Application for a Free Wave Adaptive Modular Vehicle (WAM-V)

POINTS OF CONTACT

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TEAM RESOURCES AND EXPERIENCE

Team Leaders

Rohan Kapoor – Sensor/platform integration and autonomy

Rohan Kapoor is a PhD candidate in Aerospace Engineering and Aviation at RMIT University. He has done his Bachelors in Mechanical Engineering from National Institute of Technology, Jalandhar, India and his Masters in Mechanical & Aerospace Engineering from North Carolina State University. Prior to enrolling in PhD, he has worked in the areas of intelligent transportation systems (ITS) and warehouse automation.

Suraj Bijjahalli – Sensor fusion and control systems

Suraj Bijjahalli has completed a Masters degree in engineering and is currently a researcher in the Cyber-Physical and Autonomous Systems research group in the field of intelligent avionics for unmanned aircraft systems. His research interests include multi-sensor data fusion, autonomous systems, and artificial intelligence.

Kavindu Ranasinghe – Propulsion and vehicle health monitoring

Kavindu Ranasinghe obtained his MEng in Aeronautical Engineering from Imperial College London, United Kingdom. In addition to low-emission aircraft propulsion technologies, he has a strong research background in the area of Integrated Vehicle Health Management (IVHM) systems augmented with artificial intelligence and machine learning techniques. He is currently pursuing a doctoral degree in the latter field at RMIT University, Australia.

Laboratory facilities

Aerospace Information Systems Laboratory

The Aerospace Information Systems Laboratory (AIS) has world class facilities supporting research on aircraft, spacecraft and ground-based computing systems and software. The laboratory has also demonstrated capability to provide Time and Space Position Information (TSPI) Flight Test Instrumentation with tightly coupled GPS/IMU as well as Acoustic Positioning and Navigation System (APNS) for several in-house UAS platforms and payloads in outdoor as well as GNSS-challenged indoor environments.

Autonomous Systems Laboratory

Recently, RMIT University heavily invested in Autonomous Systems Lab, including a new set of autonomous agents such as micro ground vehicles (1/10th of the actual car), autonomous ground vehicles (QBots) and quadcopters (QDrones). This environment is ideal to deploy and test the developed framework proposed in this application. The QDrones and QBots are excellent platforms for conducting research studies on the control and coordination of multiple UAVs and AGVs in industrial environment like warehouses and factories. Furthermore, they allow our students and researchers to field test their novel sensor fusion and computer vision algorithms rapidly. The devices provide our students with hands-on experiences and allow them to tackle real-life engineering challenges, such as noise and delay, which can hardly be emulated by software simulations.

Cyber-Physical and Autonomous Systems Group

At RMIT University, we are developing innovative Cyber-Physical Systems (CPS) based on advanced cognitive processing and machine learning techniques, towards enhancing human-machine teaming and building trusted autonomy. CPS are at the core of the digital innovations that are transforming our world and redefining the way we interact with intelligent machines in a growing number of industrial sectors and social contexts. RMIT University currently operates a number of robotic systems, including both Unmanned Aircraft Systems (UAS), Unmanned Ground Vehicle Systems (UGVS) and Unmanned Water/Underwater Systems (UWS/UUS). Current contributing partners include Thales, Northrop Grumman, the Defence Science Institute (DSI) and the Defence Science and Technology (DST) Group.

Unmanned Aircraft Systems Research Team

The RMIT Unmanned Aircraft Systems Research Team (RUASRT) is dedicated to enabling the safe and efficient operation of Unmanned Aircraft Systems (UAS) in a variety of civil, commercial and defence applications. RUASRT is internationally recognised for their significant research contributions in the field of Unmanned Air Systems as evidenced by the introduction of new knowledge and terminology to the discipline; patent; and the innovation awards received by key members. RUASRT researchers have access to world leading facilities and equipment, including simulation, prototyping, manufacturing and test facilities.
Besides, RMIT is also collaborating with the Department of Defence and various industry partners on the Trusted Autonomous Systems Cooperative Research Centre. The aim of this research centre, among other objectives, is to evaluate the utility of autonomous systems through capability demonstrations, build innovative IP through targeted research and technology programs, and deliver world-leading autonomous and robotic Defence technologies. Trusted Autonomous Systems aim to develop highly self-sufficient, self-determining, self-aware, and survivable systems that are human and context aware. Besides aiming to increase the speed to reach a deployable state for trusted autonomous systems, there is also a push to increase the scalability and reduce the cost of autonomous systems technology solutions. Finally, this centre will promote education in ethical and legal aspects of autonomous systems and advocate and shape policy and regulations.

