RoboBoat 2023: Technical Design Report

Ortahisar Creatiny Roboteam

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Abstract- This report was written by the Ortahisar Creatiny Roboteam team for RoboBoat 2023 contest. It includes ship design choices and software strategies. This design was chosen because for being suitable for missions of the contest. The electornic system of the ASV designed accordingly and includes jetson xavier, zed camera, hydrophone for data collection, image acquisition, and image processing.

I. COMPETITION STRATEGY

A. Software Overview

The MAVSDK library was usedfor autonomous capabilities. MAVSDK is a library suitable for controlling one or more vehicles. The functions in MAVSDK library will be used to enable Pixhawk-jetson communication and perform the desired movements. These movements are generally achieved by distance measurement and image processing through the Zed camera.

[FIGURE 1-PROCESSİNG İN REAL AREA]

Image processing based Open CV is used as autonomous software. In some of the tasks, real time gathered image colors will be processed and vehicle will be directed accordingly. In other tasks, only objects at a certain distance will be detected thanks to the zed camera so that image processing is not affected by the environment. The zed camera that detects objects at a certain distance will perform the desired tasks by detecting the colors of those objects.

TASK 1. Navigate the Panama Canal

A certain distances will be determined with the Zed camera and objects at that distance will be detected. The colors of the detected objects (buoys) will be determined by image processing and the distance between the two pontoons will be centered and the passage between the pontoons will be ensured.

TASK 2. Magellan's Route / Count the Manatees & Jellyfish

As in the first task, the colors of the pontoons, detected at a certain distance with the Zed camera, will be selected and the pontoons will be centered and the ASV will pass between them. While doing so, the yellow and black pontoons on the way will be detected and counted by the Zed camera and the counted pontoons will be dodged.

TASK 3. Beaching & Inspecting Turtle Nests

We will approach to the assigned shore upon request from us with image processing and stand at a certain distance determined by the Zed camera. Again, the eggs will be counted with image processing.

TASK 4. Northern Passage Challenge

The colors of the buoys seen from a certain distance will be detected with image processing and the ASV will pass through the middle of the buoys. When the ASV approaches the blue pontoon, it will be directed back to the gate buoys by turning 180 degrees at a certain angle around the buoy.

TASK 5. Ocean Cleanup

The pinger area in the desired range will be determined by underwater monitoring. Paddle balls will be collected by approaching the identified area.

TASK 6. Feed the Fish

Color will be detected with image processing and the correct side of the frame will be determined by proportion of the frame. After the ASV reaches the desired distance, the balls will be thrown into the holes through the frame with the help of the ball launching system.

TASK 7. Ponce de Leon / Fountain of Youth

The ASV will find the target face of the task with image processing (if it is not enough, artificial intelligence will be used). After finding it, water will be thrown at the target side from the specified distance with the help of the water cannon. This process will continue until the ball goes above the green line. Image processing will again be used to detect object.

TASK 8. Explore the Coral Reef

The first starting point will be stored in the memory and it will be used to go back to the starting point. The Zed camera will be used to detect the surrounding objects and provide an escape mechanism. The ASV will instantly escape from the object and then correct its route and return to the initial starting point.

B. Strategy For The Test Approach

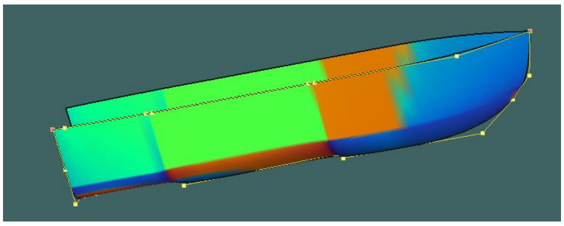
In order to ensure that nothing goes wrong with the communication with MAVSDK, a script was prepared for immediate testing. In case of differences in ambient colors due to light, the color ranges are redefined every day with a separate software. Zed camera will also be tested from time to time for accurate distance measurement. If there is a defect, the calibration will be performed again.

