UNIVERSITY OF OTTAWA ROBOBOAT TEAM

Ottabotics - uOttawa's Robotics Team

Report by: Robert Conrad, Thomas Scott Fulton, Matthew Gerger, Yanushka Gnanamuttu, Matthew Smith, Andres Torres

June 4th, 2018

Abstract
This report will outline the Ottabotics team competition strategy, creative design and experimental results in relation to how each of the sub-teams of uOttawa RoboBoat: mechanical, software and electrical dealt with challenges, development and resources around these themes. Competition strategy highlights the approach that was utilized to achieve the team's objectives. The section on design thinking emphasizes our process and decisions made for our final design. Lastly, experimental results show how ideas were tested and developed into the current implemented equipment.

Competition Strategy

This is the first year Ottabotics is competing in roboboat, and as a new team filled with undergraduate university students with little to no experience in the field of robotics, the focus of our competition strategy was on modularity and adaptability with a focus on open communication between the mechanical, software and electrical sub teams as priority.

The initial goal of the team was to build infrastructure for as many challenges as possible, without wasting resources on a larger than achievable scope. With this in mind, the focus of our software sub-team was to create software in a modular and adaptable format, with a focus on reusability of code and minimizing unnecessary development time. Another restraint that came up was the parallel development of the boat and software systems, requiring hardware abstraction to become a requirement restraint for the first few months of development.

The goal of the mechanical sub-team was to build a strong, and reliable watercraft to support onboard systems. To do this the boat was built to be as sturdy as possible. Engineered to avoid any possible water ingress. While the propulsion system was developed to support a simple & effective "tank drive" control system.

With the climate of Canada over the winter season, an initial focus on simulation was focused, however it was decided against as development resources were already tight and the focus on well developed systems able to be tested on the boat became priority for the software team with in water testing becoming our main testing near competition.

To minimize the development resource constraints, the software team's mission statement became focused on developing modules of code independent challenge independant objectives, unrestricted by fine challenge details and able to do higher level requirements such as ‘circle object’ or ‘ detect gate’. This allowed the sub-team to adapt the majority of our code to be reused throughout multiple challenges. Along with the specific design of a software architecture focusing on minimized coupling and maximize cohesion, the software sub-team followed an Agile development cycle with groups of programmers assigned goals relating to the topics of image processing, path planning, control system and navigation, and finally software architecture implementation. This allowed the groups to develop well formed modules with more resources available for testing the safety and reliability standards the team had put in place for code implemented on the boat.

To minimize the required development time, as well as root the code in a stable software infrastructure, the use of industry standard open source software including ROS, OpenCV and Tensorflow was included into the system architecture. The software team also used online tools such as Trello to create a transparent breakdown of where the team is in the software development process. This allowed a well maintained breakdown of issue tracking, task delegation and version control to be kept, keeping the sub-team up to date with each individual module of code.

Once competition became only a couple months away and smaller competition details were finalized, the focus of the software sub-team was to determine which challenges can be accomplished. This strategy led the removal of the hydrophone and drone modules from the competition code, as well as the autonomous docking challenge from the attempted challenges to ensure a stable system.

Design Creativity

The mechanical team prioritized strength and reliability. All systems are designed with strength in mind, from the use of strong materials like polycarbonate, to the geometry used in the 3D prints.

Strong materials like steel was used for shafts, while more flexible polycarbonate was used to create a thermoformed cover for the boat. The hulls made from fibreglass, and frame made of 20x20mm aluminum extrusion, insure reliability with the two 150W brushed motors driving the boat.

A considerable amount of ingenuity was used to develop a unique motor system that allows both “tank control”, and rudder control. Due to complexity in developing the control system for the motors, it is restricted to using “tank drive” only this year[1].

The electrical sub-team focused on designing a system with safety in mind. After making sure that safety was a priority the sub-team focused on creating a system that did its job without affecting any other part of the system. The electrical system also used components that would be easy to replace quickly and can be easily maintained.