TECHNICAL APPROACH

Based on the RobotX Challenge task ideas, the following requirements were identified for the UAV and the AMS:

Table 1: Primary system safety assessment.

Requirement ID	Level	Statement of requirements
FUNC	1.1	The unmanned systems must have the ability to avoid obstacles
PERF	2.1	The UAV must demonstrate ability to navigate through two pairs of buoys 30 m apart and approx. 30 m wide on land
FUNC	3.1	The UAV must demonstrate a ‘return to home’ capability that over-rides all other commands
FUNC	4.1	The UAV must guide the WAM-V through a path defined by sets of buoys

	4.2	The UAV must identify objects of interest from their unique spectral signatures and inform the WAM-V to circumnavigate the object
FUNC	5.1	The UAV must pick up an item from the dock and deliver it to a helipad ashore
FUNC	6.1	The AMS must demonstrate the ability to maintain positive control and effectively detect and navigate through two sets of channel markers
PERF	7.1	The AMS must detect the active underwater beacon, transit through the gate in which the active beacon is located, and then circle one of two buoys.
PERF	8.1	The AMS must detect and pass through the gate with the active beacon
PERF	9.1	The AMS must deploy a UAV to map the challenge task
PERF	10.1	The AMS must transit through the path marked by the pairs of red/green coloured buoys without striking any obstacle, which will be marked by four white buoys
PERF	11.1	The AMS must transit around the marine life until it has crossed its original path, transiting at least 360 degrees, with the circling direction based on the classification of the marine life by their spectral signatures
FUNC	12.1	The AMS is required to observe a light sequence displayed by an RGB buoy within a search area of 40 x 40 m^2 and report the colour pattern
FUNC	13.1	The AMS must demonstrate the ability to successfully dock in bays identified by a coloured light and once docked, will deliver a payload (racquetball) into one of the holes located above the coloured light
PERF	14.1	Teams must implement a visual feedback system and a heartbeat broadcast system using a wired RJ45 connection, where information from the team's Ground Control Station (GCS) will be transmitted to the Technical Director's (TD) network

Based on the primary system safety assessment as shown in Table 1, the components of both the unmanned platforms are selected. A waterproof UAV with a capability to mount a hyperspectral camera is selected. Various on-board sensors on the WAM-V like the GNSS, IMU, cameras, radar, and LiDAR will be integrated through multi-sensor data fusion, as shown in Figure 1. The position, velocity, and attitude estimates from the sensor fusion will feed into the control system to maintain the desired course and heading for the platform. Prior to the installation, each sensor will be characterised via laboratory experiments, and the dynamics of the WAM-V accounted for, to develop a digital twin of the autonomous system. The digital twin developed using physics-based and data-driven models from the sensor characterisation experiments, will be tested in a simulation environment with ROS and Gazebo. A high-performance low power on-board computer will rapidly process the sensor information and integrate data, including accounting for noise and incorrect data due to faulty sensor, using data filtering techniques. A robust feedback and control mechanism will be developed for real time situational awareness and autonomous decision making.

