Abydos Marine - RoboBoat 2023

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***Abstract*— Noah is a newly built autonomous surface vehicle by Abydos Marine, a team representing the Arab Academy for Science, Technology and Maritime Transport (AASTMT) to compete for the first time in the RoboBoat competition for 2023. The technical report describes the design process of the ASV and the reasoning behind the chosen design as well as the testing criteria to ensure the design suitability. It also contains the technical processes of engineering various systems that are responsible for all eight tasks after determining how each task will be approached and the testing criteria of these systems. For our first participation in the competition, our decision was not to settle for only attending the competition but to also have a significant contribution. The goal is to collect as many points as we can by attempting all tasks while maintaining our stability and maneuverability.**

Keywords—ASV, stability, system, task, software

I. Competition Goals

For our first year, we faced a lot of problems and had a real short time to solve, but with our potential and desire for competing, we did all we could. In this year's tasks, we gathered all of the team to think about the tasks and our approach to successfully pass them.

Concerning our work through the tasks, we made some decisions based on trade-offs. For example, for wanting to use an algorithm that helps us in a fast and reliable way to detect buoys, we tested YOLO v5 and YOLO v7. We found that there is such a difference in speed and accuracy, and for our need, it is preferable to use YOLO v5 in our tasks. Also, YOLO v5 uses less GPU process compared to YOLO v7, and this obviously would be easier for Noah to use in detecting and marking any buoy that could at worst case be located 100 ft away.

And will not forget that handles the way of good response in detecting close obstacles through the path. Therefore, Noah's system and computer vision will be able to measure any distance and detect any object.

Besides that, Noah's design has the stability that could bring us the best performance for its movement in the water.

A. *Task 1 – Navigate the Panama Canal and Task 8 – Explore the Coral Reel*

In these general navigation tasks, we will use the mid-point between the buoy pairs as our center for the new pathway.

B. *Task 2 – Magellan's Route / Count the Manatees & Jellyfish*

To solve this task, we will use a LIDAR to help in detecting the obstacle distances and places as shown in fig. 1. The laser sensor point cloud provides high-precision distance measurements and works very effectively for map construction with SLAM (simultaneous localization and mapping) to help in making a 3D map.

We also put a plan-B which is detecting the two buoys then dropping a mid-point; which will make Noah centered to follow the mid-point as a path. The moment it detects a black or yellow buoy, it sees if the buoy is in left-side or right-side relative to the mid-point and gives order to Noah to move in the opposite direction.

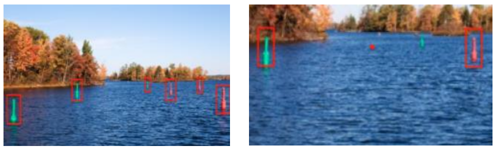


Fig. 1. Obstacle colour and location detection

C. Task 3 – Beaching & Inspecting Turtle Nests

For detecting which corner is the right one for the docking, color detection will be used to detect the balls' colors based on the color that is given. Then our docking will start based on the chosen hall by making Noah go 2 feet to the right and 2 feet to the left from the center of the detected hall. Finally, the count will be carried out by comparing using CNN.

D. Task 4 – Northern Passage Challenge

After entering the gate, the system will detect the blue buoy and keep tracking the distance between Noah and the buoy by our ZED camera as shown in fig. 2.

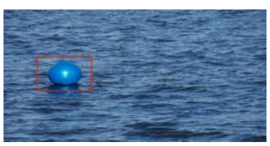


Fig. 2. The object detection capability

When we reach our desired distance, our boat will go to the right corner in the forward path, then to the left corner three times to get to the original path before we rotate around the blue buoy. We then will go back to the original path and detect the gate we entered from and move to get out. Figure 3 shows the camera's colour threshold.

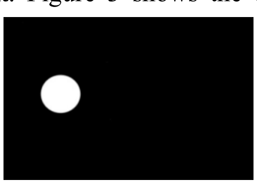


Fig. 3. Colour Threshold

E. Task 5 – Ocean Cleanup

The balls are collected by a net. The net can extend and open to collect the balls and close on them, then retract and feed a tank. The tank can then feed the disk launcher that will be used in the next task.

