ITUASTEAM

AUTONOMOUS SAILING BOAT TEAM

Application for WAM-V

CONTACTS

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May 3, 2021

I. Technical Approach and Justification

A. Hardware and Software Approach

As ITUASTEAM, we have created our software and hardware charts. We tried to draw a comprehensive software and hardware framework to complete the RobotX 2022 competition tasks. The hardware system of the platform is divided into seven subsystems, which are: Localization, Underwater Environment Perception, Object Perception, Propulsion System, Ground Control Center, Computing System, Power Center. The relationship of this subsystems is shown in Fig. 1.

1) Localization: The Localization system includes GPS and IMU sensors. To increase computation speed, platform has multiple computing systems with different features, one is for the main program and the other one is for the GPS and IMU sensors.

2) Underwater Environment Perception: The Underwater Environment Perception system includes hydrophones. Hydrophones are being used to successfully complete the "Entrance and Exit Gates" task. For this system, sensors are connected to different computing system to increase computing speed also.

3) Object Perception: The Object Perception system includes LIDAR, RADAR and Camera sensors. The goal of the Object Perception system is to identify surroundings such as buoys, obstacle balls, docks etc. With using camera sensor, we can determine the surrounding's type, color, shape etc. with the help of deep learning algorithms. With LIDAR, we can get more detailed information about surrounding, such as width, height, 3D shape, position. With RADAR, we have a high range of vision for positions of surroundings. When all these three sensors come together, we can finally know, the exact position of surrounding, the size of surrounding, the type of surrounding, the 3D shape of surrounding and so on. These strengthened data helps us to place all surroundings and task elements inside our unmanned vehicle's 3D environment in 3D type. Finally, we can determine our autonomous behaviour for the task and percieved object with the help of 3D environment.

4) Propulsion System: The Propulsion System includes two propeller thrusters and actuators to steer the thrusters. The unmanned platform has two steering mode. Tank drive mode and thrust difference mode. Thrust difference mode is being used when the unmanned platform is moving at high speeds. This mode allows us to make maneuvers while moving. The presence of two propeller thrusters on the platform allows us to maneuver at different angles and speeds. Thrust difference is more appropriate than tank drive mode for some of task such as "Follow the path", "Wildlife Encounter and Avoid" and helps us to accomplish these tasks. For "Follow the Path" task, we have to get path from our UAV and follow the path. With thrust difference mode, we can establish maneuver while on the move. For "Wildlife Encounter and Avoid" task, UAV has to detect wildlife and with the help of Image processing, the kind of animal. Then, unmanned platform has to perform different maneuvers such as clockwise turn, counter-clockwise turn and avoiding. Thrust difference mode is appropriate for accomplish this task beacuse of high speed maneuvers. The other mode is tank drive mode. This mode is being used when unmanned platform is at lower speeds or rest position. This mode uses one thruster's reverse mode and other one's forward thrust mode to turn in place. This mode allows us to percept some of task environments such as "Scan the Code", "Entrance and Exit Gates", "Dock and Deliver" more carefully and helps us to accomplish these tasks. For "Scan the Code" task, the unmanned platform has to stop then observe the RGB buoy. But, if unmanned platform has to get better view; it has to turn in place and get a better view then with the help of Deep Learning and Image Processing nodes, it can send the order of the colors in the RGB buoy to Technical Directors. For "Entrance and Exit Gates" task, unmanned platform has to stop in front of the course and with the help of it's hydrophones and mathematical equations, it detects the position of active pinger. After detection, it moves to the gate with low speed for clean pass. To approach gates carefully, tank drive mode is more appropriate. For "Dock and Deliver" task, unmanned platform has to detect correct color on the dock, with the help of this mode, unmanned platform can get better views for Deep learning and Image Processing nodes.