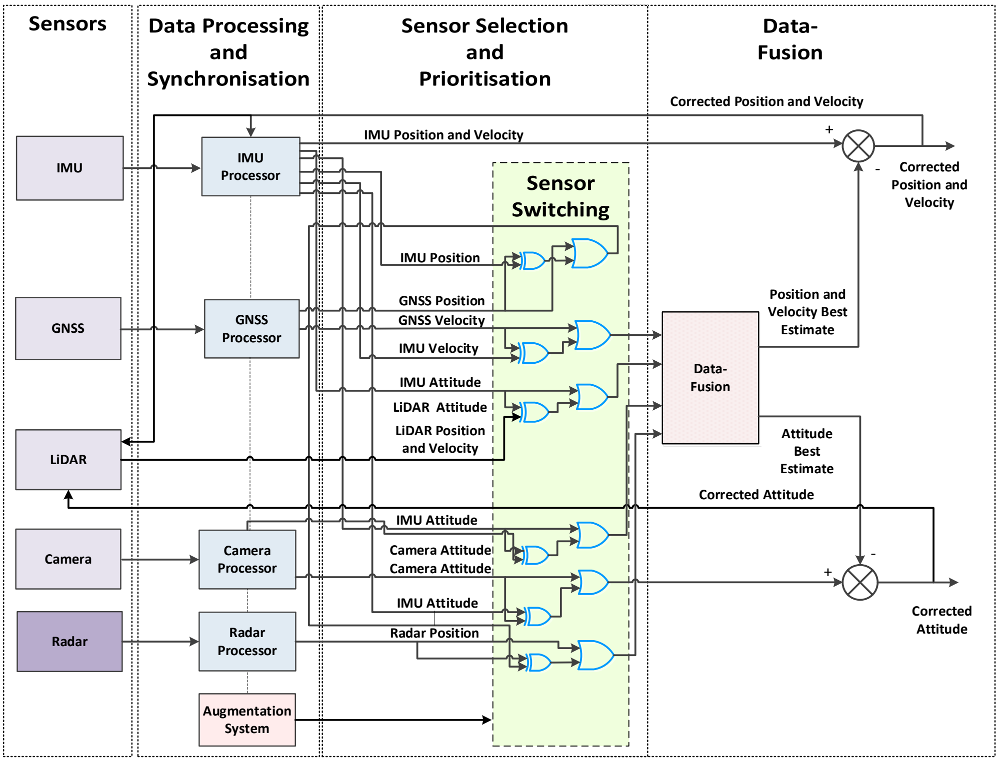


Figure 1: Multi sensor data fusion.

After completing the simulation trials, the sensors will be mounted on the WAM-V platform, as shown in Figure 2. The fully integrated platform will be tested in extensive field trials along with a waterproof UAV fitted with a hyperspectral camera. The unmanned platforms will be tested in replicated competition-like scenarios to ensure all safety and operational criteria are met. A systems health monitoring methodology will be developed with a visual feedback and a heartbeat broadcast system. There will be requisite failsafe procedures in place to ensure safety criteria are met and the systems can be diagnosed relatively quickly in case of a fault. Accurate diagnosis and in some cases, prognosis of systems and sub-systems can ensure not just safe operations but also reduced downtime and lower repair costs due to optimised and timely maintenance. Besides, using multiple sensors adds to the system redundancy and increases situational awareness.

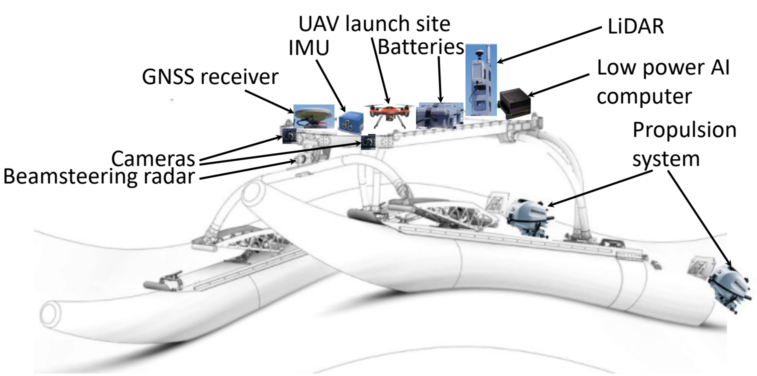


Figure 2: WAM-V platform.

PROJECT MANAGEMENT APPROACH

Budget

Component	Quantity	Cost (USD)
Sekonix SF3324-100	4	1,200.00
Velodyne ULTRA Puck VLP-32A	1	15,000.00
Metawave SPEKTRA radar	1	TBD
Geo-FENNEL GAT 300 GNSS Antenna	1	800.00
Trimble PG200 GNSS Receiver	1	3,600.00
Jetson AGX Xavier Developer Kit	1	1,000.00
Armasafe Plus 6TAGM Mil Spec (MIL-PRF 32143)	2	2,000.00
Honda 5.0 HP 4-stroke Outboard Motor	2	3,600.00
Pika L Hyperspectral Imaging Camera	1	11,000.00
SplashDrone 3+	1	1,800.00
Transport & other misc. costs, incl. small parts, field trials, lodging, food, equipment, labour, etc.	NA	45,000.00
Total		**~95,000.00**

Logistics and Personnel

RMIT has got the logistics, facilities, and personnel to handle large-scale student projects, with participation in prior competitions testimony to that capability. Moreover, RMIT intends to make the most of the 2022 Maritime RobotX Challenge taking place in Sydney, thus making it relatively easier logistically, being an Australian University based within a day's drive of the competition venue. Active recruitment of interested students is currently underway and potential partners both within and outside the University are being engaged for cash and in-kind support. The team size, excluding the academic advisors, is estimated to be 15 students, with each team leader managing a team of about 4 students. Besides, Melbourne's proximity to numerous aquatic facilities will aid in organising field trials and mock competition runs without facing significant logistic or financial challenges.

