Sobek team technical design report

Autonmous Trimran model for roboboat Competition

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Abstract— **This paper presents the RoboBoat 2022 competition strategy, the hull design, modeling, experimental results, fabrication, and testing carried out by Sobek team -a (cooperation between Alexandria University and Arab Academy for Science, Technology, and Maritime Transport)- at the team's first entry. The ASV (Autonomous surface vehicle) consists of a camera module, IMU, and GPS, Raspberry pi4 with thrusters in a "T-configuration". The ASV is led autonomously using Pixhawk hardware and mission planner as software while the tasks are completed using models trained for each task inside Gazebo simulation using Robotics Operating System (ROS).**

I. COMPETITION STRATEGY

A. *Mandatory Navigation Channel*

When navigation starts, odometry will be published from the Depth camera, although RC mode is allowed in practice we will not depend on a static map and will focus on strengthening our perception capabilities, the odometry frame which is the initial position of the trimaran will be considered the reference or global frame for our map, the camera publishes 3D Point Cloud data (point cloud library) and poses tracking fusing many sensors in one package, with the help of object classification and spatial awareness, the large red and green buoys at the entrance gates will be identified, allowing the trimaran to turn to an angle and align itself at the center between the navigation channel buoys, automatic way-points will be generated at the midpoints between the buoys with the goal pose after the navigation channel itself.

B. *Find a Seat at the Show*

Using a computer vision algorithm, the boat will recognize the shape and the color of the generated shape in the marker buoy, then will decide in which slot it will Perth using the localization technique, it will search and find the location of the same generated shape in the boards above each slot, using different image augmentation techniques, it will be possible to recognize the shape from an angle, the maneuver will be made using the motion planning algorithm with the depth camera and ultrasonic sensor to avoid collision with the slot borders, the boat will wait for 10 seconds maximum and then go back to the next task.

C. *Skeeball*

In this mission, the ASV is expected to shoot balls through the purple frame and onto the skeeball table in any of the holes. The purple frame's purpose is to give the ASV something to look for when trying to locate the task in the water, then slowly it lines up with the frame. The orange ring around the buckets serves as a target for our vision system, whether using a deep learning model like YOLO or a deep reinforcement learning model like DDPG for continuous actions. An Air Pressure gun similar to a squash In this mission, the ASV is expected to shoot balls through the purple frame and onto the skeeball table in any of the holes. The purple frame's purpose is to give the ASV something to look for when trying to locate the task in the water, then slowly it lines up with the frame. The orange ring around the buckets serves as a target for our vision system, whether using a deep learning model like YOLO or a deep reinforcement learning model like DDPG for continuous actions. An Air Pressure gun similar to a squash ball thrower was manufactured and will be used adjusted using the given dimensions and kinematic analysis to accomplish the ball delivery mission.

D. *Water blast*

In this task we have two options the first is to calculate the required water velocity and angle of attack at a known area using the projectile motion equation as each droplet of water can be treated as a projectile or to try to optimize a model with the parameters using the coding for solving a simple problem is more efficient than trying to train a model in simulation with taking into consideration that after the calculation errors in angles and/or relative height if the target is not reached many options can be tried such as changing the horizontal distance a slight distance or increasing the water velocity which is a function of flow rate and area of the outlet

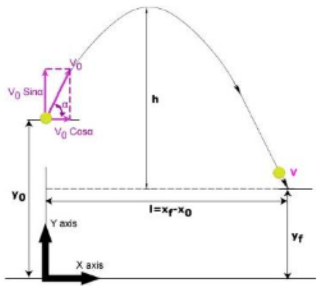

Figure 1: Projectile Motion0

II. Design Creativity

A. *Why Trimaran*

To achieve a low resistance, the team went with choosing an advanced hull design of a trimaran. The trimaran offers several capabilities to bridge the gap between monohulls and catamarans its Excellence for high speed is incomparable to any other advanced design, a good seakeeping capability better than slender monohulls and near to Catamarans, a Larger available deck area than monohulls and catamaran, and a Moderate space below the main deck.

