Robotics Club at the University of Central Florida: Design Strategy of Hippocampus AUV

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1. Abstract

The Hippocampus submarine was designed to balance the difficulties of the RoboSub competition with the limited resources of a student organization. The submarine is inspired by biological intelligence and takes a reactive behavior-based approach in contrast to a traditional planning approach. The submarine's controls and basic object detection systems have been beta tested and is functional to participate in the upcoming competition.

2. Competition Strategy

The team's strategy for the competition was to complete most tasks feasible given our limited resources. For example, we only had 2 software engineers to complete the entire software while balancing coursework and research obligations. We also had to change vehicle platforms late in the year due to the inability to waterproof our first platform. With these limitations in manpower and time, the decision was made to start with the required qualification tasks and move onto other tasks such as the play craps task only after reiterative testing. Task prioritization was determined based on point values versus the perceived difficulty of the tasks. Determining the perceived difficulty of a task was limited as the current team did not possess firsthand experience competing in RoboSub. In order to mitigate this risk, the team reviewed past RoboSub competitions to determine what tasks appeared difficult while considering that challenges differ from year to year. The team also communicated with past RoboSub members to leverage their expertise and experience to figure out which tasks to prioritize. Tasks such as play craps which only require physically hitting an object were deemed simpler then tasks such as play slots or cash in your chips which require complex manipulations.

One way to overcome the limited resources was to use the existing hull from a previous RoboSub competition. This decision was made due to challenges in waterproofing our original design that consumed valuable testing time. By leveraging a previous design, the team was able to spend more time on testing. Another important challenge was how to integrate proper testing and validation into our competition strategy. The team did not have access to a 24/7 full-size pool so the time to test our vehicle was extremely limited.

A second way to overcome the limited resources, the team created a software architecture that was general enough to allow for as many tasks to be completed, but also the limited number of algorithms that could be tuned to individual tasks. While these algorithms would only allow for a limited subset of robot behaviors, these primitives could be combined to form more complex overall behaviors. This would allow the team to only test each algorithm a single time and then use hyper parameter tuning procedures to identify the proper parameter values for different tasks.

3. Design Strategy

As previously mentioned, the architecture for hippocampus was designed to adapt to additional tasks with minimal extra effort. The inspiration for the architecture comes from the ability of humans and other animals to perform a variety of different tasks with a unified body plan and architecture. Specifically, the team was inspired by the embodied view of intelligence and the work of roboticists (such as Rodney Brooks on behavior-based architectures). This view maintains that the intelligence of humans and animals are not just abstract symbolic representations and manipulation; but is grounded in sensory system data. Behavior-based architectures traditionally eschew complex planning in favor of a collection of simple behaviors which combine to form complex behaviors.

In order to implement this concept, the team based the system around visual servoing. Visual servoing algorithms allow a robot to move directly in response to some visual cue. Contrary to modern computer vision systems, the team proposed to use a predominantly simple algorithms to fit the overall design. Specifically, the team focused on using visual saliency and color thresholding. Visual saliency is believed to play an important role in how humans segment a scene. Color thresholding was used to increase the likelihood that the detected object was the actual object (or target) that the robot needs for a given task. This was chosen due to its relative simplicity and the realization that the competition tasks had distinct colors. Further processing focused on shape detection to guarantee that the correct object was recognized. The output from the vision system was used by the servoing system to drive a small collection of simple behaviors dictating how the robot would move in response to feedback. These behaviors include actions such as aligning with an object or orbiting around it. While simple on their own these behaviors were able to be combined to form more complex behaviors needed for the tasks such as going through the start gate or playing craps. The transitions between behaviors were combined using a hierarchical state machine.

4. Experimental Results

Due to most of our algorithms being custom-made the need for testing was important to ensure each individual algorithm worked. The team set metrics that would need to be passed by each component before moving on to subsequent components. These metrics were determined predominantly by acceptable error rates achieved during testing.

An important component of this process was visualizing algorithm success in an easily interpretable method. The first component tested for the submarine was the thruster controls. This was chosen since no tasks can move forward if the submarine is unable to move properly. A 2D heat map showing the errors for different thruster values vs what was requested can be seen in Figure 1. As can be seen the error gets bigger as the thrusters approach their limit and the thruster manager tries to fulfill the values without passing the set limits. The plot shows the error magnitude with a range of surge and yaw combinations.

