Military Technical College – MW Team

Technical Design Report
RoboBoat 2023

Abstract: Military Technical College (MTC) is ready to conquer the RoboBoat competition with a bright-minded team. The team contains three groups: Mechanical, Electrical, and Multimedia. The team confronted some challenges with the old version of the boat to adapt to the new competitive strategies. The competition strategies revealed within this report briefly discuss the design process, imposing several specific requirements on the vehicle design and construction. This includes the presence of various sensors used efficiently to provide the boat with the ability to do the tasks smoothly. Also, the team encountered many mechanical and electrical trade-offs in the design discussed below.

I. Introduction

Our choice for the naming MW is "water" in the ancient Egyptian language. MW's team is divided internally into three subareas working in harmony, according to the skills required for the development of an autonomous vehicle. The electrical team works on the connections between the "Robotic Operating System" ROS, the camera as a vision for the boat, and the control system complying with signals from the ROS to each thruster, light, and electronic devices on it, Mechanical team on the design of the catamaran hull, production the overall structure of the ASV, and Media team responsible for the web page, photos, videos.

II. Competition Strategy

Our team approaches the competition tasks with minimum effort, time, and cost to collect as many points as possible. Due to the changes in the tasks this year, the team decided to make some decisions that traded off some features to adapt to some tasks. In this section, we will provide insight into how the team plans to do this. Initially, the subsystems used in the challenges will be presented, followed by a short explanation of how each challenge will be accomplished. Due to some obligations in college and a lack of members in the mechanical group, we had very limited collective hours to work on the vehicle. However, we made use of it wisely.

1. Navigate the Panama Canal

Being the main mandatory task, we gave it the highest priority. It is required that the ASV navigate through two pairs of red and green buoys in a fully autonomous manner. The two buoys are at least 6 feet apart. The two sets of buoys are at least 25 feet apart. We decided to complete this task with image processing by color detection without needing the detection of shape.

The camera was placed in the most suitable location that suits all requirements of the upcoming tasks. We made an algorithm that guides ASV and maintains the suitable distance between the red and green buoys according to camera detection. The algorithm instructs the ASV to maintain the initial direction in seek of the exit gate. As soon as ASV passes through the exit gate, it proceeds to the next task.

2. Magellan's Route

The ASV is required to sense and maneuver between multiple sets of gates consisting of pairs of red and green buoys. The ASV must not touch the buoys and avoids intermittent yellow and black buoys in the pathway. This task depends heavily on the camera, putting an extreme processing load on the NUC. So we decided not to use the LIDAR to reduce the complexity of this task. As ASV pushes forward, it must localize itself between the two buoys, putting the green buoy on its right, and the red buoys on its left using right or left thrusters independently. If a yellow or black buoy is detected, the distance between them and each buoy is calculated and the ASV is directed towards the largest distance to maintain a smooth path.

3. Beaching & Inspecting Turtle Nests

Despite being a straightforward task, it took a lot of effort for our team to perform it. We decided to use both LIDAR and a camera during this task so we constructed an extremely complex algorithm, ROS which manages to detect any obstacle by using LIDAR through the route to the docking bay while the camera detects the color and number of eggs of the required bay, then initializing docking algorithm which eventually managed to pass the task successfully.

4. Northern Passage Challenge

Starting this task in a similar manner to Navigate the Panama Canal task, then ASV had to find the blue buoy distant 40 ft. at least from the gate buoys rather than the second gate. As soon as ASV passes the first pair of buoys, it pushes forward with a full thrust with the same heading until the blue buoy is detected by the camera. ASV moves toward the buoy, reducing its speed gradually until it is at a suitable distance measured by the LIDAR. It then circumnavigates the blue buoy, and moves again toward the entrance gate with full thrust, completing this task as fast as possible.

5. Ocean Cleanup

It is the first time the team attempting this task, but eventually, we decided to keep it simple, by designing a scoop with holes drilled in it allowing for multiple racquetball catches at once, this design is chosen to maximize the number of balls ladled with minimal effort, time and complexity.