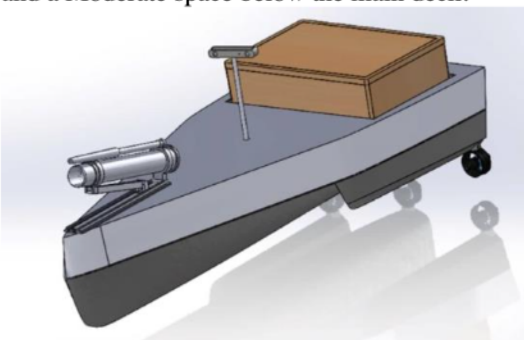

Figure 2:Solidworks assembly of the model

B. *Series based hull*

Hull generation is an important stage in ship design. There is more than a method to generate a ship hull, either by using a hull series, modifying an older hull surface, and modifying it, or sketching a surface.

The favorable method of generating a ship hull is using a series that matches the design purposes of the ship, in the case of a Trimaran that consists of three separate hulls, it was designed from two different series. NPL series for the main hull and chine hull series for the sides.Prepare Your Paper Before Styling

C. Hull surface

The main hull dimensions were determined then the offset tale used to create its surface was generated from the NPL series then a 2d lines plan was drawn from that the generated offset table

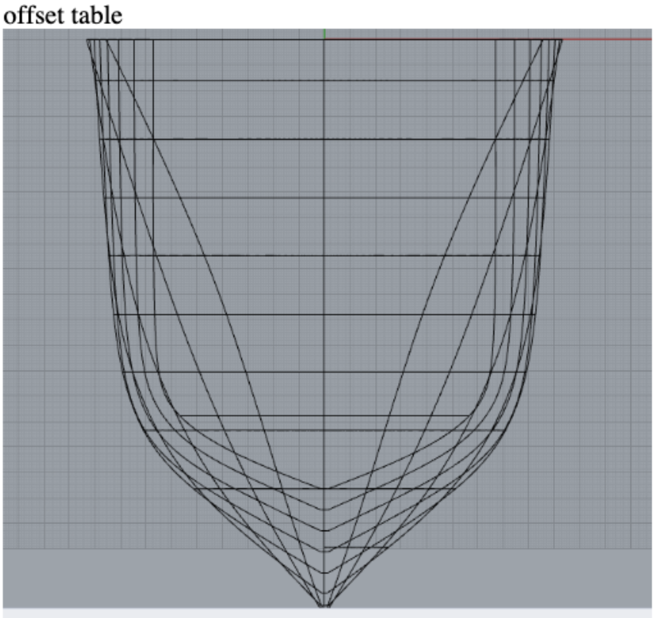

Figure 2: main hull body plan

While the side hull surface was created automatically using the orca3D plugin rhino

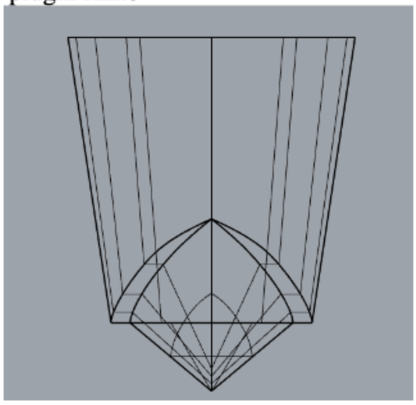

Figure 3: side hull body plan

D. *Hull fabrication*

The hull was fabricated from fiberglass. The methodology used by the team was to cut a wooden plat into the hull frames and keel, glue them together, plate them, and paint them to create a mold for the fiberglass hull.

Figure 4: Cutting hull frames using CNC

E. *Propulsionion system*

Most marine robotic vehicles around the world built with similar dimensions or built to be used as an AUV use a T200 thruster. The T200 thruster has its electric motor and a ducted propeller so it only needs a power source to propel the vessel. The T200 thruster is a good choice but hard to find so the team designed alternative propulsion systems.

Another proposed alternative was to create a jet propulsion system, that system would be created by using axial flow pumps, and drilling suction and delivery holes for each pump. The discharge of the pumps would create the thrust needed to propel the ship, the proposed configuration was to position three pumps at the stern one at each hull to propel the ship ahead, and to position two pumps at the main hull to work as bow and stern thrusters. This configuration was refused because it is hard to fabricate and the suction of the three pumps that would be positioned astern will increase the aft trim above the allowed level putting the model at the risk of drowning.