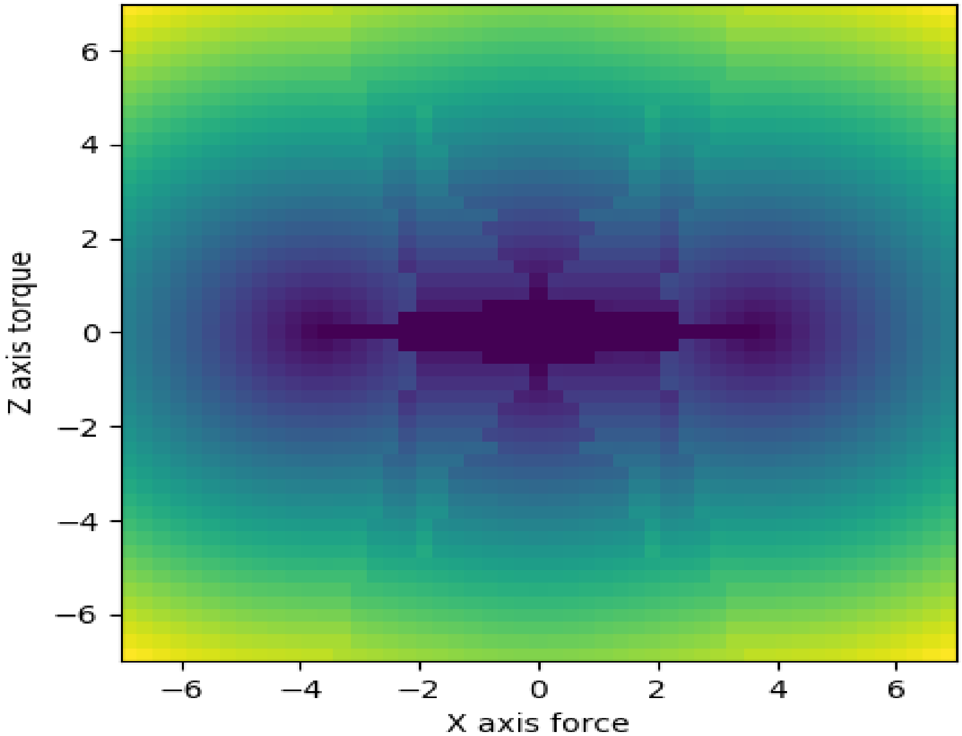

Figure 1: Heat map for thruster command errors. Errors range from dark blue for low error to yellow for high error.

The second component tested was object detection for the vision system. Figure 2 shows object detection detecting the pole in a crowded scene.

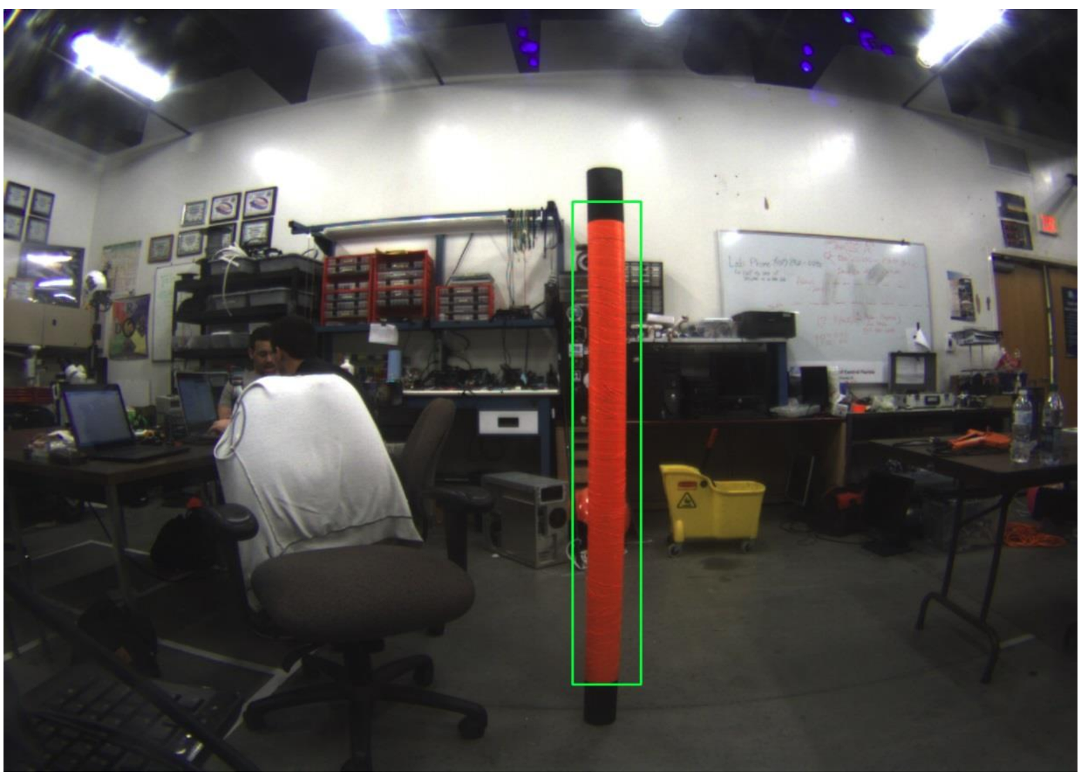

Figure 2: Object detection detecting a pole in the scene using color thresholding visual saliency.

