# RoboBoat 2022: Technical Design Report

## Edirne Gençlik Merkezi RoboBoat Team

Mustafa Semi Bozkaya, Bayram Kazık, Sevgi Sena Tursun, Efe Doruk Kokoz

Hazal Karakuş, Yağız Dilbas, Yakup Baturay Pekdemir

*Edirne Gençlik Merkezi Deneyap Atölyesi*

**Abstract—This report is written for discussing the development of the Calypso ASV (Autonomous Surface Vehicle) for RoboBoat 2022 by Rapture Robotics Team. The discussed vehicle carries several onboard sensors for autonomous decision-making according to given tasks. These onboard parts include a Raspberry Pi 3 Model B+, 2 Jetson Camera Modules, an RTK-GPS navigation sensor, a ZED2 AI Stereo Depth Camera and a Jetson NANO. The vehicle is equipped with 4 Ultras thrusters in "X" motor configuration for providing holonomic motion capability.**

*Keywords—ASV, image processing, autonomous, measure*

### I. INTRODUCTION

If we compare the 2022 RoboBoat Competition with past years, we can see that this year includes new and different tasks. In the past years, the Unmanned Aerial Vehicle took an important place. This year the competition does not include UAV missions. Instead, this year requires teams to build an Autonomous Surface Vehicle with high image processing and high location detection ability. Therefore, our ASV is equipped with a ZED2 Stereo Camera for depth perception and high location detection. The vessel is equipped with 4 Ultras thrusters from DEGZ that are mounted in an "X" configuration. This configuration provides holonomic motion. Our vessel is equipped with Lithium-Ion (Li-Ion) batteries for providing energy. In an emergency situation, we can cut the energy flow to the ASV by stopping the battery.



### II. COMPETITION STRATEGY

This section of Competition Strategy will discuss Rapture's approach to complete each mission.
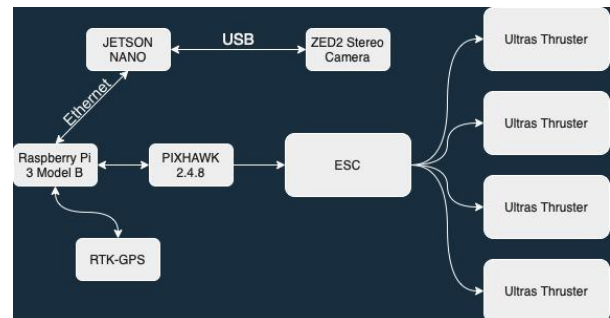


#### A. Navigation Channel

This section has to be completed first to finish other tasks. For this mission, the vehicle needs to reach a GPS location first. Then it needs to progress autonomously and pass through two sets of gates 6-10 ft wide, consisting of two red and green buoys. To perform this task, *we will use the OpenCV library to run our ZED2 dual camera and detect objects in real-time. The ASV will pass them by approaching the channel with the navigation system until the buoys are*

*detected. Once the buoy is sent to the navigation stack and the exit gate is found, it will complete the navigation channel task.*

## B. Avoid the Crowds

In this mission, the ASV needs to perceive and maneuver through the complex path filled with multiple sets of buoys on the sides without being in contact with them. The hardest part of this task is that there are intermittent yellow buoys in the middle of the path between green and red buoys, which makes it hard to continue along the path and the vessel has a high risk of hitting one. Because of that, it is important to focus on stability rather than speed in this task. *So, we modified our catamaran design to be able to accomplish this task without hitting the buoys by using the "X configuration" which we described in detail in the Design Creativity section.*

## C. Find a Seat at the Show

In this part of the competition, our team must enter the bay that has the appropriate shape or color symbol assigned before the competition. The ASV must not make contact with any part of the docking bay. Also, there are two alternative build options for the material of the buoys. The tines can be made of PVC pipes or floating dock pieces. The second task that our ASV would attempt is the Find a Seat at the Show mission. *This mission requires high camera vision and image processing capability. Our ASV system is equipped with a ZED2 stereo depth camera. By utilizing this camera, we can measure objects' distances.*

