Title page

Team name
AI Mariners

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Technical points of contact

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Technical Approach and Justification

The RobotX challenges provide tasks that a fully autonomous vessel should be able to complete. Therefore, they provide a necessary baseline for the functions that need to be carried out by future autonomous vessels. The RobotX 2022 challenge is no exception and provides 6 tasks that test a vessel's autonomy.

The course of the first task will have three gates, with four marker buoys of different colour designating the gates; a red and a white buoy indicating the first gate, two white buoys indicating the second gate, and a white and green buoy indicating the third gate. Within each gate there will be an underwater beacon with only one being active. The goal of this task is for the vessel to detect the gate with the active beacon and pass through it, circling one of the two buoys of the gate. To this end, the onboard cameras of the WAM-V platform will be employed first. Initially, the gazebo simulator[1] will be used to gather images of the marker buoys with different colours. Then, the YOLOv3 neural network[2], a well established real-time object detector, will be trained on the gathered images. This will allow the vessel to identify the marker buoys from the cameras and recognize each buoy and gate respectively in real-time. Furthermore, the onboard lidar sensor will be employed in combination with the cameras to locate the exact position of the buoys in the 2D space of the course. This will allow the vessel to efficiently navigate through the gate with the active beacon. Data from the lidar will be gathered in real-time and will be clustered at frequent intervals using the k-means clustering algorithm, with k being equal to the number of buoys. The centroids of the k clusters will be converted to geodetic coordinates, allowing the WAM-V to travel towards the gates and between the buoys with the use of its onboard GPS sensor. Finally, the WAM-V will be employed with two hydrophones able to approximate the position of the underwater active beacon. The location data provided by the acoustic device in combination with the cameras, the lidar sensor and the GPS sensor will navigate the WAM-V through the respective gate.

In this task, the Autonomous Maritime System (AMS) must deploy a UAV to map the course of this task and help guide the WAM-V platform through a path defined by buoys of red and green colour. Obstacles may be located inside the path. To solve this task the deployed UAV will fly at a predefined height and use its onboard camera to identify the buoys and create a virtual map. Based on the height of the UAV, the size of the identified objects and their position in the camera, the UAV will be able to create a set of coordinates for each buoy. This virtual map will be exploited by the WAM-V which will create a suitable path to traverse through the buoys in real-time using well-established path planning algorithms such as motion planning and grid-based search. Furthermore, the lidar from the WAM-V will also be used to verify the set of coordinates sent from the UAV and to identify potential obstacles in the course of task.

The third task requires the WAM-V to locate objects of interest that represent Australian wildlife. Each object will be a horizontal plywood with a different coating that has a unique spectral signature, with each coating representing a different animal. The goal of this task is to identify the animals and transit around them until the WAM-V has crossed its original path, transiting at least 360 degrees. The WAM-V will circumnavigate the object either clockwise or counter-clockwise depending on the classification of the animal. To achieve this goal, the UAV will be employed with its onboard hyperspectral sensor that is able to identify the different spectral signatures of each coating. This sensor will then send the data to the WAM-V platform which in combination with its onboard lidar sensor will be able to give a precise location of the plywood. Then, similarly to the second task, the WAM-V will use real-time path planning algorithms to travel towards the plywoods and around them making a full 360-degree circle. To further verify that the WAM-V has crossed its original trajectory,

[1] http://gazebosim.org/
[2] https://pjreddie.com/darknet/yolo/

the GPS sensor will be employed and track the coordinates at frequent intervals. The coordinates will then create a trajectory or a linestring for which self-intersections can be identified by the use of python libraries such as Geopandas[3] and PyProj[4].

The fourth task will test the WAM-V's ability to identify colours through the onboard cameras. To this end, a floating platform with a vertical pole and a light bar atop the pole will be used to display different colours to generate a colour sequence. No same colours will be displayed in a row and a black colour will be displayed when the light bar is off. The goal of this task is to successfully identify the colour sequence. To do so, the WAM-V will employ the cameras onboard to first identify the light bar and then recognize the colour of the light bar. Similarly to the previous tasks the YOLOv3 neural network will be employed to recognize the light bar and classify the colour of the light that will be displayed. Furthermore, the image of the light bar identified by the neural network will be further analyzed to detect the colour of the lightbar. Specifically, for each snapshot of the light bar, a colour histogram will be created, with each bin of the histogram denoting the number of pixels that have a particular colour. The bin with the most pixels will indicate the colour displayed by the light bar. As a result, a sequence of identified colours will be generated by the sequence of snapshots. Finally, the results of the histogram technique and the detections of the neural network will be averaged in order to provide a more accurate classification of the colour sequence.