F. Task 6 – Feed the Fish

First, we will use color detection to determine the feeding table, then we will allocate the place of the circles by using our shooting gun.

The shooting gun is made by using a disk that rotates at a high speed that launches the balls at the target. Accuracy is not certain, but it can be achieved to an extent.

The tank can be placed at a higher level than the launcher and a door will be opened that lets the balls slide into a tube that leads them to be launched. We will direct them in the suitable track by using our mechanical system.

G. Task 7 – Ponce de Leon / Fountain of Youth

The pump is attached to the boat to pump water to the canon system. Two Servo motors are organized in a pan and tilt system to independently aim the canon regardless of the boat orientation or heading. By using YOLO, we can detect the target face, then detect the center of the target by using point cloud; then we will send the coordinates from the point cloud to the servo motor to push the water.

By using color detection, we will detect the green line then we will take shots after every 5 seconds to this part of the line then when the pixels' difference become more than the usual, that means that the ball passed the line.

II. Design Strategy

In this section, we aim to identify our strategies in designing Noah and how we figured the final shape of the hull in order to maintain the best stability and buoyancy. Also, knowing how we used our technical thinking in figuring out the optical components we used to ensure that we have the best automated system for our ASV.

A. Boat Design

Noah is a new design of RoboBoat with a multi-hull. The shape was inspired by the turtle shell, which is characterized by its smoothness, similarity, and strength all at the same time. Merging that with a catamaran design helped achieve a stability like no other. Firstly, the competition requirements were considered during our design process. We determined the purpose of the competition, how to approach each task, and the dimension limitations, and according to that, the competition targets were set to be maneuverability and stability.

Preliminary design: We made four different designs of catamaran hulls using Rhinoceros and SOLIDWORKS software, then the ideas were combined until we reached the appropriate design, on which any modification will be made to improve it and achieve the tasks efficiently. Our adopted design is symmetrical about the longitudinal axis to improve maneuverability and multi-hulled to improve stability. The main dimensions of the boat are

148 cm long, 87 cm wide, and 24 cm high. The general arrangement of the boat was drawn, the internal shape was modified, and the compartments were changed to create a better distribution of components onboard.

Verification of preliminary design: At this stage of the design, calculations were carried out to verify the capabilities of the design. Revised characteristics included buoyancy, stability, maneuverability, strength, displacement, and flooding capability.

Final design: At this stage, some modifications were made to increase the smoothness of the hull and improve its shape, and all of the above were confirmed from the calculations.

B. *Systems Design*

Our approach to successfully complete the tasks meant we needed to engineer systems that we can rely on which led to selecting some key elements of advanced optical and navigational capabilities to use.

LiDAR: RPLIDAR S2 is our chosen lidar "360-degree 2D laser scanner". The generated 2D point cloud data can be used in mapping, localization and object/environment modelling in our tasks. We are going to use the general simultaneous localization and mapping (SLAM) feature in our work.

Transmitting and Rreceiver: We chose to use a NRF24L01 transceiver associated with antenna 800 – 1k meter for manual controlling as shown in fig. 4.

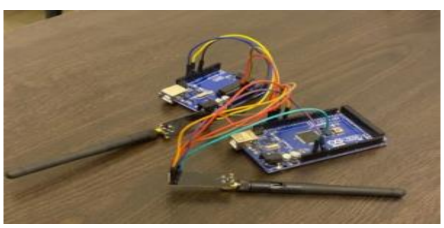


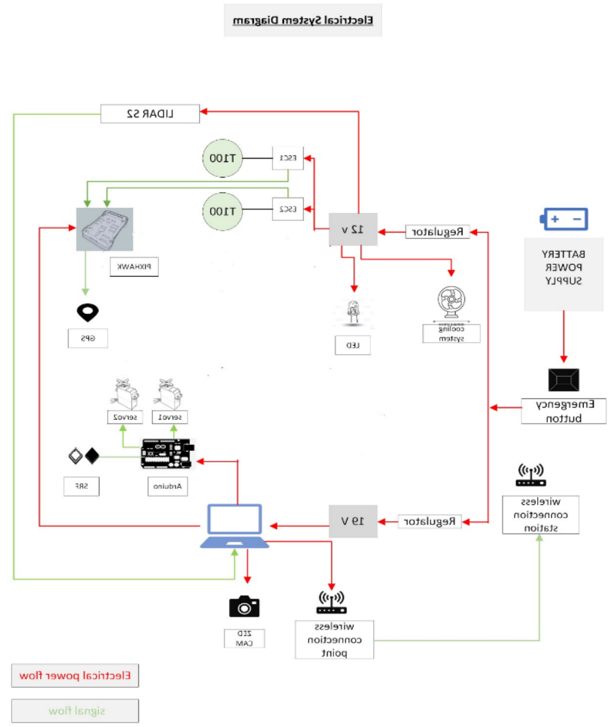
Fig. 4. The transmitter and receiver circuit used.

