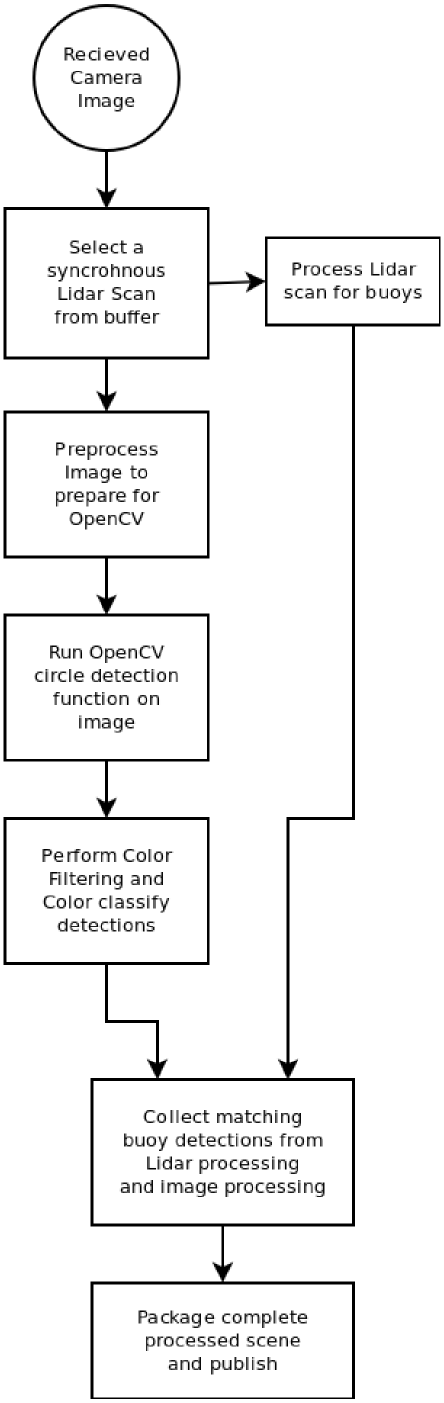


Figure 3: Flow chart of vision processing

After processing that image with OpenCV, we then take the identified circles and check their areas to see if they have a color matching a buoy, and filter out the circles that don't. To determine a color of a circle we average the HSV values of each pixel in the circle by averaging the Hue and Saturation values as if they were polar coordinates in Euclidean space, with Hue being theta and Saturation being the radius. Value is averaged normally. This averaging scheme works well for confirming that a circle has a strong, solid color.

A secondary type of buoy detection is done using the LIDAR. The LIDAR provides a 'scan' over a plane, giving points where the Laser it contains was reflected back to the sensor. A buoy placed in the plane of the LIDAR will create a half–circle like shape no matter the orientation or how far it's center is from the plane. The LIDAR scan is broken up into contiguous segments by checking for large changes in distance between points, signifying the edge of an object. These segments are then to the half circular shape of a buoy outline. The distance between the edge points gives us an estimate of the radius and the center position can be assumed by adding that radius to the center most point of the segment. Finally we check if the points in that segment actually fall along a circular outline with a least–squares error calculation. This algorithm is simple and fast, and will allow us to provide frequent buoy–tracking data to our navigation systems.

3.3.4 LIDAR and Vision Integration

One of the biggest new things this year was the establishment of a system to map the LIDAR data to points in the camera images. OpenCV provides functionality to undistort images based on a specific camera model for which there are toolboxes to help you perform a calibration for. Originally we planned to use it for undistorting images but we decided that it wouldn't be worth the processing time because the lens for our new camera has very low distortion. However, the camera calibration provided us with the parameters to fill in that camera model, allowing us to map our LIDAR data onto the image and associate LIDAR data points to buoys identified by our image processing. In addition the calibration allows us to assign a direction to buoys that we identify but have no LIDAR points for that we can use to estimate the location of that buoy assuming it's on the surface of the water.