The fifth task requires the WAM-V to dock in a bay out of three bays of a predefined parallel configuration. Each bay will have a different coloured light with each coloured light indicating the correct bay to dock. Finally, the WAM-V will be carrying four balls that should be launched or inserted into specific holes located on top of the coloured light of the bay. To successfully complete this task, methodologies for object and colour detection similar to the first and fourth task will be used to identify the correct bay to dock. Then, the onboard lidar sensor will be employed to identify the dock configuration in the 3D space of the course and path planning algorithms will be exploited to dock the WAM-V properly inside the correct bay. Finally, solutions such as "ball launchers" or robotic arms will be investigated to place the set of balls in the square holes of the bay. In each case, the onboard cameras of the WAM-V will be used to identify the correct hole based on size and its precise location in the y axis (height) and the x axis. Again, the lidar sensor can be employed to identify the correct distance of the hole from the WAM-V to properly launch or place the ball inside it.

For the final task, a UAV is required to launch from the WAM-V and pick up an item from the dock and deliver it to a helipad ashore. In each dock there will be a disc with a different colour, matching the colour of the dock. To successfully deliver the items from the docks to the helipad that will be identified by a light beacon, the team's UAV will use object detection algorithms through the camera feed to identify the items and the light beacon as well, similar to the previous tasks.

Despite the fact that each task is unique and tests a different kind of ability of autonomous vessels, all tasks share several similarities in terms of algorithmic approach. For that reason and in order to be ahead of system failures, attempts will be made to solve the tasks with the exploitation of every sensor and camera of the AMS and different algorithms and methodologies will be developed for the tasks, with each methodology exploiting a different kind of sensor. Furthermore, the expertise of the team members and the facilities provided by the facilities described in the next pages will allow the team to develop the tools, algorithms and hardware modifications according to the timeline illustrated in the gantt chart.

In the gantt chart below, the time between now and the time of the competition has been segmented into 19 months with May 2021 being the first month (M1) and November 2022 being the last month (M19). The outer left column indicates the phases of the project starting from Phase 1 (P1) up to Phase

[3] https://geopandas.org/

[4] https://pyproj4.github.io/pyproj/stable/

X (PX). P1 refers to the system design during which the appropriate equipment for the completion of the tasks will be decided such as sensors, GPUs or other external hardware not included in the WAM-V platform. This phase also includes the delivery of the hardware. The second phase (P2) includes the simulator setup during which an initial sketch map of the tasks will be incorporated in the gazebo simulator and algorithmic methodologies will be designed to solve the tasks. Phase 3 (P3) includes the real tests and experiments that will be conducted with the physical WAM-V platform and will mostly run in parallel with simulator experiments of P2. In this phase, feedback taken from the real-world experiments will be incorporated in the simulator experiments and then into the real-world setup, acting as a continuous loop of testing, fine-tuning and development. Furthermore, this phase also includes the incorporation of the external hardware and sensors in the WAM-V platform.The fourth and final phase is the shipment of the WAM-V platform and all the necessary hardware components in the competition's location. Finally, this phase also includes the tests that will be conducted in the competition's location.

	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15	M16	M17	M18	M19
P1	■	■	■	■	■	■													
P2					■	■	■	■	■	■	■	■	■	■					
P3							■	■	■	■	■	■	■	■	■	■	■		
P4																		■	■

Team Qualifications

The team that will take part in the RobotX 2022 challenge is composed of four main members with both academic and industrial expertise in the maritime domain. The technical contact of this application is Mr. Ioannis Kontopoulos which is currently a PhD student in the Harokopio University of Athens and a researcher at MarineTraffic, the largest global ship tracking intelligence. He has a five-year research experience in EU-funded projects and his expertise ranges from trajectory analytics and spatio-temporal data mining to machine learning and real-time and distributed processing. The second member is Dr. Professor Konstantinos Tserpes of Harokopio University of Athens which is a supervisor of Mr. Kontopoulos. He has many years of research experience in IoT, cloud and edge storage as well as maritime analytics from EU-funded and national projects and he is also a researcher and professor in the National Technical University of Athens. The third member is Dr. Professor Dimitris Zissis and he is currently the head of research at MarineTraffic and a professor at the University of the Aegean. He has many years of experience in trajectory analytics, machine learning and Big Data and has participated in numerous EU-funded and national projects. The fourth and final member is Dr. Professor Elias Xidias and he is currently a professor and researcher in the University of the Aegean. His expertise revolves around robotics and intelligent transportation systems and has many years of experience in EU-funded projects. The combined expertise from all the members of the team is suitable to address and solve problems posed by the competition in both software and hardware.