One of the alternative systems is to use waterproof motors and mount 3d-printed propellers to them, the team designed 2 fixed-pitch propellers with outer diameters of 25 and 10 cm. Those two propellers were designed with the use of the Wageningen b series.

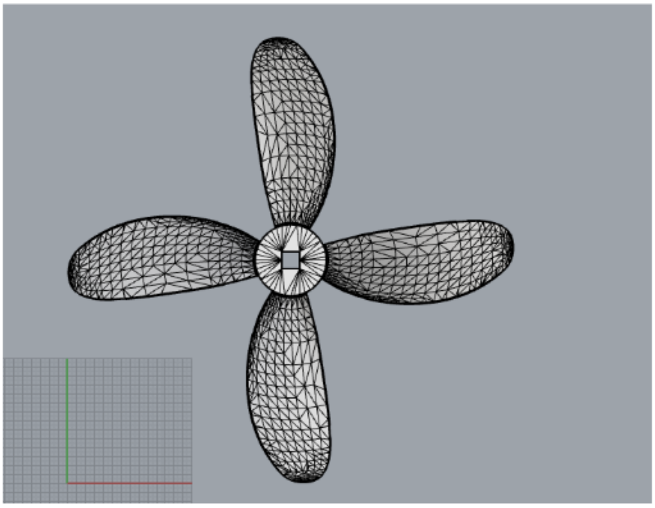

Figure 5: CAD model of the designed propeller

Figure 6: 3D printed propeller

III. Mechanical committee involvment

the 3D model was divided into Frame and a keel per hull the cuts were nested on the board using ARTCAM after cutting the assembly using glue to generate the hull Skelton sanding the frames and keels helped fitting well after that skinning the hull started using mild wooden plates and wrapping the hull with a fibric this generated the continuity of the surface painting the mold with iron putty finished the process .the fiberglass stages consist gel coat and molding the fiberglass the wooden hull was used as mold, after extraction the body sanding made it ready and we moved to the testing stage. determining the distance between the side hull and the main hull began to reach a positive wave interference, after that the process of designing the double barrel gun, which will be used for the tasks 4 and 5. The water gun design was made on Solidworks the linear and rotational motion mechanism system. telescopic mechanism for the camera helped the camera to change its vertical distance in case the gun blocks the view

IV. Electrical committee involvement

A. Sensor Selection

The ASV Contains main elements like Arduino uno and embedded system controller which is ESP 32 as the first trial and will update it to Raspberry Pi4. Therefore, several sources of energy such as 5, 12, and 24 V With them get all the volts suitable for all the components.

AI Camera due to its ability to add position and motion-assisted capabilities. With IMU. to calculate and report an exact body force, angular rate, and direction, which can be accomplished by combining three sensors such as a gyroscope, magnetometer, and accelerometer

GPS sensor to detect a signal to give sufficient data for triangulation of target position.

With Kill switch due to possible seal failure Finally, in the event of an emergency, a visible, accessible mechanical kill switch is incorporated to disconnect power to all vehicle subsystems.

B. System architecture

The robotic operating system(ROS) will give us the capability to reuse packages and stacks, drivers, and other useful solutions, for example, a fusion filter between the IMU and GPS will help in pose estimation and localization, this fusion can be also used to make an extended Kalman if needed, with frames fixed over the base link of the boat in the URDF file and the depth camera which contains all the motion sensors and the GPS, the vehicle should be able to localize itself well on the map, while also tracking objects relative to the Depth Camera and the boat and updating their locations. the global planner sets the goal desired and implements an optimal path to that point while avoiding obstacles, the local planner will implement this path sending velocity messages to the controller while also avoiding any obstacles not initially recognized by the global planner, velocity commands will be sent to the microcontroller for motor control. As for the perception part, the depth camera should identify objects and also locate them about the boat, objects' positions will be uploaded to the map using ORB_SLAM2 and computer vision Using the YOLO V2 algorithm with more extensive data augmentation techniques to better identify objects.