Pixhawk: We used the two features that will help us most in navigating and avoiding obstacles with the help of the LiDAR. First, the waypoints feature will help in making setpoints that create paths to make Noah navigate through any task. Second, the collision prevention feature will slow down the speed of the ASV once it detects an obstacle, until it reaches the minimum distance, then slides left or right until it is no longer blocked.

ZED camera: The ZED camera will provide the distance between Noah and any object it detects, so that the ASV could react to avoid these obstacles. Also, the camera will be used for color and object detection which will allow the determination of the buoys' location.

C. *Electrical System*

The following diagram represents the complete electrical system employed for the ASV.



III. Testing Strategy

A. *Boat Stability*

After an initial design was reached, we used the software MAXSURF Modeler and Stability to calculate the displacement of the boat at a total depth of 20 cm and was found insufficient, the depth was then changed to 22 cm and an additional factor of safety was taken yielding a total depth of 24 cm to obtain the boat's required displacement.

The displacement of the ASV was calculated at both the lightweight and the load case condition of the added equipment. The results were collected and can be found in Appendix B.

The fluid's behaviour around the hull of the ASV was simulated on ANSYS Fluent software given the wave and current conditions assumed in the location of the lake.

B. *Battery Test*

During our testing process in the pool, a single 11.1 Volt, 5.2 Amp-Hour, lithium polymer battery was used as our only source of power for the boat. This battery supplied enough power to the boat for our testing in the laboratory and for 20 minutes of cruising in the low-current area of the pool. As a result, our power sources for the thrusters and the rest of our electronic systems and mechanisms will be separated. The thrusters will have sole access to a 22 Volt, 21 Amp-Hour lithium polymer battery and the 11.1 Volt, 5.2 Amp-Hour batteries will be utilized to power all of the other electronic components. The skid ball and water shooting mechanisms are yet to be implemented onto the boat, however, they are not expected to consume more energy for it to be of concern with our adjusted power distribution.

C. *Circuits Test*

PCB has a better current-carrying capacity compared to a breadboard; the traces are made wider to take more current so that works well. Terminals were also added to the printed circuit board for external connections. Heat sinks were mounted to the board to make it rigid.

D. *Sensors Test*

The ZED camera was successfully tested by clearly measuring the distance between our ASV and any obstacle it can face. The camera's color detection threshold will also help in giving immediate order to the thrusters to avoid any buoy obstacle. Also, our LiDAR that was tested by 2D scanning gives more performance-reliable output in automated tasks, especially in the Magellan's Route task.

E. *In-Water Test*

The Marine Safety Institute Pool where we conduct our tests, the boat was cruised for about 3-4 feet to test our thrusters performance in water. The boat can move forward and backward while turning, as well as turn in place. The boat can also sail at a speed up to 1.5 meters per second. The thrusters were capable to successfully propel the ASV either sailing or stationary as well as for long distances.

Acknowledgment

Our participation in the competition wouldn't have been possible without the support of Dr. Ahmed Samir, the head of the Marine & Offshore Engineering department at AASTMT, and his continuous encouragement and advice throughout the process. We would also like to thank Eng. Wagdy El-Mogy, Eng. Andrew Helmy; teaching assistants in the Marine & Offshore Engineering department, and Eng. Amr Awad for their time in helping us with the boat design and simulation.

In addition, special thanks to the Industry Service Complex at AASTMT and Eng. Nancy Fareed and Eng. Moataz for helping with the boat fabrication and purchasing of fiber glass and other materials. We would also like to thank Dr. Ahmed Shenawy for arranging our shipping plans.