Following iterative testing, the team believes that the submarine will be functional and ready for the upcoming competition. In-water testing for reliability is also important, and the team attempts to have the sub in the water at least once a week, weather permitting. This testing revealed issues with the propulsion system sometimes not initializing when in the water and the thrusters not having enough low end control to avoid oscillation when in depth or orientation hold modes, which may require updated speed controllers or algorithm adjustments to reduce or compensate for the deadband. In water testing has also allowed us to validate the use of a color correcting filter on the cameras to compensate for the shift in white balance underwater. Water testing has verified that the torpedoes glide straight far enough to keep the targets in the forward cameras' field of view, pending bore sighting of the launchers.

5. Acknowledgements

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6.References

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Appendix A: Component Specifications

Component	Vendor	Model/Type	Important Specs	Cost if new
Buoyancy control	Home Depot	Static ballast made of rebar	Variable number of 2ft rebar rods	$20
Frame		Waterjet aluminum plates and 80/20		
Waterproof housing	ePlastics	Cast acrylic tube		
Waterproof connectors	Subconn	Micro circular connectors	4 pin: 10A per contact 6-8 pin: 5A per contact Wet mateable 300bar pressure rating	
Thrusters	BlueRobotics	T200	5.1 kgf max thrust at 16V Brushless outrunner motor 3 bladed prop with nozzle/shroud	$170x8
Motor Control	BlueRobotics	BasicESC R1	30A, 17V max I2C support with modified firmware	$25x8
Battery	BatterySpace	Polymer Li-ion cell PL-8570170-2C	3.7V, 12.6AH, 2C cells 2 packs of 4 series cells	$30x8
Battery Protection Module	BatterySpace	PCM-SM10-14.8V	14.8V, 30A Over/under voltage, over current, over temperature protection Continuous balancing	$50x2
CPU/Motherboard	NVIDIA	Jetson TX2 dev kit	256 CUDA core Pascal GPU 2 NVIDIA Denver + 4 ARM A57 CPU cores 8GB DDR4 RAM 32GB eMMC GigE, USB3, I2C, UART, SPI,GPIO	$300 (Edu discount)
Comm Network	Subconn + misc	Circular Ethernet with power	1 Gbps support to ground station	
IMU/AHRS	Sparton	AHRS-8 Starter kit	+-4G or +-8G 1 degree orientation accuracy	
Forward Cameras	Point Grey	Blackfly BFLY-U3-13S2C-CS	1288 x 964 30FPS USB 3	$345x2
Vertical Cameras	Logitech	C920	1080p USB2	$80x2
Hydrophones	Teledyne			
Hydrophone DSP	Diligent	Zybo	Zynq-7000 FPGA+ARM processor	$200

Power Management Board	OSHPark + Digikey	Custom design	2 battery inputs, 1 shore power input, 8 motor outputs, 2 logic outputs Automatic changeover to shore power Relays for main and motor power to provide estop without disabling computers	$55
Jetson Breakout Board	OSHPark + Digikey	Custom design	JST-GH connectors for I2C, UART, SPI, power 3 I2C zones with automatic disconnect of stuck busses Internal Temperature/ Humidity sensor	$35
Battery Fuel Gauge	OSHPark + Digikey	Custom design, LTC4303 based	Measures charge, current, voltage, and temperature I2C connection	$10x2
Programming Languages		Python, C++		
Software libraries		ROS, scipy/numpy, opencv		
Total				$3410

Team Size	10
HW/SW ratio	5:5

Appendix B: Outreach

As the Robotics Club at UCF is not limited to only the RoboSub team, we have numerous opportunities for community outreach. Every semester, with our sponsor the Institute of Simulation and Training, we conduct demonstrations with our robots and simulations to local youth STEM-related groups in an event called STEM day held at UCF.

Also this year, we demonstrated our robots to three groups of Boys and Girls Club students in a program designed to inspire teens to pursue college degrees.

In order to facilitate our outreach efforts, we have a separate team called Demobot that builds robots of varying complexity and function that are intended to be taken to outreach events. These robots are designed for interactivity with crowds, particularly children, with enough novel functions to provide talking points for a demonstration. This Demobot team is rather freeform and has no deadlines, and is intended to help new and inexperienced members of our club learn robotics concepts from zero.