C. Actuators

A 4 Bilge Pumps which each of them is a water pump and converted it into motors Due to rising prices, high traffic shipping, and delayed extraction of certain declarations, we could not buy T200. and the propeller designs which were 3d printed showed great performance. Arranged in T-Shape only one propeller of 25cm thrusting solo could achieve around 800gm of thrust force

And for the camera. The mechanism consists of Screw and Stepper Motor "Nema 17", And it can be used in the vertical position together to give the camera a higher position, leading to the tolerance of movement. But in ball shooter. Two types of motor Nema 23 for rotational movement of shooter and NEMA 17 for ball arm movement attached at the horizontal axis

D. Battery and power distribution

Calculations were made to know the correct amount of power needed to power the model for the longest number of hours which will allow us to practice using more time, with the need for a single battery swap, the ASV needs 823.2 Watt per hour to work. This means 53.2 Ampere\hour with 160-ampere capacities; this amount will allow us to work for 3 hours straight. Furthermore, all calculations determined 220 A. for addition, the customization PCB is designed to give all the volt components you need from the main batteries knowing that the PCB.

E. Control and GUI

In the early stages of the experiment, HC-05 was used for initial connectivity and control of the vehicle, and work was done to develop the delivery method to use Radio-NRF as a means of communication to reach the highest range. But we hope to use Xbee to also use it to transfer data and images to be analyzed and to reach the maximum distance to move the compound from the beginning of the competition until the beginning and then use it to transfer the data.

V. SIMULATION ENVIRONMENT

Gazebo is used for the simulation with buoyancy and wind plugins, the team made great use of the VRX and RobotX environments, we have encountered many errors while we were trying to launch the reinforcement learning agent and also, we had so bad time when we were deploying the motion planning algorithm.
we are planning to use the zed v2 camera for the localization and mapping tasks

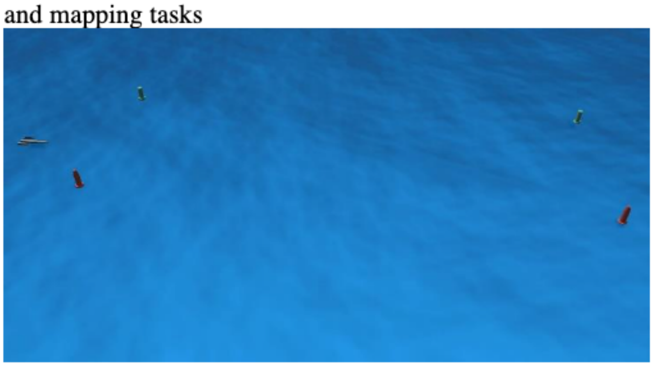

Figure 7:Gazebo Simulation

A. Software architecture

Our team is working on two different approaches, so we will cover both here. MATLAB is used as it is a powerful tool with many plugins that makes it easier to implement and visualize the motion planning, model, and environment. It is compatible with Robotic Operating System (ROS) for short, which is the best choice when it comes to the robotics field. ROS will give us the capability to reuse packages and stacks, drivers, and other useful solutions.
Fusion between the IMU and GPS will help in pose estimation and localization, the vehicle should be able to localize itself well, and objects' positions will be uploaded to the map using ORB_SLAM2 and computer vision using the YOLO algorithm with more extensive data augmentation techniques to better identify objects. For the path planning, different sampling-based algorithms after dense research are being tested and evaluated for this task based on many criteria such as computing power and storage required for such a task, time, and velocity. MATLAB is used to implement many sampling-based algorithms to compare and evaluate them to choose the best suited for that task.
Our Guidance, Navigation, and Control architecture are shown in Figure 8: a first approach

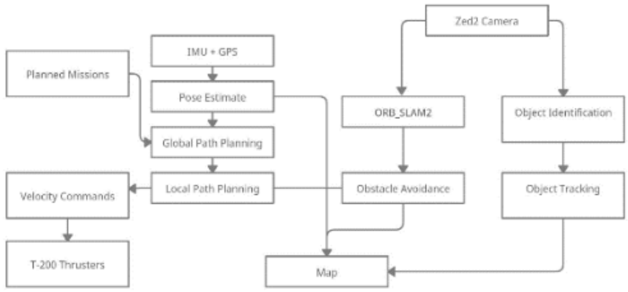

Figure 8: a first approach

VI. EXPERIMENTAL RESULTS

The team planned tests to measure resistance, hydrostatics, strength, electric parts efficiency, and maximum hull speed. To test the hydrostatics of the hull the hull was marked on its sides to create draft marks and a water angle scale was used to measure the hull inclination. Different weights were positioned on the hull and moved around the hull while recording the change in the aft and forward drafts for an inclination test.