The electrical system is comprised of 4 main sections these being the motor board, the distribution board, emergency stop/ kill switch board and lastly the data processing and communication board. The motor board is in charge of dealing with both the servos and motor used with the propellers. This boards power comes from our large 24V battery. The second section is the distribution board, this sections main function is to distribute the power of each battery to the appropriate port. The sub-team also included all the fuses and safety equipment on this board. The third section is comprised of the emergency stop/kill switch which would cut power to the whole electrical system. This emergency stop can be triggered remotely as well as by the on board button. Lastly the data processing and communication board is built around the Mini PC which is our data processing unit.

The software system was specifically designed with modularity and adaptability with data coupling minimized to allow parallel development of multiple subsystems at once. The final architecture is designed with the structure shown in figure 1.

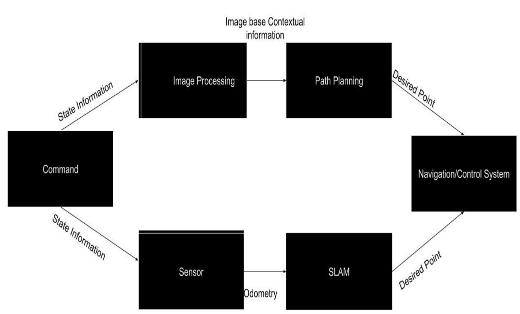

Figure 1: Black Box Diagram

The software system acts as a pipeline architecture, where the system begins with a command module, which analyses and responds to the current state of the boat (autonomous, safe etc). This controls the state of the image processing subsystem, which is in charge of taking an image, analysing the image for buoys and flags and outputting the relevant information onto the path planning module, which through the use of SLAM and submodules including ‘circle object’ and ‘gate detection’ produce the required output velocity and angular velocity which the control system then uses to move the boat to the desired location

With the use of ROS, each module is run asynchronously and the modules request information when required to minimize unnecessary computations.

In combination the system is built with modularity and adaptability, with each subsystem able to be easily substituted in the event of failure. This system was built specifically to minimize development time and to ensure a complete system by competition .

Experimental Results

For the mechanical portion force and flow testing of the motor system gave us good results. Showing our motor system can withstand the force output from the motor, and that the propellers can give significant thrust with minimal stress concentration.

Control system graphing and visualization in Simulink allowed the team to see how the boat will react to different location inputs.

On the electrical side a power consumption from the motors was calculated to be approximately 144 Watts. Each motor using 72 Watts at a cruising velocity. The power consumption from our sensors, visual system as well as the on board PC was measured to be approximately 42.6 Watts.

Acknowledgements

The university of Ottawa for monetary contributions through team funding, and facilities.

The employees of uOttawa's Brunsfield centre & Makerspace whose assistance with learning tools and troubleshooting unforeseen issues during the mechanical build.

Dr. Patrick Dumond, Jason Demers, and Dr. Hanan Anis for advice and keeping our team's ambition in check.

All other PITs and Sandbox teams for their contributions from co-ordinating access with us when our key holders were unavailable, to letting us borrow tools that were crucial in the build.

The software team would like thank the gracious help of Professors David Knox and Dr. Umar Iqbal for their continuous assistance in the development of both our software systems and our software students throughout our entire development period. We would also like to acknowledge the help of the team behind MathWorks for all their help with getting our team setup with Simulink and Simscape.

A big thank you to the graduated members of uOttawa Roboboat, and finally much love to our parents for putting up with our late night robotics work.

References

[1] Huang, Y., & Ji, Z. (n.d.). Autonomous boat dynamics: How far away is simulation from the high sea? Retrieved April 4, 2018, from https://researchportal.port.ac.uk/portal/files/8528390/2017_04_14_final_paper_boat_sim_copy.pdf