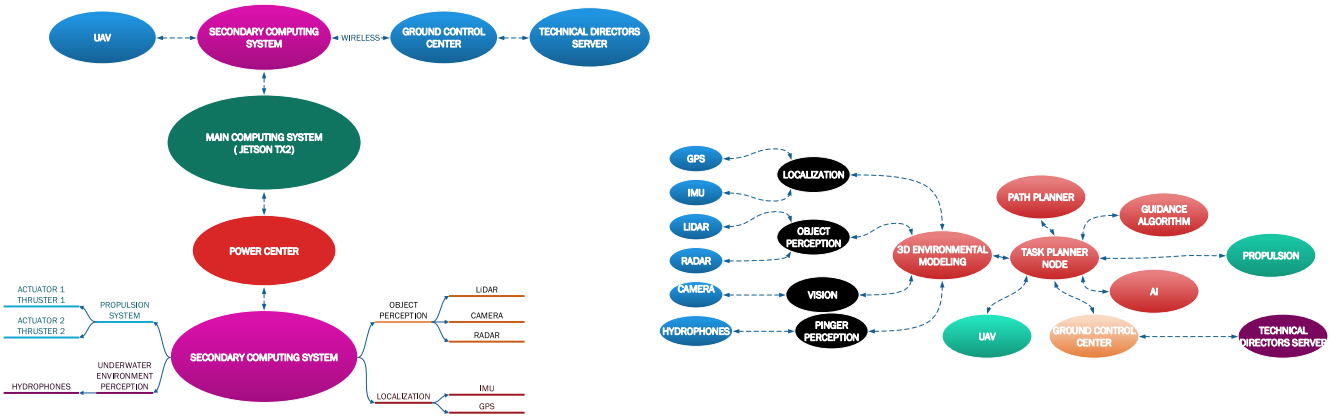

Fig. 1. Our software and hardware diagram.

Also, for approaching the correct dock carefully, unmanned platform has to move slowly and use this mode for accomplishing delivery.

5) Ground Control Center(GCC): Ground Control Center is being used to monitor all the data for situational awareness and prevent and predict any failure. The Ground Control Center, supported by a user-friendly interface, will be used both to develop and learn autonomous capabilities in different compositions during the preparation process, and to gain moment-to-moment information from the autonomous platform and UAV during the competition process and to define the tasks to the platform and UAV. The Ground Control Center includes one operational computer and communication system to connect with autonomous platform and UAV wireless. The Ground Control Center is connected to Technical Director Server with wired RJ45 ethernet connection to deliver heartbeat of autonomous platform. The heartbeat can be monitored at ground control center by our team also. In preparation for competition process, practice, qualifying, competition sessions; GCC allows us to define tasks to autonomous platform. This GCC is helpful for accomplishing and monitoring all tasks. The further details of Ground Control Center monitoring system will be mentioned in Strategies for Situational Awareness part in this paper.

6) Computing System: Computing System includes multiple computers divided into two parts: Main computing system and secondary computing systems. The role of the computing system in autonomous platform is to communicate with GCC and UAV both ways(data sending, recieving tasks and paths). The other role is getting data from sensors(by secondary computing systems) and processing data for mission nodes to accomplish various tasks. Then, computing system controls propulsion system.

7) Power Center: Power Center manages the power throughout the hardware system. It also communicates with GCC to send data and recieve orders when dangerous situation happens to cut off power.

B. Testing Approach

First experiments will be on the computer environment simulation. Main operating system is ROS and the simulation environment is Gazebo. We are import the data of lake on our campus to Gazebo. Autonomy simulations are realized at this lake in Gazebo. There is a ship modelling experiment laboratory on our campus that we will use this laboratory simultaneously with computer simulations. At this laboratory, hydrodynamic tests will be realized. There is an also electric motors laboratory to test our motors. After these simulations and laboratory testings, we will use the lake on our campus. This lake has approximately 10000 metersquare area. We are able to test for autonomy on this lake before the competiton.

C. Strategies to Overcome Failure

First and most important safeyt system is e-stop buttons. If there are fatal error on the boat, all system will be shut down with this button.

Another safety measure is circuit braker on every subsystem of power system. The other important precaution which prevent unwanted results is when the one of the engine fails the boat will stop and run rescue mode. Another measure for system redundancy sensor failure situation. If one or more sensor will be failed rest of them tries to configure themselves as fully functional sensor set.

D. Strategies for Situational Awareness

Obviously, working on autonomous systems lead to innumerable risks. Thanks to the ınterface planned by ITUASTEAM, the risks will be prevented and situational awareness will be provided. In addition, the components that are Propulsion system, LiDAR, Thruster, Camera, IMU, RADAR, GPS, Engine will be managed through the interface. In this way, all conditions about components will be observed by ITUASTEAM while the system is progress .The interface comprises 6 segment as *Mission Tracker*, *3D Visualized Map*, *Sensor Data Monitoring*, *Propulsion System*, *Path Planner*, *Vision*.

1) Mission Tracker: In this section, every task that the vehicle will do is defined on the interface. What the vehicle will do during the competition and test stages is managed in this section.

2) 3D Visualized Map: This map includes various sensors'(LIDAR, RADAR, GPS, IMU, Camera) processed and combined data. Combining LIDAR points with processed data with the help of Deep Learning and Image Processing from Camera gives an object space. RADAR helps us to localize these objects more accurately. With the support from GPS and IMU sensors, we also can localize our vehicle very accurately. At the end, with all these data; we can create a 3D visualized map including unmanned platform, UAV, task elements and environment. This map gives us better development process and awareness.