II. TECHNİCAL

A. SHIP DESIGN ref.[1]

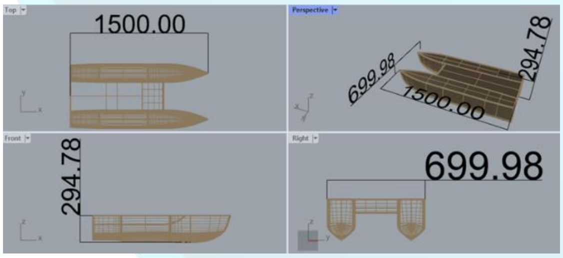
Our design has been finalized with certain features that would become handy to fulfill the missions. Due to these missions, the hull form was chosen as a catamaran to improve load carrying capacity and stability. The optimum form was created with the help of Rhino drawing program and Maxsurf analysis program by performing weight balance analysis to carry the necessary equipment of the ship.

The material we plan to use for the production of the hull is fiber glass reinforced composite material, which is preferred due to its superior properties when the hull size and design criteria are taken into consideration.



[FIGURE 2-MAXSURF ANALYSİS]

Fiber glass reinforced composite material has a long life span, is not affected by heat or cold, has high impact resistance and crack propagation resistance. With its high resistance to corrosion and being maintenance-free, as well as its light weight, it provides a great advantage to our vehicle against similar boats. Maneuverability has been increased by keeping the vehicle length as short as 150 cm in the design. At the same time, while making this choice, care was taken not to reduce the stability of the vehicle. The design was completed by aiming to expose the vessel to the least frictional resistance in the water.



[FIGURE 3-SHIP'S SIZES]

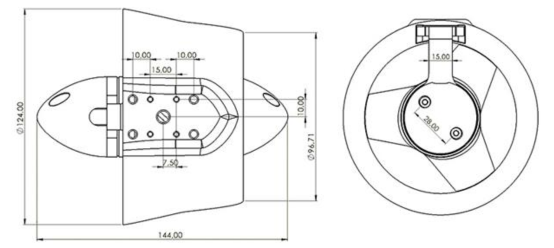
B. Propulsion Systems ref.[2]

The propulsion system to be used on our ship is two nozzle propellers. In this type of propulsion system, propulsion efficiency is further increased by placing a cort drum around the fixed blade propellers. Low efficiency values are observed with high thrust loadings and high efficiency values are observed when low thrust is applied. It is therefore possible to increase propeller efficiency by reducing thrust loadings. Another method of changing the thrust loading is to convert the propeller into a propeller operating in a nozzle by placing a ring around the propeller. This unit is also called a cort-nozzle. Propellers with cort nozzles are either stationary or rotate around a vertical axis up to a certain angle. At high loading coefficients, the efficiency of the propeller with nozzle is higher than the one without nozzle. This excess is returned as 8-15% power gain or increase in ship speed.

[FIGURE 4-UTRAS]

The requirement for a high thrust and high efficiency thruster was met with the "Utras Thruster" produced by Degz Robotik. These thrusters, produced by injection molding method, are highly resistant to impacts and provide long-lasting performance underwater. Technical specifications of Utras thruster powered by M5 brushless motor provided in Table 5.

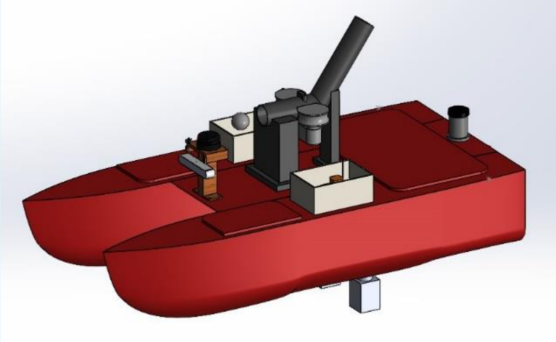
Propulsion Force(24V) : ~ 8,5 Kgf	Voltage Range: 3s-6s (12v – 24v)	Recommended Esc: 50A
Maximum Depth: 500m	Propeller Material : Polycarbon	Body Material: Polyurethane



[FIGURE 5-UTRAS TECHNICAL DETAILS]

C. Ship Layout ref.[3]

Considering the center of gravity of the ship, we placed a 355x600mm hatch cover on the stern of the ship for easy access to the ship. In the same way, we placed a 165X285mm hatch cover, one each on the right and left hull, to reach the nose of the ship. In order to protect the electronic devices against any contact with water, we chose our boxes with IP67 features and placed one each on the right and left center hull. By staying in constant communication with our electronics teammates, we designed a special mast for the zed camera, lidar and fosteer mini camera that we will use in line with their requests and placed it in the front center hull of the ship. We placed the Here 3 GPS at a certain height at the stern of the ship, again at the request of our electronics team, taking into account that it is away from interference. We placed the cannon launching mechanism, which we produced as a result of the mission requirements, in the middle hull of the ship in order to maintain the balance during the mission and to center the platform from which the cannon will be launched. Likewise, we placed the water pump, which we produced as a result of the mission requirements, in the middle aft part of the ship, which we considered to be the safest place, considering that the ship could hit anywhere during the mission.



