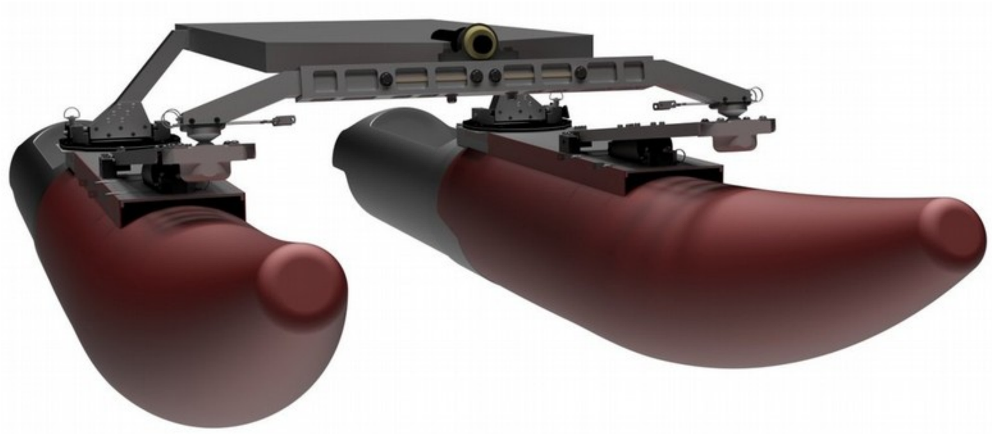
WAM-V Application

2022 Maritime RobotX Challenge



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1 Background

The University of Western Australia has been proposed taking part in the 2022 Maritime RobotX competition in Sydney, Australia. This would be the first time UWA would participate to this particular competition, noting nonetheless that our institution is familiar with other academic competitions (Formula SAE , 2014).
The below document aims both at applying for the grant of a Marine Advanced Research WAM-V surface craft by RoboNation, and outlining the personnel, technical and budgetary resources required for the participation in the competition.

2 Technical approach and justification

The consultation of the "2022 Maritime RobotX Challenge Task Ideas" document has allowed to define both the level of technical specifications and a number of observations. The following aims at summarising the findings issued after analysis of the task summary, and comparison with our current level of achievement, notably in relation with the SolarBoat project.

2.1 Challenges

2.1.1 Type of units involved

Referring to the Maritime RobotX forum, it would appear that the 2022 edition is the first one that involves the collaboration between a marine unmanned surface vehicle (USV) and an unmanned aerial vehicle (UAV).

Therefore, the students will need to split into two operational teams, marine and aerial, and a budget/task list attributed to each sub-teams.

2.1.2 Control system

While the control systems are broadly involving the same components for both types of vehicle, and likely to be operated from a common software or at least a common protocol. The author's field of research involves multiple marine unit operations and therefore the RobotX challenge appears in line with the works currently undertaken as part of his studies.

2.1.3 Marine power and propulsion system

Specifically to the marine system, the WAM-V will be delivered as a bare hull, without propulsion and power systems. This may be perceived as a budgetary hindrance for first-time competitors, but would also allow the UWA team to reuse some of the works already undertaken in that field. The proposal brief requires to define a level of redundancy which can be based on systems encountered on industrial size dynamically positioned ships and familiar.

The base design criteria would be to offer an independent battery and propulsion system for each floats, each of them being fitted with a stern azimuthal thruster and a bow transversal thruster. This would allow a degraded propulsive mode where the station-keeping ability of the craft is maintained even if one complete side fails. Depending on the budget available, and noting that the size of the USV is quite large, rim propellers can be used and are fairly immune to waterborne debris. Failure of any propulsive component can be detected through comparing measure and a baseline for torque absorbed by the steering and power absorbed by the thrust, respectively.

2.1.4 Instrumentation and task specific equipment

Regardless of the type of autonomous unit (aerial or marine), the instrumentation suite is expected to consist in at least one Real Time Kinematics (RTK) corrected GPS reference system, giving a millimetric positional accuracy, coupled with an Attitude and Heading Reference System (AHRS), and are integrated in the autopilots most commonly found on the market (i.e. PixHawk).