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APPENDIX A: COMPONENT LIST

This appendix includes a list of all equipment used for the completion either mechanical or electrical/electronic components.

Given the great help AASTMT provided, hhe hull of the boat was manufactured in our Marine Engineering workshop given help from the Industry Service Complex. The systems used onboard were also installed in the workshop.

Component	Vendor	Model	Specifications	Cost	Purchase Year
Fiberglass	Jushi Fiber Glass	DEN300	Density of 300 kg/m^3	$35	2023
Wood	-	-	Blank wooden board MDF 13 mm thick	$20	2023
Wood	-	-	Plywood 3 mm thick	$6	2023
Polyester resin	Boytek	-	BRE 325	$95	2023
Gel coat	-	-	-	$15	2023
Acetone	-	-	6 liters	$20	2023
Hardener	Kapci	-	0.5 kilograms	$10	2023
Liquid cobalt	-	-	-	$5	2023
Iron putty	Kapci	-	3 kilograms	$8	2023
Filler	Kapci	-	1 kilogram	$10	2023
Two-part adhesive	AKFix	-	400 millilitres	$3	2023
Waterproof Connectors	Blue Robotics	Potted cable penetrator	https://bluerobotics.com/store/cables-connectors/penetrators/penetrator-vp/	$6	2021
Propulsion	Blue Robotics	T200	https://bluerobotics.com/store/thrusters/t100-t200-thrusters/t200-thruster-r2-rp/	$173	2020
Power System	Turnigy	Lithium polymer battery	11.1 V, 5200 mAH, 40 C 7.4 V, 2200 mAH, 25C	$60	2023
Motor Controls	Cube pilot	Cube Black	https://ardupilot.org/copter/docs/common-thecube-overview.html#specifications	$185	2020
CPU	Lenovo	Legion Y540	https://www.lenovo.com/in/en/accessories-and-monitors/keyboards-and-mice/dc/undefined/laptops/legion-laptops/legion-y-series/Lenovo-Legion-Y540-15/p/88GMY501214	$1250	2019
Teleoperation	Radio link	AT9S Pro + R9DS	https://www.radiolink.com/at9sprospecifications	$120	2023
LiDAR	RP	RPLIDAR S2E	https://www.slamtec.com/en/S2/Spec	$299	2023
Camera	Stereo labs	ZED 2i	https://www.stereolabs.com/zed-2i/	$449	2023
Compass & Global Positioning System (GPS)	DJI	A2 GPS PRO PLUS	https://www-v1.dji.com/product/a2/spec.html	$199	2023
Algorithms	Abydos Marine	-	-	-	-
Image Processing	OpenCV	-	-	-	-
Computer Vision	YOLO v5	x	-	-	-
Open-Source Software	ROS	Noetic	-	-	-

APPENDIX B: TEST PLAN AND RESULTS

Testing is a crucial step to ensure the satisfactory performance of the ASV constructed.

Starting with the boat design, the starting design was a single hexagonal hull that was thought to provide the best maneuverability for our work conditions as shown in fig. 5.

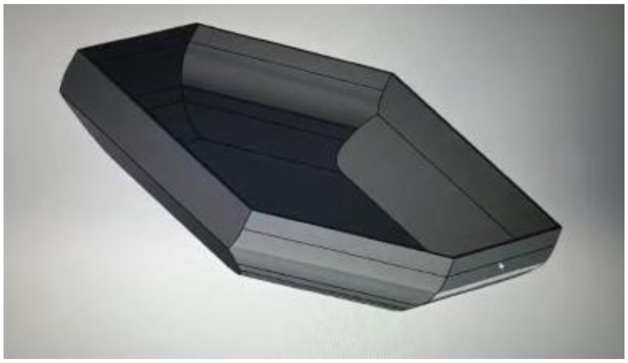


Fig. 5. The first hexagonal hull design on SOLIDWORKS.

The boat was initially designed on SOLIDWORKS but then the design was changed into a modified catamaran hull as shown in fig. 6. This second design was introduced into MAXSURF Modeler and Stability, and the buoyancy and stability were obtained.