Figure 10: inclination test

After that steel bars with constant weights were used to compare the ship drafts at different displacements, creating the ship hydrostatics.

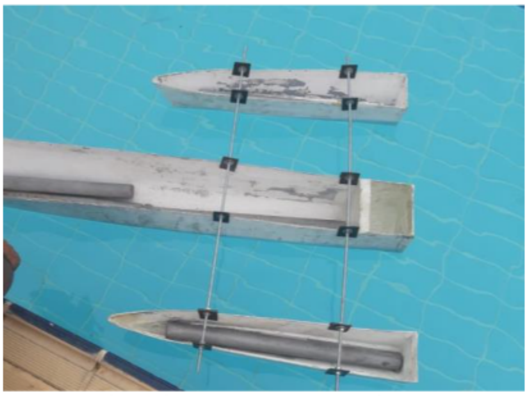

Figure 11: draft-displacement test with bars each weight 2424gram

hydrostatic curves were created by using Maxsurf stability, and draft-displacement data was collected.

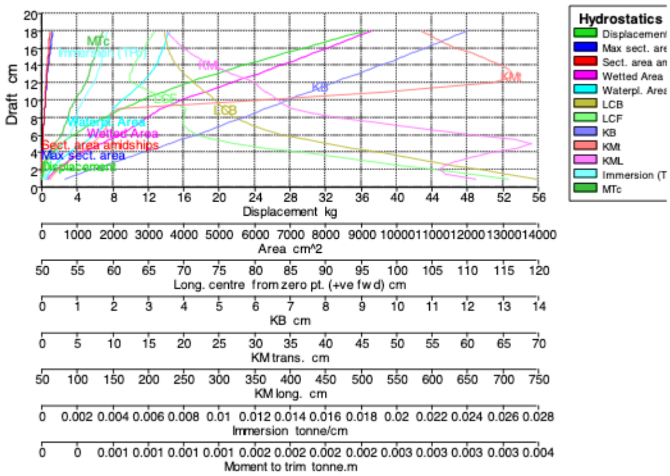

Figure 12: hydrostatic curves

Regarding the ship's resistance, the team is planning to use Ansys CFD simulation, and for structural strength, Ansys static structure is to be used. All the electrical components and parts are tested before installation and fully sealed when mounted on the hull to ensure that no water reaches them.

Figure 13: testing a propeller and a pump before using them on the hull.

VII. Acknowledgements

It was a great opportunity to gain a lot of experience with real time projects, followed by learning how to design and analyze real projects. We want to thank all the people who made this possible for students like us. We thank RoboBoat for their efforts in develop and promote a community of innovators in the field of Autonomous Surface Vehicles (ASV), and then we would like to thank our support parsons [Dr./ Essam Ezzat El-Bokl, Assistant President of the Academy for Technological Education at AAST - Prof. Dr. Khaled Said El-Kilany, Dean of Service Complex Industry at AAST- Dr. Essam Badawy, Den of Maritime Safety Institute - Dr. Ahmed Sadiq Shoair, manager of the Technical and *Vocational Institute at AAST - Prof. Dr. Mohamed El Gohary, Head of Marine Engineering Department at Alexandria University - Prof. Dr. Adel Banwan, Professor of ship design at Alexandria University].*

We would like to take this opportunity, we extend our heartfelt thanks to Dr. Ahmed Gomaa, who accompanied us on our journey to accomplish this research and had clear fingerprints through his directives, constructive criticism and academic support. At all levels, we thank friends and loved ones and everyone who provided us with material or moral support, and finally we extend special thanks to the Service Workshops Department at AAST for helping us understand the technical issues related to the project.

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