Academic Support

Alessandro Gardi – Path planning and optimisation

Alessandro Gardi received his BSc and MSc degrees in Aerospace Engineering from the Polytechnic University of Milan (Italy) and a PhD in the same discipline from RMIT University (Melbourne, Australia). Dr Gardi is currently the THALES Senior Research Fellow in the School of Engineering of RMIT University and the Program Leader for Trusted Autonomy and Human-Machine Systems in the CPS research group. He has over 8 years of research experience in Aerospace Engineering. Email: alessandro.gardi@rmit.edu.au # +61399256075

Amirali K. Gostar – Stochastic filtering, sensor management and information fusion

Amirali K. Gostar was awarded his PhD at the School of Engineering at RMIT University. From May 2017 to Jan 2020, he has held different research positions. Most of his time has been devoted to research but also had other responsibilities including industry collaborations, teaching and student supervision. In 2020 he started a new position as a lecturer at RMIT University. In 2021 Gostar took on a full-time research role funded by a DECRA ARC Fellowship. Email: amirali.khodadadian@rmit.edu.au # +61399254593

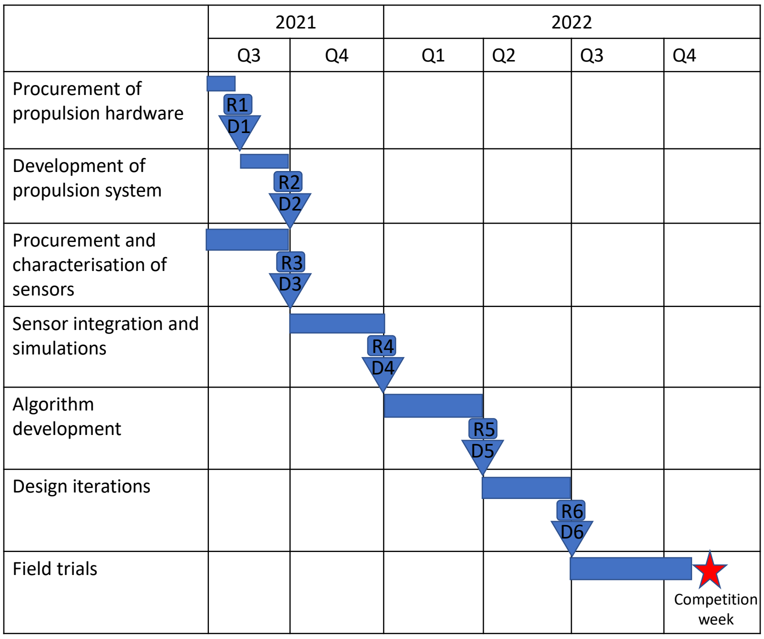
Chi-Tsun (Ben) Cheng – Wireless communications and digital twins

Chi-Tsun, Cheng (Ben) received the B.Eng. and M.Sc. degrees from the University of Hong Kong in 2004 and 2005, respectively, and the Ph.D. degree from the Hong Kong Polytechnic University in 2009. Since June 2018, he has been a Senior Lecturer at Manufacturing, Materials and Mechatronics, School of Engineering, RMIT University, Melbourne, Australia. He is the academic supervisor of the RMIT Rover Team. His research interests include Wireless Sensor Networks, Internet of Things, Industry 4.0 Technologies, Cloud Computing, and Additive Manufacturing. Email: ben.cheng@rmit.edu.au # +61399256009

Ehsan Asadi – Robot Vision and field robotics

Ehsan Asadi received the B.Sc. and M.Eng. degrees in mechanical engineering and the Ph.D. degree from Politecnico di Milano, Milan, Italy. He is currently a Senior Lecturer within the discipline of Manufacturing, Materials and Mechatronics in the School of Engineering, RMIT University. He is the academic supervisor of the Warman Design and Build team. Prior to this, he worked as postdoctoral research fellow in the Robotic Research Center at Nanyang Technological University, Singapore, and co-founded a robotic start-up company, Transforma Robotics Pte. Ltd. He continues his research in mechatronics, sensor fusion, robot vision, and intelligent robotics for field applications. Email: ehsan.asadi@rmit.edu.au # +61399254515

Schedule and Timeline



Summary

To summarise, RMIT, in partnership with its industry and academic partners, has demonstrated capability to organise as well as participate in student competitions involving logistical and technical complexities. These student competitions were able to attract significant sponsorships and generate the required traction to successfully compete. With RMIT's commitment to foster student skills by encouraging learning by doing and preparing students for future workplaces, this competition will provide a golden opportunity for RMIT students to showcase their skills.