Additional computer vision oriented systems will be implemented with different spectrum cameras depending on the task and type of unit. While the USV will be fitted with common visible spectrum cameras, the task 3, as described below, requires a hyper-spectral camera to mounted on the UAV. This camera can also be used for landing phases.

More specifically to the USV, the following is also expected to be fitted:

- a LIDAR system (3D SICK), in order to recoup and refine the data (azimuth/range) of the obstacles obtained visually.
- A wind sensor (Matsutec ultrasonic type sensor) will also be integrated as being the main disturbance in the station-keeping process.
- An underwater pinger interrogator plus mounting kit (Teledyne DRI-267 & ACU-266), along with an orientation controller.
- A helipad for the UAV
- An internally designed catapult or cannon for task 5

The UAV will require a hyper-spectral camera (Bayspec GoldenEye) and an internally designed ball recovery device.

2.1.5 Simulation and testing

The utilisation the previous year's simulation software (Virtual RobotX - VRX) environment is an obvious step, although it is preliminary noted that the implementation of the UAV part needs to be done. A brief consultation of the Github page of the simulator indicated that VRX is based on Gazebo, and the integration of the UAV should not pose serious difficulties.

While the simulation is a necessary step, the fabrication of a replica competition course is also to be considered in order to identify and eliminate the real-world problems. This step by itself will require a dedicated and the purchase/rental of several pieces of equipment (pingers, buoys, sundry materials etc).

2.2 Task general approach

2.2.1 Task 0: Safety tests

Coloured markers/buoys are to be identified through computer vision, outputting type and bearing of each object. A geodesic fix for each object is to be generated by temporal transfer of the bearings (TTB) at a known heading/speed/position. Position of the markers will be confirmed with LIDAR data (bearings and distance). A way-point list is to be periodically and automatically generated by the onboard companion computer via potential field method or derivative and transferred to the autopilot. The return-home function is implement in the APM stack and just needs to be properly parametered.

2.2.2 Task 1: Entrance and exit gates

Visual mapping and localisation of the buoys pattern (red, white, white, green) using a computer vision algorithm, by the same TTB method to obtain geodesic fixes of the gates. Stand by away from the gates and identification of the active gate by orienting the Teledyne pinger, discrimination of the gate through maximum signal/bearing. Establishment of a way point list. Navigation around the corresponding black buoy and return to the relevant gate using TTB method. All geodesic location to be confirmed using the LIDAR.

2.2.3 Task 2: Follow the path

As a prerequisite, the camera embarked on the UAV needs to be accurately calibrated, and corrections for the lenses recorded in order correlate altitude, position of the objects in the field of vision and their relative geodesic coordinates to the aerial carrier. During the competition, the UAV is launched from the USV, and will describe a 2-step survey pattern (medium altitude and low altitude) first to identify the competition's geographic boundaries (orange markers) and then to localise and characterise all objects within the boundaries, generate absolute geodesic coordinates for each of the object, the list being eventually sent to the USV companion computer. Two strategies are to be implemented for path planning, one defining the navigation between green and red pairs, and the other one avoiding all other coloured objects, with a certain safety distance to be defined wia obstacle growth. The navigation is be effectuated with way-points, and visual/LIDAR confirmation during the passage, in case some of the obstacles are mobile.

2.2.4 Task 3: Wildlife encounter and avoid

Task 3 will use a very similar method as for task 2, apart from the characterisation of the objects, defined by hyper-spectral methods. Once characterised, two strategies are to be implemented (avoid or circle) for the passage planning based again on potential fields methods. Navigation to be followed along the path and confirmed visually.

2.2.5 Task 4: Scan the code

Task 4 is to be implemented using a visual search pattern using computer vision, noting that the position of the white buoy and obstacles may have already been roughened out by the previous searches carried out by the UAV. The sequence is to be analysed using regular CV while circling the coded buoy until full acquisition, and sent to the ground control station using ROS status message.

2.2.6 Task 5: Dock and deliver

The docking phase of the task would be in practice very similar to the task 1, with a slower approach strategy, and discrimination using colours instead of an US pinger. The stabilisation of the craft can achieved either using thrust against the dock or positioning dynamically the USV. The delivery method of the balls inside the targets will need further work, but preliminary, a ballistic method using a camera/range finder mounted on a catapult can be envisioned. The accuracy of the delivery is likely to be ascertained and developed empirically.