3) Sensor Data Monitoring: In this section, the values of the data coming from the sensors to the vehicle at certain times are analyzed. This makes it easy to analyze errors.

4) Propulsion System: In the propulsion system section, the instantaneous status of the important parameters of the motor(temperature, RPM) we use is examined. In addition, the conditions of the motor controllers such as current and voltage are also examined.

5) Path Plan: This is the section we have created to examine the 2-dimensional route created by the data obtained by the modules we use for route estimation. This is the section we have created to monitor the 2D path planned by autonomous platform. We can monitor planned path and actual path drawing by autonomous platform. We can add waypoints. We have "return to base" mode to return the vehicle to base when necessary, for example, a failure happened.

6) Vision: The data from the 2 (port and starboard) cameras to be used in our autonomous vehicle and the cameras on the drone will be used simultaneously. This monitor has been created to use these data.

II. Team Qualification

Our team consisting of 40 members and team adviser, consists of undergraduate and graduate students from multiple disciplines. We also have experienced members working in the industry in our team. To talk about the qualifications of our team members at the sub-team level, we have four subteams to utilize experiences and capabilities at the highest level. These are Organization, Boat, Electric and Electronics, Software and AI subteams. For Boat subteam, we are capable at hull design, propulsion systems design, localization of payloads. Some of our members have 2-3 years project team and international competition experience. For Electric and Electronics subteam, we are capable at embedded systems, power electronics, communication and electric machines. For Software and AI subteam, our specialities are control interfaces, path planning, sensor fusion, guidance algorithm, PID control, embedded software, image processing, deep and machine learning and ROS.

III. Facilities

A. Simulation Testing(ROS)

We can test almost everything in simulation environment. It is easy and fast to test when small changes made on algorithms or autonomous platform. As algorithms, we can test "Path Planning", "Guidance Algorithm", "PID Control tests and improvements", "Deep Learning algorithms

developed against water stream", "Sensor Fusion".

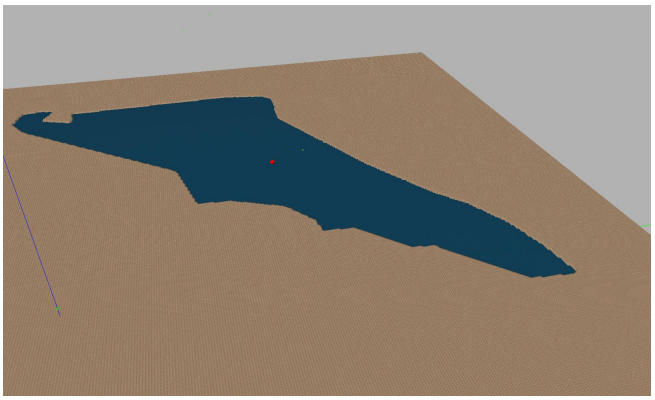

Fig. 2. Our lake on campus modelled in Gazebo environment.

B. Lake Testing

We are able to test all kinds of scenarios that can be encountered in the competition environment thanks to the lake with an area of 10000 square meters in our campus. To improve image processing algorithms at low and high light conditions, different angle conditions and to improve capabilities for real scenarios at water stream conditions and sensor and motor failure conditions, lake testing is a compulsory phase for our vehicle. We are able to set up a similar course to the competition site in our lake.

C. Ship Model and Experiment Laboratory

Thanks to the laboratory in our faculty we can test our vehicle for these test types:

1) Propeller design and analysis
2) Resistance tests and analysis
3) Power performance analysis
4) Propulsion tests
5) 3D trace measurement and analysis

D. Team Workshop

We can test our almost all electronic elements including sensors and computing systems in our workshop.

E. Electrical Machinery Laboratory

Electric Machinery Laboratory, motors are tested by loding it with a dynamo-brake. Torque, speed, shaft power and all electircal quantites can be measured and can be recorded. Heating test can be performed according to EN-60030 standard. Rotating electrical machine test capacity is 60 kW, 3000 rpm.

Power electronic driver circuits can also be tested under different load conditions and their operational characteristics can also be determined. The laboratory has capabilities to provide electrical quantities at a rated power of 250 kVA. Quantities between 0-440 V (AC), 0-100 Hz, 0-250 V (DC) can be provided.