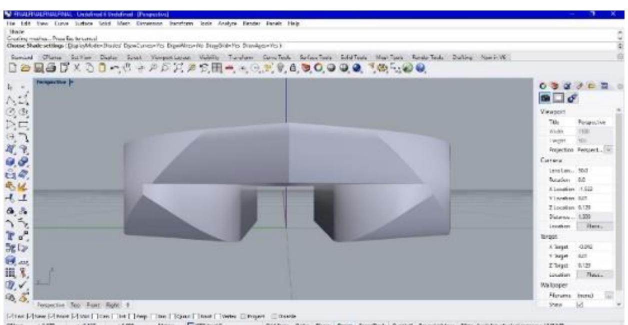


Fig. 6. The second modified catamaran design on Rhinocerous.

Given the sharp edges of the hull, the design was altered to introduce some curvature that helped in improving the boat's entrance thus reducing its resistance and providing better maneuverability as shown in fig. 7 and fig 8.

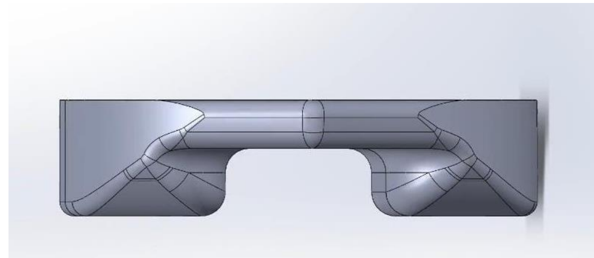


Fig. 7. The final hybrid design on SOLIDWORKS.

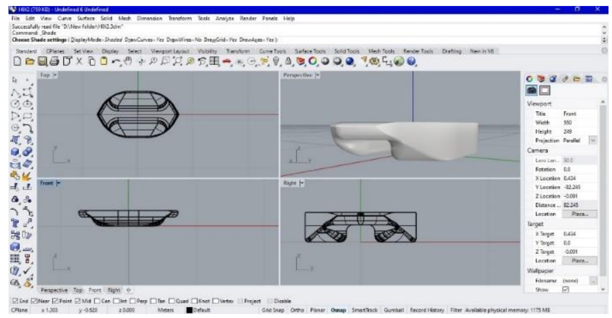


Fig. 8. The final hybrid design on Rhinocerous.

After the design was finalized, it was opened on MAXSURF Modeler and Stability for the needed calculations as shown in fig. 9 and fig. 10.

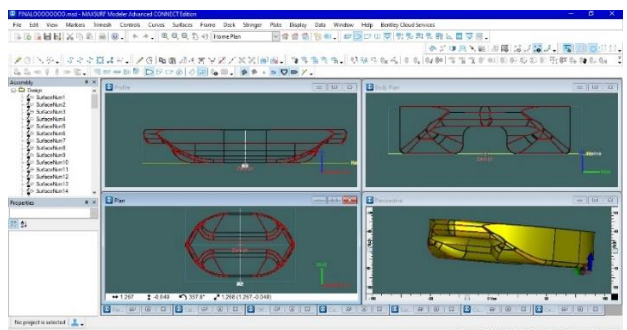


Fig. 9. The design on MAXSURF Modeler.

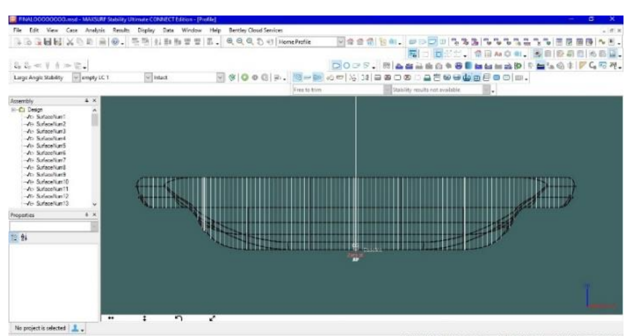


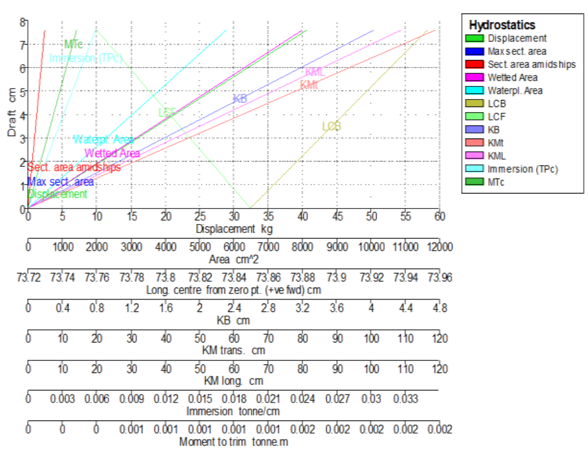
Fig. 10. The design on MAXSURF Stability.