6. Feed The Fish

Through this task, we made some adjustments to the boat's mechanical design, we added a small pipe to hold and shoot the balls via the water jet. As a trade-off, we decided to make the water jet fixed instead of using servomotors to decrease the complexity and weight of the ASV. ASV detects the frame using the camera then holds the position at a suitable distance from it, using trial-and-error then deploys balls through the frame and onto the feeding table, in any of the three holes.

Figure 1: Water Pump

7. Ponce de Leon

Using the same water jet mechanism used in the previous task, water is delivered through the center of the target, after its detection using a camera, and a suitable distance from the dock is maintained using trial-and-error. Water is pumped from the surrounding environment instead of storing it onboard to decrease weight and increase stability.

8. Explore the Coral Reel

RTK is trained to locate the next task from data collected from the camera and VectorNav making sure to avoid all obstacles in the way (floating buoys, balls, docks, previous task equipment, etc.) until eventually finding the two black buoys, passing through them announcing all tasks successfully passed.

III. Design Creativity

1. Hull Design

We decided to go with a double-hull design as it grants increasing in stability than a single-hull design. However, it increases resistance in water thus decreasing the ASV speed which is an acceptable trade-off due to competition tasks containing a lot of steering-based tasks compared to high-speed tasks. Another trade-off we took on was increased buoyancy thus increasing the maximum load onboard of the ASV which increases the overall weight. So as a countermeasure, we replaced last year's batteries with lighter batteries.

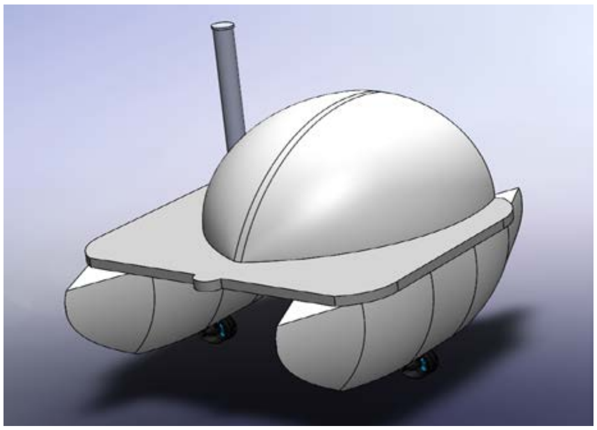

Figure 2: The Final Design of ASV

2. Navigation system

We integrated the IMU and GPS to move from one point to another using the Kalman filter. We encountered many issues with the GPS module due to local restrictions but we managed to solve them.

ASV heads towards the next waypoint with aid of IMU and GPS module rotating in a closer direction, then as LIDAR detects any nearby obstacle, it uses a special algorithm to avoid it.

3. Cooling System

A new design for the AUV was essential to counter our weak points in the previous design where we noticed that performance was degraded due to a rise in NUC's temperature. The cover provides enough space for the internal components with calculated spacing for each component to prevent any interferences between them and allow for the air to flow releasing the heat accumulated from the NUC where the air enters through the top side of the cover and is exhausted through the back making sure the is no water particles may enter. The new fiberglass hull design ensures more hydrodynamic efficiency and generates less drag force upon movement and is both lighter and smaller than the previous wood hull design. We also used silica gel to absorb humidity in the air from the surrounding environment. The new cover also provides an interface for charging the battery and showing its status externally through an LCD so the cover needn't be removed.

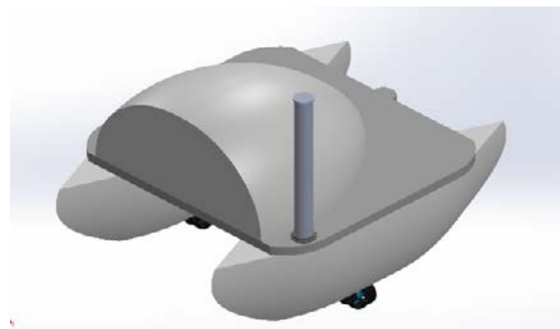

Figure 3: Cooling system and charging interface in the cover

4. Software

We used LabVIEW for control due to its simplicity & creativity. We integrated our ROS work with LabVIEW by sending only command velocity to the controller, we have tried to keep it as simple as possible. Our design is modular & easy to modify.