IV. Sponsorship and Partnership

TABLE I
Potential Sponsors

NAME	EMAIL	PHONE NUMBER
HAVELSAN A.Ş.	kince@havelsan.com.tr	+90 (532) 789 42 87
UZMAR SHIPYARD	nalan.erol@uzmar.net	+90 (262) 341 45 10 +90 (537) 966 84 90
MATESİS MARINE ENGINEERING LTD.	info@matesis.com.tr	+90 (216) 290 43 13

TABLE II
Potential Partners

NAME	EMAIL	PHONE NUMBER
Istanbul Technical University	gemi.dekanlik@itu.edu.tr	+90 (212) 285 64 64

V. Managment Approach

The team management is divided into 5 parts: Board of Directors, Organization subteam, Boat subteam, Electric and Electronics subteam and Software and AI subteam. Board of Directors consist of every subteams directors and the roles of board are arranging general team meetings and organizing multi-subteam tasks for successfully finish in time. Board also manages budget. General meetings are held with our adviser and team at least once a week, the situation of the team is reviewed and plans are made accordingly. The Organization subteam takes care of the promotion of the team, official correspondence, sponsorship affairs and the advertisement of the team. The Boat subteam takes care of propulsion system,

designing side mechanical parts, components' distribution and deriving the physical equations of the unmanned platform. The Boat subteam calculates power requirement of the boat with Electric and Electronics subteam. The Electric and Electronics subteam takes care of embedded systems, power electronics, communication systems, propulsion drive systems and UAV's electronic development. The Software and AI subteam deals with path planning, sensor fusion, image processing, deep learning, machine learning, guidance algorithm and UAV's software design. The recruitment process consists of two stages. The first stage application form is announced publicly. In the second stage, those who are equipped and willing are selected from those who fill out the form and are taken to the pre-assignment process. In the pre-assignment process, tasks are assigned to applicants of sub-teams and the person's desire, interest and knowledge level are measured. Then, satisfying ones are taken from those who completed the assignment.

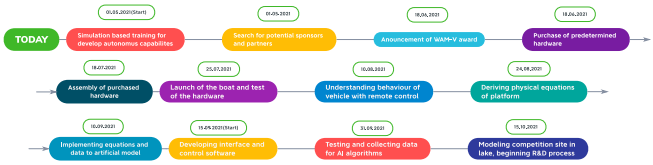

Fig. 3. Timeline of our R&D progress.

VI. Rough Order of Magnitude Cost

TABLE III
Total Magnitude of Costs

	Total Cost	Est. Fund
Electronics Components	$18.544,00	$12.000,00
Logistics of Vehicle and Equipments	$13.264,26	$7.000,00
Team's Travel and Accommodation	$10.966,71	$7.000,00
Total	$42.774,97	$26.000,00

TABLE IV
Electronic Components

Hardware	Total Cost	Quantity	Customs Duty
RADAR	$2.200,00	1	$396,00
LiDAR	$3.250,00	1	$593,00
Hydrophone	$300,00	3	$115,00
Camera	$1.020,00	2	
IMU	$3.600,00	1	$656,00
JETSON TX2	$611,00	1	
Antenna & Remote	$213,00	1	
Ground Station	$1.120,00	1	
RaspberryPi 4	$189,00	2	
STM32F4	$60,00	2	
Arduino Mega	$40,00	3	
UAV	$395,00	1	$173,00
Safety & Warning Circuits	$120,00		
Propulsion System	$1.460,00	2	$271,00
Linear Actuator	$240,00	2	
Motor Driver	$100,00	2	$26,00
Battery	$602,00	1	$117,00
BMS	$482,00	1	$95,00
Cables	$100,00		
Total	$16.102,00		$2.442,00
Total with Customs	$18.544,00		

TABLE V
Logistics of Vehicle and Equipments

	Start	Finish	
Shipment from ITU to Istanbul Port	26.09.2022	26.09.2022	$74,77
Loading cargo into the port with forklift	26.09.2022	26.09.2022	$24,45
Customs process (ATA and MSDS Report)	26.09.2022	29.09.2022	$159,19
Shipment of vehicle and equipment via Ship	30.09.2022	01.11.2022	$6.030,00
Customs process of vehicle (Reports check)	01.11.2022	04.11.2022	$140,00
Loading cargo into the truck with forklift	04.11.2022	04.11.2022	$65,28
Shipment from Sydney Port to Regatta Centre	04.11.2022	04.11.2022	$112,44
Loading cargo into the centre with forklift	04.11.2022	04.11.2022	$65,28
Competition and Testing Time	04.11.2022	18.11.2022	
Loading cargo into the truck with forklift	19.11.2022	19.11.2022	$65,28
Shipment from Regatta Centre to Sydney Port	19.11.2022	19.11.2022	$112,44
Loading cargo into the port with forklift	19.11.2022	19.11.2022	$65,28
Customs process (Vehicle, MSDS Report)	19.11.2022	22.11.2022	$133,68
Shipment of vehicle and equipment via Ship	23.11.2022	25.12.2022	$6.030,00
Customs process of vehicle (Reports check)	25.12.2022	27.12.2022	$86,95
Loading cargo into the truck with forklift	27.12.2022	27.12.2022	$24,45
Shipment from Istanbul Port to ITU	27.12.2022	27.12.2022	$74,77
Total			$13.264,26