## D. Snack Run

The Snack Run mission is the third mission among other competition tasks. It is established to prove the ASV's ability to recognize objects, make decisions, and perceive tasks. This task reveals the body form efficiency and maneuverability of the ASV. The ASV passes through the door buoys as quickly as possible, goes around the

beacon buoy, and exits through the same buoys. The distance between the door floats will be 3 to 6 ft. The beacon buoy shall be 40 to 100 ft. *We will be using the OpenCV library and our object detection model to recognize the buoys and move accordingly.*

## E. Skeeball Game

The Skeeball Game task is the fourth mission that our ASV would attempt. The vehicle can contact this mission's dock, and it has to find the side that has a purple frame. It will then be shooting racquetballs through the frame onto the skeeball table. *This task requires object detection, navigation capacity as well as a shooter mechanism. Our ASV is equipped with a shooter to fulfill this mission with an accurate shot. The vehicle will be making use of its navigation system for pathfinding and holonomic motion capability.*

## F. Water Blast

After the Skeeball mission, our boat will pass to the Water Blast task. This task demonstrates the aim and computer vision capabilities of the vehicle. In this part of the competition, our ASV must deliver enough water to raise the ball above the green line without making contact with the dock the task sits on. *The ASV will pump the water from the environment.*

## G. Return to Home

The Return to Home task demonstrates the ability of the ASV to go back to the launch point at this time. It has to turn with the help of sensors without touching any obstacles. The ASV returns after completing the missions in autonomous mode through the door created by two black buoys. On the way back, the ASV must avoid making contact with any obstacles or mission equipment. *The vehicle will autonomously plan the path for return using the map created by the navigation system throughout the tasks.*

## III. DESIGN CREATIVITY



### A. Motors

We decided that the performance of the engines we used in our previous competition experiences would not be effective at this size. That's why we bought Ultras thrusters with greater thrust. These thrusters were producing more thrust than we wanted. For this reason, we placed the engines at an angle of 45 degrees and used the power of our engine to increase our maneuverability. Thus, we were able to increase the maneuverability of the vehicle and bring its speed to stable levels.

### B. Motor Configuration

The most important part of our robot was its mobility. In order to increase its mobility, we used 4 high-torque motors in our robot. These motors are placed at an angle of 45 degrees, and this placement gave our robot holonomic motion, that is, the ability to move like a crab so that it can easily overcome the obstacles in front of it.
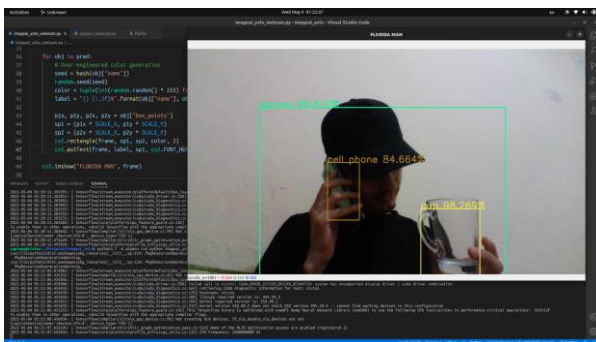


### C. Object Detection

We trained a YOLOv4 (You Only Look Once) CNN (Convolutional Neural Network) model for the real-time detection of objects throughout the competition tasks. The training of the neural network model is done with a custom dataset consisting of manually labeled images. We utilized the DarkNet framework specialized for object detection and the OpenCV library for image manipulation tasks.

### D. Data Acquisition

Two NVIDIA Jetson Cameras are being used in order to acquire image data from many angles for the object detection model dataset. This dataset is enriched with several other open-source datasets for higher accuracy with fewer manually taken photos by our team.