[FIGURE 6-SHIP DESING]

While positioning the sonar system that we will use in the ocean cleaning mission, we made a 25 cm long extension to the right and left of the ship with our electronics teammates so that it would remain under the ship. Afterwards, we integrated servos, one each to the right and left of the ship's center front hull, to collect the balls in the area we reached. At the end of the servos, we made an extension and stretched a net between the two extensions to collect the balls.

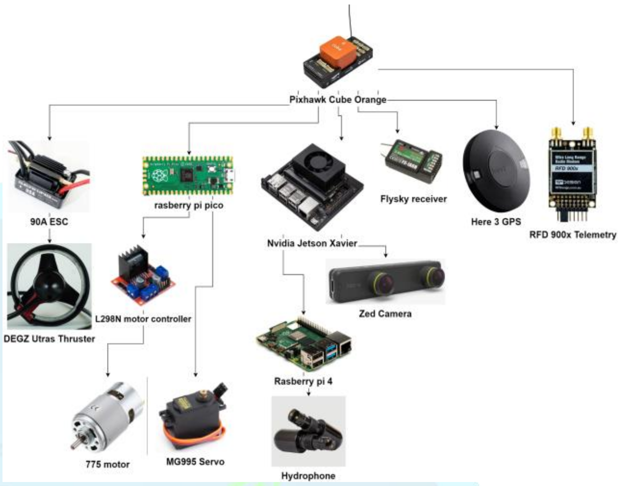
C.1. Ball Launching System

Two RS 775 motors are positioned opposite each other in the ball launching system. The motor dimensions are given in the image below.

[FIGURE 7-MOTOR]

There are cylindrical objects with a diameter of 5.5 cm at the ends of the motors. These objects are mounted on the ends of the motors and rotate in the opposite direction to each other with the motor. The ball is thrown by gaining forward momentum with the effect of compression between these two objects. By adjusting the rotation speed of these motors, the position where the ball will hit will be determined and the task will be completed by throwing the balls accordingly. This system was designed with the Fusion 360 program. The designed system is shown in the visual. 1 RS 775 motor was used in the water pump system. Different propeller designs were tested and the most pressurized propeller design was integrated into the system. The system consists of 4 parts in total: Water extraction part, impeller, body, motor cover. These parts were printed separately from a 3D printer and fixed to each other with m3x8 screws. Two MG995 servo motors were used in the ball collection system. The gear parts in these motors were preferred because they are metal. These motors can move between 0 and 180 degrees. A 30 cm long plastic apparatus was fixed to the ends of these motors. A net is fixed to these two apparatus. While performing this task, the Servo motor will be set to 90 degrees and the balls will be collected. When the task is completed, the vehicle will move towards the next task by moving to 0 degrees again.

D. Electronics



[FIGURE 8- ELECTRONIC SCHEMA]

D.1. Pixhawk Cube Orange
Pixhawk Cube Orange was used to ensure that our vehicle can successfully perform autonomous missions.

D.2. RFD 900x Telemetry
It was used to provide communication between the ASV and the ground control station.

D.3. Here 3 GPS
It was used to receive the GPS data required to return to the starting point.

D.4. Flysky IA6B Receiver
It was used to provide communication between the vehicle and the controller.

D.5. Nvidia Jetson Xavier
It was used because of its high performance at Image classification, image processing and object detection

D.6. Raspberry Pico
It was used to control the ball collection, water pump system, ball launching systems.

D.7. SeaKing 90A ESC
It was used to drive the motors used in the propulsion systems of the vehicle.

D.8. Zed camera
It was used to measure distance and get a live view.

D.9. Raspberry pi 4

It was used to classify the data collected by the receiver to find the underwater pinger.