4 Mission specific equipment

4.1 Rock, paper, scissor, lizard, Spock

A hand held digital thermometer (Rosewell RTMT–12001) was modified to give heat readings as computer inputs. This heat sensor was selected for superior temperature resolution and aperture size, compared with similarly priced infrared sensors with standard computer interfaces. The modified heat sensor is interfaced with a Netburner Mod5270 development board. The heat sensor uses a modified pulse width modulated output to pass relevant heat information. The signal from the heat sensor is passed into an on board direct memory access (DMA) timer. The DMA timer triggers a system interrupt on the Netburner every time a rising edge is detected. This allows the relative heat of an object to be determined by taking the differential of the count received through the timer input. This setup is expected to provide ±2°C accuracy with a 12:1 range to aperture size ratio.

4.2 Shoot through the hoops

To perform the task of shooting through hoops with foam darts a toy foam dart gun was attached to the vehicle. The Buzz–Bee Toys Air Warriors Overlord Motorized Belt–Fed Foam Dart Blaster was the weapon of choice. With a firing rate of almost 3 rounds per second and an automatic loading system and lightweight construction, this platform was decided as the best candidate for the task.

The Buzz Bee foam dart gun was modified to make it a feasible solution to the mission. First the physical trigger was removed and replaced by two relay circuits. Stock, the gun has two reed switches in the trigger that fire the weapon. The first switch spins two flywheels that are used to shoot the darts and the second switch is to operate the mechanism that loads the dart into the chamber and pushes the dart through the flywheels. The second modification to the gun was removal of the barrel to reduce weight and increase maneuverability on board the vehicle.

The foam dart gun was mounted on a Hitec HS–6585MH servo on the deck of the vehicle to provide the ability for the weapon to pan to a position perpendicular to the boat to fire upon the targets. To reduce the amount of strain on the servo, the gun mount was rested on a Rulon sleeve bearing with a shaft that extends through the deck of the vehicle. The servo was then attached to the shaft beneath the deck of the boat in such a way that the weight of the gun assembly would not be on the servo, but instead on the Rulon bearing and the vehicle deck.

4.3 Sneaky sprinkler

The sneaky sprinkler task has been consistent over the past few years in the RoboBoat competition, which has allowed for the development of a very consistent vision detection algorithm for the red button. The challenge of detecting an underwater buoy is still outstanding, and this years team will attempt this detection using a SONAR system. This system is basically a modification of a test setup used in the URI ocean engineering acoustics class, and is based on an Airmar ultrasonic range measurement board. A 200 kHz signal is generated on this board, and it also amplifies the received echo for convenient processing. An underwater transducer with an extremely narrow beam width of approximately 2° was also selected for this system.

The challenge for using this SONAR setup on the RamBoat is processing the 200 kHz echo. This signal is undetectable using the audio frequency microphone input on the FitPCs. To avoid using a high frequency analog to digital converter, simple AM radio demodulation techniques will be used instead. An analog envelope detection circuit was designed to only detect the low frequency amplitude changes in the signal. This circuit will allow for the detection of buoy ranges using data sampling rates of less than 10 kHz, far below the 44 kHz frequency cutoff of standard digital audio sampling.

5 Conclusions

Using the solid foundation of past year's ASV and many new additions, there is potential to to successfully complete each competition task. A new power system ensures that each component will be able to draw required power even under extreme heat, which will prevent brown outs when computers are under max load. The combined camera and LIDAR mount allows the vision system to detect buoys with increased accuracy by combining the strengths of each sensor. A sonar and heat sensor were added so that mission code can utilize them to detect the correct button to press and target to report. Team members have worked hard on advanced algorithms to take advantage of these new sensors during testing. Analyzing the log files from these tests and refining the approach to the competition tasks has improved the robustness of the system. URI's ASV team is eager to compete in this year's RoboBoat competition.