We used MyRio as the controller, where it's compatible with LabVIEW in addition to its quick response compared to other microcontrollers. We used ROS to send command velocity to MyRio. Hence, it sends PWM signals out to the thrusters.

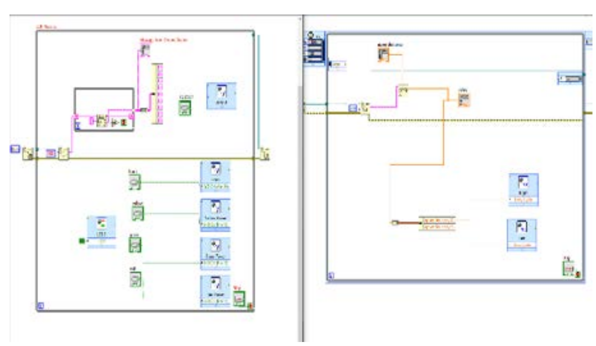

Figure 4: Communication between ROS & LabVIEW

IV. Experimental Results

1. Vehicle's performance:

We used the double hull structure (catamaran) which proved to be more stable with a decent buoyancy, using both Maxsurf stability gave us satisfying results which encouraged us to use this design model.

Fiberglass was used to improve the buoyancy where the overall weight decreased which increased speed and freeboard.