D.10. Hydrophone

It was used to find the underwater pinger.

D.11. Degz Utras Thruster

It was used to provide the movement and maneuvering capabilities of the ASV in the water during navigation

D.12. L298N motor driver

It was used to control the speed of the motors used in the water pump system and ball launching systems

D.13. RS775 motor

These motors were used in the water pump system and ball launching systems.

D.14. Emergency Stop Button

It was used to turn off the vehicle's electronic system in possible emergencies.

D.15. Mg995 Servo

It was used for the ball collection task.

III.Special Thanks

We would like to express our sincere thanks to our main sponsor Ortahisar Municipality for providing us with material and moral support while participating in this competition, to Ares Shipyard for helping us in the construction of our ship, to DEGZ for supporting with the propulsion systems we used in our ship, to Armelsan for supplying electronic parts and to Meteksan for supporting us in the software part.

REFERENCES

Profesör Doktor Tamer Yılmaz [1] Gemi Mühendisliği El Kitabı

[2] Denizde Çatışmayı Önleme Tüzüğü (COLREGs)

[3] Türk Loydu

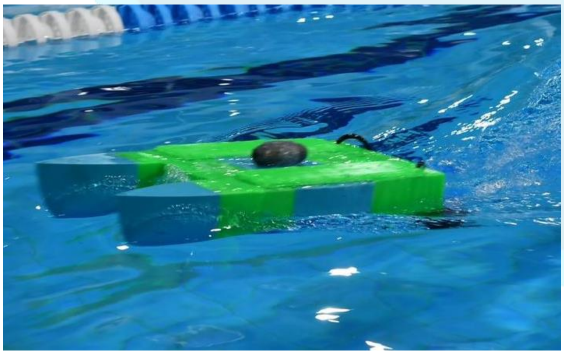
Appendix A: Component List

	Vendor	**Model/Type**	**Specs**	**Custom/Purchased**	**Cost (USD)**	**Year of Purchase**
ASV Hull Form/ Platform	Student	---	Made by ourselves	Custom	4.247,38	2023
Waterproof Connectors	Mete Enerji	IP67	Thermoplastic box	Purchased	9,76	2023
Propulsion	DEGZ	Ultras	~ 8,5 Kgf	Purchased	220,84	2023
Power System	Sony	Vtc6	3.7V 3000 Mah Li-İon	Purchased	220,84	2023
Motor Controls	Hobbywing	SEAKING 90A V3	540A 6V/5A	Purchased	50,71	2023
CPU	Jetson	Xaiver NX	10 Watt	Purchased	896,21	2023
Teleoperation	RFD900X	RFD900C Plus	Over 40 KM range	Purchased	603,35	2023
Compass	Pixhawk	The Cube	Power input voltage / rated input current: 4.1-5.7 V / 2.5 A Rated power output / input power: 14 W	Purchased	716,62	2023
Inertial Measurement Unit	Pixhawk	The Cube	Power input voltage / rated input current: 4.1-5.7 V / 2.5 A Rated power output / input power: 14 W	Purchased	716,62	2023
Doppler Velocity Logger	---	---	---	---	0	0
Camera(s)	Zed	Mini	Built on the same sensor technology	Purchased	668,68	2023
Hydrophones	Sonar	-	-	donated	0	2023
Algorithims	Student	---	Made by ourselves	Costum	0	2023
Vision	Zed	Mini	Built on the same sensor technology	Purchased	668,68	2023
Localization and Mapping	Pixhawk	Here 3	U-blox M8 high precision GNSS modules (M8P)	Purchased	716,69	2023
Autonomy	Pixhawk	The Cube	Power input voltage / rated input current: 4.1-5.7 V / 2.5 A Rated power output / input power: 14 W	Purchased	716,62	2023
Open Source Software	Opencv	Opencv	huge open source library	Purchased	0	2023

Appendix B: Test Plan & Results

B.1. Mechanical Test

A scaled-down prototype of the ship's hull was printed on a 3D printer and the necessary propulsion system was integrated. It was then subjected to pool tests. During the tests, it was aimed to identify and prevent any problems that may occur during the competition and to successfully perform the autonomous missions of the ship. In the propulsion system used in the integration of the prototype ship, a scaled-down version of the propellers (mitras) of our actual ship was used. The necessary equipment was integrated in a way to be compatible with each other and with the manufactured portable ship. During the testing process, firstly, the maneuverability of the prototype of the boat, its navigation in the water and the positioning of the engines were observed. As a result of these observations, final changes were made on the hull and the positions of the engines were determined. The center of gravity was changed to different positions and the effect was observed. While performing these tests, the vehicle was controlled by remote control.