### E. Navigation

Our ASV will be using a modal approach for navigating through the competition tasks. It will use a state machine that determines the current mode according to the given environment sensor inputs. These inputs include but not limited to the current predicted object data from pictures taken, LiDAR distance range estimations for nearby bodies, and GPS location data. When a nearby body is detected as a known task object in ode to the corresponding task mode according to the identified task object. Through our round time slot, ASV will be marking all the approximate locations of the identified tasks in the memory and will use this data to create a map to assist the navigation state machine.

### F. Distance Calculation

In order to calculate the distances of the objects identified with onboard cameras, we can go with two different approaches: LiDAR or AI Stereo Camera.

### By using LiDAR

With this approach; when an object is predicted by our object detection model, we are going to calculate the angle of the object by performing a mathematical calculation according to camera FOV and object coordinate information. The LiDAR can be then rotated to the target angle for a read operation. It will then obtain the distance data using the Time Difference of Arrival technique.

### By using AI Stereo Camera

Another approach for calculating the distance of an object is to use a well-established 3D stereo camera solution. A stereo camera of this type can take multiple pictures using multiple cameras at the same time and can compute the distance by comparing the difference between the pictures and the gap between the cameras. An AI Stereo Camera such as ZED2 can reach a distance accuracy close to a typical LiDAR without mechanical movement overhead.

## IV. EXPERIMENTAL RESULTS

At first, we encountered problems based on aerodynamics and balance in our vehicle, which we started to test in the simulation. Therefore, we changed our design and made it more compatible with the conditions in the simulation. In the first tests made after the construction of the robot, we saw that the changes we made thanks to the simulation increased the speed and maneuverability of our vehicle.

### Movement, speed, and fluid permeability test:

We took our completed robot to a local pool. We applied the driving test to test the mobility and speed ability. We drove at maximum speed from the beginning of the pool to the end, and we allowed it to maneuver at this speed, then we found the most stable maneuvering speed. While testing water permeability, we tested whether the robot absorbs water by immersing various parts of it in water at different times. As a result of these tests, we decided to change the engine angles. In the impermeability test, we saw that the material we used achieved the desired

### Success against liquids and water jet test:

We took our robot to a local lake and performed balance tests in clear and windy weather, and then we shot water from our vehicle to test the water jet. In our first shots, the water jet was not able to throw water far enough, but it was throwing water with a lower pressure than we expected. For the 2nd trial, we took the robot out of the water and made changes to its software by the lake. For the second trial, we placed our robot in the water, then after maneuvering and a few speed tests, we started to try the water jet again. As a result of the changes, we made in the software, we achieved the desired efficiency.

## V. ACKNOWLEDGEMENTS

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## COMPONENT SPECIFICATIONS

| Component | Vendor | Model/Type | Specs | Custom/Purchased | Cost | Year of Purchase |
|---|---|---|---|---|---|---|
| ASV Hull Form/Platform | Custom | Asv2022v3 | Aluminum pvc pe | Custom | 200$ | custom |
| Waterproof Connectors | Lentamarine | penetrator | aluminum | purchased | 4$ per piece | 2022 |
| Propulsion | Degz | Ultras | 8kg/f thrust | purchased | 200$ per piece | 2022 |
| Power System | | | | | | |
| Motor Controls | Degz | MAMBA F50_BLS Dshot600 4IN1 ESC 50A 6S | 50A 4 in 1 | purchased | 150$ | 2022 |
| CPU | Aliexpress | Jetson nano | Gpu and a cpu | purchased | 440$ | 2022 |
| Control unit | robomarket | pixhawk | sersors | purchased | 200$ | 2021 |
| Teleoperation (in pixhawk) | | | | | | |
| Compass (in pixhawk) | | | | | | |
| Intertial Measurement Unit (IMU) (in pixhawk) | | | | | | |
| Doppler Velocity Logger (DVL) (in pixhawk) | | | | | | |
| Camera(s) | direnc | Jetson nano camera | imx219 | purchased | 15$ | 2022 |
| Vision | openzeka | Zed2 | Stereo camera | Not yet | 1000$ | 2022 |
| Open-Source Software | ardusub | Ardusub | | | | |