Facilities

To test the Autonomous Maritime System, the WAM-V and all the necessary hardware will be transported to Syros island, Greece, where the University of the Aegean is located. As such, the facilities of the university will be exploited where an existing test bed of Wi-Fi connections at sea has already been installed and used for maritime experiments. The university's facilities are capable to host and deploy every type of UVs: air, land, sea and subsurface. A provision for UAV flights is also made inside the Testbed's geographical limits (up to 300ft-AMSL). The infrastructure is supported by a conference room and several classrooms. The aforementioned rooms and their equipment (fast internet connection, teleconference module, projector, whiteboards etc) are ideal to host the Control Center for the trials. Furthermore, a Maritime Informatics and Big Data Analytics summer school[5] is scheduled to be organized where world renowned speakers will be invited to give lectures about maritime informatics and a group of 50 students will participate. During the one week of the summer school a number of experiments and demonstrations will take place at sea using state-of-the-art naval robotics equipment. This will allow the participating team to gain knowledge, exchange ideas and demonstrate the findings of their research when trying to address the tasks of the RobotX challenge.

Sponsorships and Partnerships

Organization	**website**
IEEE Oceanic Engineering Society (OES)	https://ieeeoes.org/
MarineTraffic	https://www.marinetraffic.com/
ALTUS LSA	https://altus-lsa.com/
International Society of Information Fusion (ISIF)	https://isif.org/
INFORE	http://www.infore-project.eu/
VesselAI	https://vessel-ai.eu/
Maritime Informatics and Big Data Analytics summer school	https://summer-schools.aegean.gr/MaritimeInformatics2020

Management Approach

From the time of writing this application until the time of the competition a balanced time schedule has been designed that takes into account summer vacations and holidays that may delay the process. The entire process of system design, building and testing has been segmented in four phases and the time allocation of the phases has been distributed to the entire time schedule. The time allocation of each phase overlaps with its previous and next phase, thus allowing interoperability between them, design and testing in a continuous loop of fine-tuning and improvement. To fully exploit the time towards the date of the competition, partnerships from previous collaborations of Harokopio University, Aegean University and MarineTraffic will be used to not only save time but to financially support the team. Moreover, already funded projects such as INFORE and VesselAI will financially

[5] https://summer-schools.aegean.gr/MaritimeInformatics2020

support the team in an attempt to advance the projects' research conducted in the fields of maritime informatics and autonomous vessels respectively. Additionally, a summer school will be organised, which has already partnered with the organisations of the previous section such as the IEEE Oceanic Engineering Society, to act as a test venue and a dissemination activity of the team's work for the RobotX challenge. Furthermore, through the summer school, students from several universities will have the opportunity to not only gain knowledge in the respective research fields, but to also be recruited as members of this team. Through their membership and their work, PhD opportunities will arise for them with universities participating in the summer school, and the research of autonomous vessels and maritime informatics will be further extended in the future.

Rough Order of Magnitude Cost

Component	**Quantity**	**Cost**
Shipment costs	1	10,000 euros (12,000 dollars)
NVIDIA GeForce GTX 1660 Super	2	1200 euros (1,450 dollars)
DJI P4 Multispectral	1	5,400 euros (6,500 dollars)
Teledyne RESON TC4013 Hydrophone	2	4,000 euros (4,800 dollars)
Other equipment	1	5,000 euros (6,000 dollars)
Total		25,600 euros (30,750 dollars)

Summary

Each year the RobotX challenges provide a series of tasks that try to test a vessel's autonomy functions in an attempt to advance the research in the respective field. Consequently, the 2022's challenge has designed six tasks that challenge the technical skills of the participating teams in terms of hardware and software. To this end, this team is composed of members that have the technical knowledge in the fields of trajectory analytics, machine learning, IoT, robotics and intelligent transport systems and the academic and industrial experience to address the tasks at hand. Their combined experience will allow them to employ algorithms of both the research literature and the industry to tackle each task of the challenge. Methodologies used in one task will be exploited and re-used in other tasks where applicable. Every sensor of the Autonomous Maritime System will be employed in each task thus decreasing the failure of the completion and providing alternative solutions. Additionally, the support of academia and industry through the partnerships and sponsorships will greatly enhance the team financially. Furthermore, a test bed with Wi-Fi connections at sea, infrastructure and relevant equipment provided by the Aegean university will allow the team to rapidly design, build and field test their AMS. Finally, the Maritime Informatics and Big Data analytics summer school will increase the visibility of the team, advance their knowledge and enable the recruitment of more team members such as students with PhD opportunities in the respective fields.