TABLE VI
Team's Travel and Accommodation

	Start	Finish	
Ticket purchase for whole team(8 people)	25.06.2021	25.06.2021	$3.860,00
Accommodation reservation for whole team(8 people)	25.06.2021	25.06.2021	$1.865,00
Journey to Istanbul Airport(Leading Team)	01.11.2022	01.11.2022	$18,09
Travel to Sydney Airport via Plane(Leading Team)	01.11.2022	03.11.2022	
Leading team's travel to competition area	03.11.2022	03.11.2022	$144,71
Leading team picks up the vehicle	04.11.2022	04.11.2022	$144,71
Journey to Istanbul Airport(Team)	07.11.2022	07.11.2022	$18,09
Travel to Sydney Airport via Plane(Team)	07.11.2022	08.11.2022	
Team's travel to competition area	08.11.2022	08.11.2022	$144,71
Team's total costs for food	03.11.2022	19.11.2022	$3.980,00
Travel for electronic purchase	03.11.2022	19.11.2022	$423,65
Journey to Sydney Airport	19.11.2022	19.11.2022	$289,42
Team's travel to ITU	20.11.2022	20.11.2022	$36,18
Team picks up the vehicle from Istanbul Port	27.12.2022	27.12.2022	$42,15
Total			$10.966,71

VII. Summary

Our team, whose foundation purpose is autonomous marine vehicles, will have the opportunity to exhibit its knowledge and experience gained from its work in this field in an international competition. Preparing for this competition with the support of our sponsors and ındustry experts will be a valuable experience for our team. The success that we will get from RobotX will hold an important place in our team for the work to be done in this field.

HAVELSAN

Number: E-52628938-0-17119 03.05.2021
Subject : HAVELSAN Support To ITU ITUASTEAM
Autonomous Sailboat Team

ROBOTX ORGANIZATION

To whom it may concern,

HAVELSAN offers new generation technologies from end to end with 38 years of experience in the fields of defense, simulation, ICT, homeland security and cyber security. As HAVELSAN, we hereby declare that we will support ITU ITUASTEAM Autonomous Sailboat Team for RobotX Challenge 2022 Event, and provide further assistance as needed. As an industrial partner who support activities of university students, we will share our experiences with the team who participate to this RobotX challenge under the guidance of Istanbul Technical University.

Yours sincerely.

Deniz Remzi DUMLU
CCDT R&D AND PLATFORM
INTEGR. DIR.

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01/05/2021

To whom it may concern,

MATESİS DENİZCİLİK DANIŞMANLIK GÖZETİM VE MÜHENDİSLİK HİZMETLERİ SANAYİ VE TİCARET LİMİTED ŞİRKETİ is an experienced company having design and manufacturing capabilities. As MATESİS DENİZCİLİK DANIŞMANLIK GÖZETİM VE MÜHENDİSLİK HİZMETLERİ SANAYİ VE TİCARET LİMİTED ŞİRKETİ, we hereby declare that our company will give support to ITU Autonomous Sailing Boat Team on the preparation period for the competition Robotx, 2022.

We will share our experiences with the team to be a one of the industrial partners supporting academic and engineering activities of university students performed under the guidance of Istanbul Technical University.

Yours sincerely,

MATESİS DENİZCİLİK DANIŞMANLIK
GÖZ. VE MÜHENDİSLİK HİZ.SAN.TİC.LTD.ŞTİ.
Sanayi Mah.Teknopark Blv.Teknopark A
No: 1/1 A/210 Pendik /İSTANBUL
Pendik V.D. 613 0[illegible]3 1356

UZMAR®

03.05.2021

To whom it may concern,

UZMAR SHIPYARD is an experienced company having design and manufacturing capabilities. As UZMAR, we hereby declare that our company will give support to ITU ITUASTEAM Autonomous Sailboat Team on the preparation period for the competition Robotx, 2022.

We will share our experiences with the team to be a one of the industrial partners supporting academic and engineering activities of university students performed under the guidance of Istanbul Technical University.

Yours sincerely

Gökhan KAMER
Design Manager

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