RobotX Proposal

University of South Australia and the Student Robotics Club of South Australia, Inc.

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RoboRoos

Introduction

The Maritime RobotX Challenge is an exciting opportunity for any university student. This proposal seeks to combine the strengths of two South Australian organisations - the University of South Australia and the Student Robotics Club of South Australia, Inc - to form a new team to compete in the RobotX challenge, providing undergraduate and graduate university students an opportunity to develop their skills in an unusual and challenging environment under the guidance of experienced mentors from both academia and industry.

- The University of South Australia (UniSA) is the largest university in South Australia. Founded in 1991, the university has research centers and expertise in Augmented Reality, Industrial AI, Mechatronics, Image Processing and propulsion systems, and has experience competing in the Warman Challenge and the NI Robotics Competition, as well as extensive experience developing vehicles for Formula SAE-A.

- Student Robotics Club of South Australia, Inc (SRCSA), also known as the "RoboRoos", is a community robotics club that has a ten year track record of student robotics programs covering five different levels. They take students on a STEM journey from lower primary, through high school into tertiary STEM courses and Engineering and Science positions in the workforce. RoboRoos has nurtured and encouraged over 450 students through programs, engaging more than 30 mentors and 50 volunteers, and has been a significant force in encouraging gender diversity within STEM in South Australia.

Technical Approach

Based on the SRCSA's extensive experience in robotics competitions, the specifics for any technical solution are best developed through an iterative process led by the students. Thus it is expected considerable time will be spent prototyping various approaches, and any initial plans will be subject to change.

The robot is to be developed as a series of discrete modules which manage specific tasks that will then be integrated on the WAM-V. The development of each module will be led by student subteams. Due to the involvement of the SRCSA in the FIRST FRC competitions, the team has access to a pool of large ground-based robots and a practice area in which replicas of key competition elements will be constructed. One of the ground-based robots will be reconfigured to emulate the expected behaviour of the WAM-V. This will allow the team to work on the development of their subsystems even when it is not possible to conduct on-water testing, and will permit more time to be spent in the development cycles. It will increase the complexity of the integration, as it will be impossible to fully emulate the behaviour of a WAM-V when away

from the water, but the additional development time is expected to more than offset the added integration time, and add vitality and student involvement at SRCSA's workshop facility.

Navigation and Propulsion

General positioning and navigation of the AMS is to be handled by an integrated GPS and IMU. Within the tasks, relative positioning will be determined with a combination of vision-based systems and LIDAR. The team has a close relationship with the Australian Submarine Corporation (ASC) through UniSA and the SRCSA, and will capitalise on this by extending the current Feasibility Gate framework to this competition, thereby enabling ASC technical staff to provide guidance and input. The expertise of the ASC will be core to assist the students in developing the propulsion subsystem.

Vision Systems

Prior team experience using OpenCV and single-board computers such as the Jetson Nano have demonstrated that the combination is effective, and it has proven successful for the team in robotics competitions. Based on the reports from previous competitors in RobotX, considerable computing power needs to be expended to manage the complexity of the tasks, so a variety of hardware platforms will be tested using a distributed model. Two tasks in particular lend themselves to OpenCV solutions - Task 4 (Scan the Code) and Task 5 (Dock and Deliver). In addition to OpenCV, in the FIRST Technology Challenge (FTC) students were introduced to the use of TensorFlow for machine learning and the Vuforia AR SDK. These have been employed by FTC students to locate and track the robot's position on the field in real time. UniSA and SRCSA also have access to one of Australia's foremost Electronic Warfare experts at BAE Systems, who has previously worked with the students on positioning and targeting systems.

Challenge Task 1: Entrance and Exit Gates

The Teledyne Marine RESON hydrophone has been identified as an ideal candidate for detecting the beacon, and it is proposed that the combination of the LIDAR and OpenCV will be able to identify buoy locations and colours. Using GPS and the mapping data provided by the LIDAR, the robot should be able to identify and traverse through the correct gateway.