2.2.7 Task 6: UAV replenishment

The task does appear to be fairly straight forward as being a 2 way point navigation with automated take-off and landing, although more specifications are needed to devise the object to be picked up (size, weight, magnetic or mechanical handle, etc), and maximum altitude allowed for the detection of the landing zone. Further details would also be needed.

2.2.8 Task 7: Finals

While this task is not one as such, the brief defines the finals as a combination of the above-mentioned tasks. One that comes to mind would be the succession of all tasks into one, and not necessarily in the presented order. For the sake of preparation, and as part of the simulation/testing program, several configurations/variations will have to be tested. As far as practicable, each of the tasks scripts will have to be defined using parameters, etc. however leaving space for improvisation.

2.3 Timeline and general approach

A complete timeline is not practical to expose in this document, however, prior to the project management being put in place the following is a reasonable approach:

- The start date for the project is fixed on May18th 2021, date at which the confirmation of the award of a WAM-V unit. The competition date is on November 11th 2022.
- The complete time frame is a bit more than 3 semesters (77 weeks), including school holidays.

The general project will therefore be split into 5 periods:

- Project preparation (now until the beginning of S2 2021): refine project timeline, split phases into elementary tasks, setup the PM software basis, quoting and purchasing process, logistics, student recruitment, sponsors and technical partners communication and approach. Milestone: resources and PM fully defined.
- Elementary task execution (S2 2021): Execution of all the elementary tasks among the 5 poles of activity: Simulation and high level control, Marine Power/Propulsion and low level control, Instrumentation and communications, Marine mechatronics and outfitting, Aerial outfitting and operations, External communication, project follow up and cost control (sponsorship/activity report/social media presence etc). Milestone: All elementary tasks completed and individual systems are operational.
- Merger and real-world testing (S1 2022): Progressive merger of the results of all 5 poles of activity, in water testing of all components, setup of the course replica, problem identification and troubleshooting. Milestone: Complete system operational and able to perform each of the tasks independently.
- Performance and adaptability (S2 2022): Intensification of real world testing, Focus on association randomised tasks, identification of the flaws/bottlenecks in scripts & algorithm, tests on variations of the task, rehearsal of operational deployment. Benchmark established on the execution of the tasks. Milestone: The system is optimised, the team is operationally ready, and both able to cope with heavy variations on operational conditions.
- Competition date: (01/11/22 until 17/11/22): Transport of the equipment, on site logistics assembly, practice runs, qualifying runs, semi finals and finals. Pack-up and return logistics, after action review.

3 Team qualifications

The below aims at presenting the management team for this project, noting that several students have expressed interest but would be acting as supervisors. The ground level level

3.1 Pr. Thomas Braunl – Overall project manager

Thomas Bräunl is a Professor in the Faculty of Engineering and Mathematical Sciences of The University of Western Australia, Perth, where he directs the Robotics & Automation Lab as well as the Renewable Energy Vehicle Project (REV). He has developed numerous robotics systems, including the EyeBot robot family and the EyeSim simulation system. On the automotive side, he has done research on electric drive and charging systems, and is developing AI solutions for autonomous driving.
Thomas Braunl will ensure the liaison with the University administration, alumnis, industrial partners and overall project supervision.

3.2 Pierre-Louis Constant – Operations manager

Pierre-Louis Constant is a Class 1 Marine Engineer. He has worked 23 years at sea, including the last 12 years as Chief Engineer/Technical Superintendent on dynamically positioned offshore vessels, directing the technical operations of vessels and their periodic refits. He is currently furthering his studies in the field of automation and robotics under the supervision of Pr. Braunl, and has started his own company, Oceanomatics Pty Ltd in 2017, which develops autonomous marine crafts and associated systems. His activities within UWA led to him to work on the SolarBoat with the Robotics and Automation Lab, and the Hydrofoil jetski with the REV lab.
Pierre-Louis Constant will ensure the coordination of all the tasks, bring his technical experience to ensure compliance with the project progression both on the technical and general side.