The necessary stabilization tests were carried out for the camera that will be placed on the ship by subjecting our integrated ship to tests in the pool belonging to our municipality. In the same way, the tests continued, taking into account the flow analysis to ensure the hull form. Tests were carried out until the desired values were achieved and the ship was constantly revised according to the test results.

B.2. Electronic Test

B.2.1 Motor- ESC Direction Test

ESCs are programmed bidirectional. Connection was made between ESCs and motors. Then, in order to check whether the ESCs are working properly, the PWM signals given to the ESCs were changed and the motor rotation directions were observed while the system was under power and no problem was encountered.

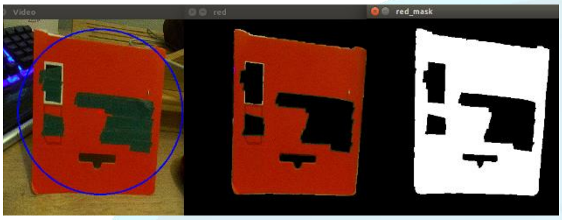
B.2.2 ASV Direction Test

Thrusters were placed in their positions. When the right-left command was given with the controller, it was observed that the ship moved in the opposite direction. The problem was solved when the engine positions were changed.

B.3.Software Tests

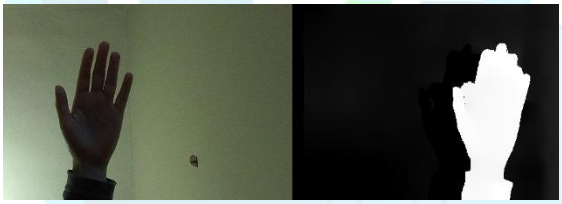
B.3.1 Color Detection Test With Image Processing

Algorithm tests were performed for color detection, which is specifically needed in some tasks.Algorithms with maximum efficiency were developed.



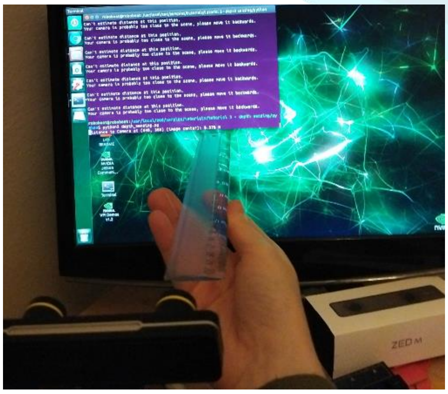
B.3.2 Depth measurement test with Zed camera

It was examined whether the depth algorithm works in the Zed camera.



B.3.3 Distance measurement test with Zed camera

It was checked whether the correct measurement was taken from a certain distance with the Zed camera. There was no deviation in distance measurement.



Appendix C: Main Dimensions of the Ship

Length (LOA) = 1500 mm	Depth= 295 mm
Width= 700 mm	Draft= 16 mm
Displacement 0,0256 t	Volume (displaced) 0,025 m^3
Draft Amidships0,146 m	Immersed depth 0,145 m
WL Length 1,448 m	Beam max extents on WL 0,200 m
Wetted Area 0,486 m^2	Max sect. Area 0,021 m^2
Waterpl. Area 0,253 m^2	LCF length 0,656 from zero pt. (+ve fwd)m
Prismatic coeff. (Cp) 0,816	LCB % 44,649 from zero pt. (+ve fwd) % Lwl
Block coeff. (Cb) 0,596	LCF % 45,259 from zero pt. (+ve fwd) % Lwl
Max Sect. area coeff. (Cm) 0,757	KB 0,093 m
Waterpl. area coeff. (Cwp) 0,873	BMt 0,030 m
LCB length 0,647 from zero pt. (+ve fwd) m	BML 1,454 m
GMt corrected 0,123 m	KML 1,547 m
GML 1,547 m	KMt 0,123 m