Challenge Task 2: Follow the Path

Rather than processing the image of the field on the UAV, a video livestream will be sent to the AMS for image processing via a dedicated module. Markings on the WAM-V will allow the system to identify the location and orientation of the boat along with the buoys, and this data will be employed to calculate the relative position and distances between the objects. A variation of the A* algorithm will be used to calculate the route, and the AMS will employ GPS, a LIDAR and on-board vision to cross reference the UAV data with the location of identified obstacles.

Challenge Task 3: Wildlife Encounter and Avoid

As with task 2, rather than the drone processing images on board, a livestream will be transmitted back to the WAM-V for processing. The drone will use a wide angle camera mounted on a gimbal to give an overall picture of the scene, and WAM-V will use these images to identify two targets - the WAM-V and the "objects of interest". This will provide data for relative positioning, and cross reference the location with GPS data. The objects will be identified using machine learning through TensorFlow or PyTorch, depending on student capabilities.

Challenge Task 4: Scan the Code

OpenCV is ideal for identifying a sequence of colours. It is proposed that a subteam focuses on the development of the independent module to identify and report back colour sequences by employing OpenCV on a dedicated computer. Once the vision target is identified the system will maintain a lock such that the camera will continue to be trained on the target while it collects the required data.

Challenge Task 5: Dock and Deliver

The first part of the task is similar to task 4, in that OpenCV can be used to detect the correct bay and provide both range and heading. The use of a LIDAR will provide an accurate picture of the docking bay for navigation. Student leaders in the team have had considerable experience developing systems to deliver objects into goals, incorporating catapults, hooded-shooter designs and twin-wheel shooters into their robots. It is proposed that the team employ a single-wheel hooded shooter design, mounted on a turret with two degrees of freedom. Encoders will maintain a target velocity, and data from OpenCV and the LIDAR will be used to calculate distance and angle. An integrated IMU will be used to detect and counter any movement from the WAM-V.

Initial Timeline

2021	
June	Strategy/planning; construct field elements; modify ground-based robot
July-November	Propulsion system; power; comms. UniSA ICT project for task 4
2022	
January-March	University break. Navigation; subsystems for tasks 1 & 2.
March-June	UniSA ICT project for task 5; integration; subsystem development
July-November	UniSA ICT project for task 3; integration; subsystem development
November, 2022	Final testing; competition

Team

The team will be led by a core student team with extensive experience in competitive robotics, complemented by specialist students from UniSA and mentors from the university and industry.

Student Leadership Team

- Charlie Ryan-Kane, Adelaide University, 9 years experience robotics, Mechanical lead.
- Bailey Woolridge, UniSA. Studying Bachelor of Systems Engineering (Honours). 6 years experience as a competitor; 2 years mentoring robotics teams. Software lead.
- Jessica Shannon, UniSA. 6 years experience as a competitor; 2 years mentoring robotics teams. Electronics lead.

Mentors

- Rob Zibell, Senior Systems Engineer, BAE Systems. 30 years experience in developing defence systems; ten years experience in mentoring students in robot competitions.
- Dr Ivan Lee, Senior Lecturer, UniSA. Extensive experience in multimedia signal processing and computer vision; heads research lab encompassing ground, aerial and underwater unmanned vehicles.
- Adam Jenkins, Lecturer, UniSA. 20 years experience teaching undergraduate and graduate programming; eight years mentoring students in robotics competitions.
- Jeremey Hamlyn, Network Security Consultant, Teletraffic Research Center, Adelaide University. 16 years experience as an engineering officer in the Royal Australian Navy; 20 years experience as consultant in telecommunications.

Facilities

For fabrication, facilities and expertise will be provided by combining the resources of both UniSA and the SRCSA. UniSA has extensive fabrication facilities at the Mawson Lakes campus, while the SRCSA maintains a workshop at the Royal Adelaide Showgrounds. The UniSA facilities have been used to construct open-wheel Formula SAE-A race cars, most recently in the Electronic Vehicle (EV) categories. The SCRSA workshop has been employed to develop and test robots to enter into the FIRST Robotics Competition.