3.3 Alishan Aziz – Technical manager

Alishan Aziz is a Final year student pursuing an Electrical and Electronic Engineering Master, who has stood out by his various successful involvement in the Hydrofoil jetski and the SolarBoat. He is also a part-time employee of Oceanomatics Pty Ltd, having been both involved in the Research and Development and Naval Repair side. He is most qualified to lead the technical team, as having a relentless, down to earth and pragmatic vision.
Alishan Aziz will supervise the progress of all the technical tasks, and ensure compliance with the technical scope of work.

4 Facilities

The team will have access to all the technical facilities at UWA, including:

- The UWA Mobile Robotics and REV Lab of the Department of Electrical, Electronic and Computer Engineering school.
- The UWA Department of Mechanical Engineering facilities and workshop.
- The UWA Oceans Institute facilities and equipment.
- The UWA Communication and Media facilities and equipment.

In addition to the above, the main technical partner Oceanomatics Pty Ltd offers a 350 m2 workshop, including industrial CNC machining and 3d printing capability. This facility is in direct proximity of the Australian Marine Complex, where several of the company's historical partners are located, giving full access to the Strategic Marine wharf and lifting capability.
The team will have nonetheless access to several types of waterways, from protected swimming pools at the UWA facility, to sheltered estuarine conditions in the Swan river, to semi-sheltered

waterways in the Cockburn Sound, to full oceanic conditions off the Perth Coast.

5 Sponsorships and partnerships

At this stage, the firm sponsorship and partnerships are publicly limited to UWA and Oceanomatics Pty Ltd.
UWA being a first-time contender, the general consensus among a number of contacted partners is that they have expressed interest but do not wish to be mentioned in external communication until a firm commitment through the award of the WAM-V is confirmed. One of the key point retained from the early discussions is that any sponsorship will require an extensive public relation campaign and therefore the PR campaign has to be study and will require full time resources.
The budget as expressed below is nonetheless met at approx.50% and would allow for pursing the challenge should the first step of the challenge be concluded.

6 Management approach

While the management team as described earlier in the document is definitively going to be committed and available throughout the competition project timeline, communications between UWA and Oceanomatics Pty Ltd have identified the need for continuity among the students who are going to be involved. The period referred to extends beyond the usual duration (one or two semesters) during which the most qualified and performant students are available, and enrolled in the relevant units.
One of of the strategies envisioned and agreed to is to recruit among the 4^{th} and 5^{th} year students a team that will follow a customised pathway, specifically involved in the competition project, but at the same time meeting the deliverables required by their study cursus.
On the broader management approach this would not constitute a major hindrance as long as the tasks to be performed are defined to their most elementary and represent an outcome that is valuable both for UWA and at the students personal study level.

7 Budgeting

The following table summarises the budget involved by poles of activity. These are estimates and are based on publicly available costings, noting that the actual budget will be refined to a much more accurate level, but has been inflated by approx. 40%.

Description	**Cost**
Simulation and high level control	$5,000
Marine Power/Propulsion and low level control	$20,000
Instrumentation and communications	$20,000
Marine mechatronics and outfitting	$10,000
Instrumentation and communications	$10,000
PR operations	$10,000
External consultancy	$60,000

Logistics	$10,000
TOTAL	**$145,000**

The budget involved, while being accessible within the industrial range, is not accessible to any university, and will be unlocked only if the award of a working platform.

8 Summary

UWA would be a first time contender in this competition and that does reflect in the initial budget. While it also does present a level of risk for potential sponsors that is not negligible, it would be balanced by the reputational outcome that is definitively substantial.

While the attribution of budget and project management is still pending, the technical tasks, after review, appears to be within the technical capability of the management team. The sponsors/partners are willing to support under the condition that a first step that is represented by the award of a development platform is achieved.

Nonetheless the project represent a unique opportunity for UWA to be present on an international level and the rewards are worth the undertaking.

As a general conclusion to this report, we expect the competition to be happening on the water, but hope to find a general collaboration atmosphere ashore, as should scientific undertakings be.

We, on behalf of UWA, hope to be part of the competition.