Appendix A: Component Specifications

Component	Vendor	Model/Type	Specs	Cost (CAD)
ASV Hull	N/A	Custom	Polystyrene base, hot wire cutter, sanded, & reinforced with fibreglass	$863.63
Waterproof connectors	N/A	Custom	Gasketed or caulked.	N/A
Propulsion	N/A	Custom	Dual motor system using custom 80mm Diam. props. Motors mounted in boat, power transferred 90° using a gearbox with couplings to connect shafts. Casings and props are 3D printed	$240.45 + $476.29 + $123.26 + $53.60 = $893.60
Power System	N/A	Custom	Custom architecture, 24V actuator-powering Lipo battery, 12V computer hardware power supply (Lipo)	$492.84 + $83.19 = 576.03
Motor Controls	Mathworks	MATLAB, Simulink, & Simscape	“Tank drive”	N/A
CPU	Minix	Neo U1	Quad-Core Cortex A53 Processor(64-bit), 2GB DDR3, Penta Core Mali-450 GPU, Ubuntu	$244.90
Teleoperation	Microsoft	Xbox Controller	Double joysticks with buttons and triggers for comfortable operation	N/A
Compass	Pololu	MinIMU-9 v5	Included in the MiniIMU	$31.21
IMU	Pololu	MinIMU-9 v5	User-configurable range	$31.21
DVL	NOT USED	N/A	N/A	N/A

Camera	Microsoft	Xbox Kinect	Sterocamera	$54.98
Hydrophones	Aquarian Hydrophones	(3x) H3	16.5mm diam., High sensitivity, Balanced element design minimizes acceleration noise	$258.29 ea.
UAV	NOT USED	N/A	N/A	N/A
Algorithms	A* (AStar)	ROS - nav_core	N/A	N/A
Vision	OpenCV, TensorFlow	N/A	N/A	N/A
Lidar	RobotShop	RPLidar A1	360º omnidirectional	$150
Team Size	43 members (active / inactive)			
Expertise Ratio	None. No members with relevant prior experience			
Inter-vehicle communication	ROS - rosserial, freenect,			
Programming Languages	C++, Python, Matlab			

The twin hulls are built using a core of styrofoam coated in 2mm of epoxy impregnated fiberglass. The fibreglass provides a significant amount of redgidity to the hull, while the styrofoam core helps support it.

The frame of 20x20mm aluminum extrusion was used to connect the hulls. Steel strapping is embedded within the fibreglass shell and bolted to the keels to ensure the hulls remain attached to the frame even in cases of significant wind and boat acceleration.

Polycarbonate (lexan) sheets are thermoformed and attached to both the hulls and frame to provide water protection from any weather conditions. Lexan sheets are used to cover the sides of the boat without thermoforming, while a large sheet is thermoformed to overlap the entirety of the boat to insure no water can enter the boat without being splashed almost directly upwards. The underside of the boat where the truss spans between the hulls is a third lexan sheet, thermoformed to the hulls, and mounted to the truss.

The boat is sealed using a mixture of caulking, shaft seals, and expanding foam. Shaft seals are used for the motor system. Caulking are used to seal up thin cracks such as in where all underwater 3D prints are connected. Expanding foam is used to seal larger separations, such as as between the lexan and hulls where caulking can easily separate.

The motor system is designed uniquely to allow rudder control, “tank drive”, or a mixture of the two. “Tank drive” controls have been decided upon due to time constraints. 3D prints were used to create the majority of the motor assembly due to ease of configuration and budgeting. The 3D prints were tested using both Solidworks force and flow simulations, to insure reliability. The 3D prints exposed to water are sealed using epoxy for exteriors, and caulking where parts are joined and to protect bolts.

Appendix B: Outreach Activities

The uOttawa RoboBoat team is fundamentally rooted in inclusivity. The entire recruitment process is based on introducing members of all ages, from all backgrounds, and within all disciplines to the fundamentals of robotics, and allowing them to explore a branch of engineering not offered by the University of Ottawa through practical, team-oriented hands-on experience. Our recruitment involves a three-week *learning project* in which new members are guided through the construction of a team-based kitbot designed to teach them about the basics of mechanical design, electrical prototyping, and programming architecture while introducing them to the many available resources offered by the University such as 3D printers, laser cutters, electrical equipment, and machine shops.

The uOttawa RoboBoat team has proudly accepted every applicant to date. We are proud to boast a diverse team of all ages, undergraduate and graduate, and we are in the process of refining our platform to not only reach more potentially interested students, but also facilitate students at the highschool level from participating and learning from the experience of our more seasoned members.