The design hydrostatics were calculated and are shown in table 1.

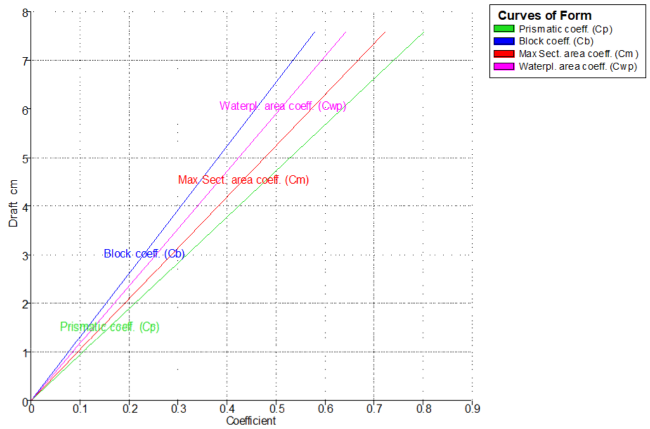
TABLE I. THE BOAT PARAMETERS AND THEIR VALUES.

Parameter	Value
Draft Amidships (cm)	7.58
Displacement (kg)	40.60
Heel (deg)	0.0
Trim (+ve by stern) (cm)	0.00
Waterline Length (cm)	103.54
Beam maximum extents on waterline (cm)	87.00
Wetted Area (cm^2)	8002.18
Waterplane. Area (cm^2)	5784.93
Prismatic coefficient (Cp)	0.803
Block coefficient (Cb)	0.580
Maximum section area coefficient (Cm)	0.723
Waterplane area coefficient (Cwp)	0.642
LCB from amidships (+ve fwd) (cm)	73.95
LCF from amidships (+ve fwd) (cm)	73.76
KB (cm)	4.03
KG (cm)	12.46
BMt (cm)	114.71
BML (cm)	104.64
GMt (cm)	106.28
GML (cm)	96.21
KMt (cm)	118.74
KML (cm)	108.67
Immersion (TPc) (tonne/cm)	0.006
Trim angle (+ve by stern) (deg)	0.0000

The hydrostatic results are shown in the graph below.



The boat's curves of form which describe the shape of the hull compared to a rectangular box are shown.



After making sure that the boat is stable in its lightweight condition, the weights of the equipment that will be placed in the hull were added to check the ASV's stability in this load condition which is shown in table 2.

TABLE II. LOAD CASE FOR THE COMPONENTS.

Item Name	Quantity	Unit Mass (kg)	Total Mass (kg)	Long. Arm (cm)	Trans. Arm (cm)	Vert. Arm (cm)
Lightship	1	23.0	23.0	74.00	0.00	14.00
Battery 1	1	2.5	2.5	49.00	14.50	4.00
Battery 2	1	2.5	2.5	49.00	-14.50	4.00
Battery 3	1	2.5	2.5	97.00	14.50	4.00
Battery 4	1	2.5	2.5	97.00	-14.50	4.00
Water Canon	1	3.0	3.0	71.40	0.00	30.00
laptop	1	3.0	3.0	71.40	0.00	16.00
Lidar	1	0.2	0.2	130.00	0.00	30.00
Zed Camera	1	0.2	0.2	138.00	0.00	30.00
Thruster T100 1	1	0.3	0.3	54.00	26.85	-5.00
Thruster T100 2	1	0.3	0.3	54.00	-26.85	-5.00
Thruster T100 3	1	0.3	0.3	94.00	26.85	-5.00
Thruster T100 4	1	0.3	0.3	94.00	-26.85	-5.00
Total Load case			40.6	73.96	0.00	12.46
VCG fluid						12.46

The stability of the boat at different angles of heel are studied to obtain the stability range, angle of vanishing stability as well as the maximum righting lever as shown in the graph.