It is proposed that on-water testing will be conducted at West Lakes, Adelaide, which provides a similar environment to that of the site of the 2022 competition, and is used for club and school rowing practice and regattas. However, much of the development in the sensor suite is to be conducted through independent modules, and this testing will initially be conducted on land, employing modified existing FRC robots as test bases, to be integrated with the WAM-V once they reach a suitable level of refinement.

Sponsorships and Partnerships

The SCRCSA has a ten year track record and has raised Government and Corporate sponsorship each year, totalling more than AUD 300,000. The team is confident that this new competition would be engaging for further industry sponsorship and government funding opportunities.

Category	Entity	Year	Amount	Contact
Industry	BAE Systems	2011-2022	150,000	nicole.hunnisett@baesystems.com
	ASC	2016-21	30,000	Martin.edwards@asc.com.au
	Science Alive	2012-2022	50,000	brian@sciencealive.net.au
	Don Alan	2012-2021	15,000	donald@donalan.com.au
	TechnoPlas	2015-2021	20,000	sbilling@technoplas.com.au
	APS	2012-2021	10,000	john@adelaidepneumatic.com.au
	Blackbird Ventures	2017	20,000	joel@blackbird.com
Government	State	2012-2021	140,000	various
	Federal	2014-2021	45000	various
	Local	2011-21	35,000	various

Future sponsors SRCSA are in discussion with include SAAB, Naval Group, Sage Automation, Raytheon, and Lockheed Martin who are all major employers in the State. Past supporters of smaller magnitude include Applidyne, RS Components, Altium, and Braemac.

Management Approach

The combined expertise of UniSA and SRCSA has managed many robot builds and competition entries over the past ten years. A framework is set up for each build and competition, with identified key Mentors, Build Managers, and Support volunteers. A program budget is established, along with a purchasing manager, Feasibility Gate manager, outside experts panel, build space and practice arrangements. For Maritime RobotX Challenge there will be two components to the team: a core group of students with prior experience in robotics, largely recruited from the students who have participated in the SRCSA and are now engaged in tertiary study; and a second group of students who are focused on subsystems and may not have any prior robotics experience. In regard to the second group, undergraduate and graduate students from UniSA engaged in industry (ICT) projects will be given the option of working on this project as part of their degree. The core group of mentors will be complemented with specialist mentors drawn from UniSA's division of STEM and from industry partners - in particular BAE Systems Australia and the Australian Submarine Corporation.

High Level Budget

Component	Cost
Propulsion & power subsystems	8000
Velodyne Puck LIDAR	3500
Vision system components	1500
NUC/Communications	1600
Sensors/IMU/GPS	1800
Weatherproofing & mechanical components	2600
UAV	3000
Transport and accomodation: (Sydney Olympic Park Lodge)	1700
Total	23,700

Summary

UniSA has a long history of developing programs with high levels of community and industry engagement, and have conducted extensive research in the public and defence sectors in AI, image and signal processing, augmented reality and mechatronics. The SRCSA has a well-deserved reputation of completing robots, being competitive and making it happen. They have successfully recruited students, raised funding, purchased equipment and supplies, recruited and retained mentors and sustained an inclusive learning environment. They have competed in Sydney, Hawaii, St Louis, Detroit and Houston and are accustomed to the rigours of getting robots, tools, and equipment to competition sites. They have arrangements with logistics and freight companies that will enable the team to get the robot from one place to another.

By forming a university/community/industry alliance, the team can combine the strengths of one of Australia's leading universities, one of the country's top community robotics organisations, and industry partners heavily involved in the maritime and defence industries. The SRCSA brings a decade of competition expertise along with tertiary students with a proven love of robotics; UniSA brings academic research expertise and both graduate and undergraduate students in engineering and information technology; and the industry partners will bring real-world expertise and advice that will help drive the team to successfully complete the tasks.

Finally, in addition to building and competing with robots, UniSA and the SRCSA have very active community outreach programs that promote STEM in the community. The RobotX Challenge will provide an additional avenue to engage the public in robotics, hopefully encouraging more people into STEM in general and maritime robotics in particular.