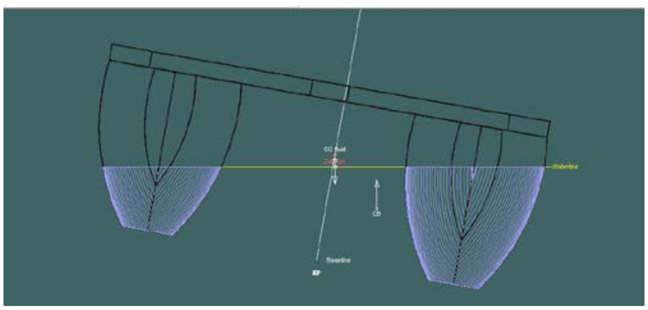

Figure 5: Vehicle's stability test

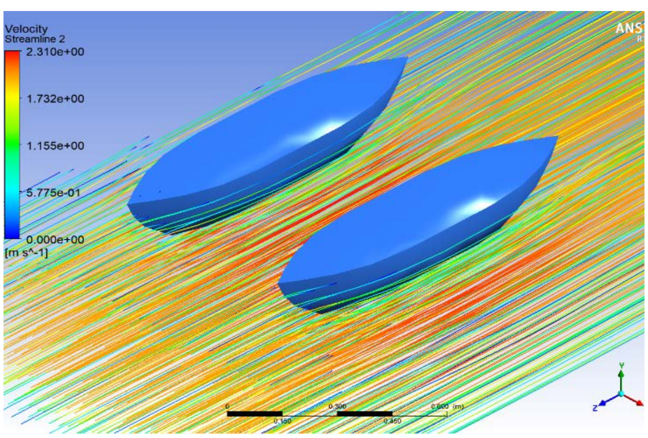

Figure 6: Water streamlines

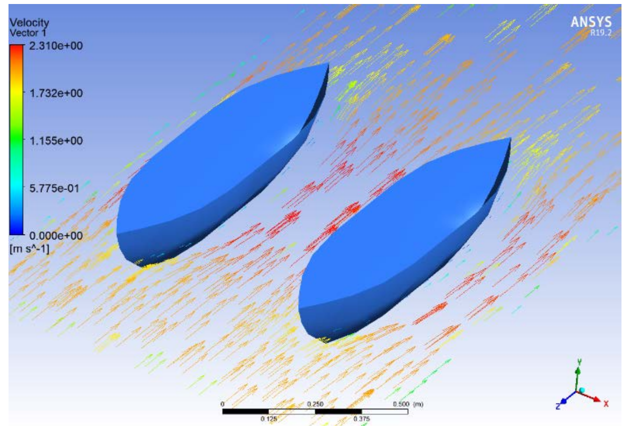

Figure 7: Water flow vectors

The hull design used was taken from many experiments where we picked the best volume-to-force and good speed in the water as water drag ratio.

The Catamaran was designed to maintain a high transverse righting moment even at high heeling angles to maintain high stability and a fairly high longitudinal righting moment, to ensure the ASV is always at its ideal working conditions either at idle or in motion.

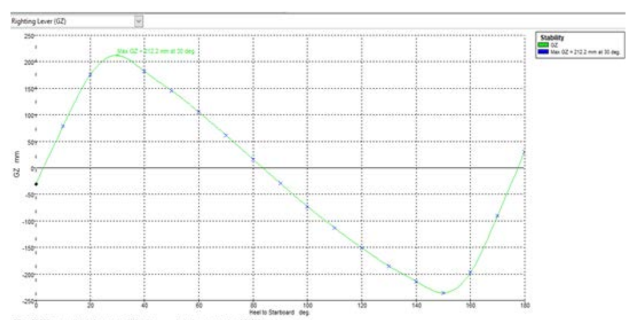

Figure 8: Water streamlines

The hulls were designed to withstand high loads up to 60 kg which is the max load allowed at the draft of 200 mm

	Draft Amidships mm	-36.4	43.1	65.2	83.7	100.3	115.5	129.6	143.2	156.1	168.7	180.9
1	Displacement kg	0.0000	5.000	9.999	15.00	20.00	25.00	30.00	35.00	40.00	45.01	50.00
2	Heel deg	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	Draft at FP mm	-36.4	43.1	65.2	83.7	100.3	115.5	129.6	143.2	156.1	168.7	180.9
4	Draft at AP mm	-36.4	43.1	65.2	83.7	100.3	115.5	129.6	143.2	156.1	168.7	180.9
5	Draft at LCF mm	-36.4	43.1	65.2	83.7	100.3	115.5	129.6	143.2	156.1	168.7	180.9
6	Trim (+ve by stern) mm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	WL Length mm	0.0	868.5	916.5	950.3	977.6	1000.5	1019.7	1036.5	1050.8	1063.0	1073.3
8	Beam max extents on	0.0	727.8	750.1	766.4	779.5	790.1	799.1	806.6	813.0	818.4	823.0
9	Wetted Area mm^2	0.0	264691.	363027.	445740.	519390.	587184.	650509.	710798.	768570.	824426.	878702.
10	Waterpl. Area mm^2	0.0	196503.	244536.	280611.	309383.	333044.	352723.	369249.	383097.	394575.	403954.
11	Prismatic coeff. (Cp)	0.000	0.422	0.530	0.582	0.611	0.630	0.643	0.652	0.660	0.665	0.671
12	Block coeff. (Cb)	0.000	0.239	0.308	0.344	0.366	0.382	0.394	0.405	0.414	0.422	0.430
13	Max Sect. area coeff. (		0.724	0.721	0.724	0.720	0.727	0.727	0.730	0.738	0.742	0.747
14	Waterpl. area coeff. (C	0.000	0.766	0.784	0.792	0.793	0.792	0.790	0.786	0.782	0.778	0.774
15	LCB from zero pt. (+ve	596.8	463.0	494.4	506.4	513.1	517.5	520.7	523.2	525.1	526.7	528.1
16	LCF from zero pt. (+ve	596.8	522.2	528.6	532.0	534.3	536.0	537.3	538.3	539.2	539.9	540.5
17	KB mm	-312.9	31.1	40.0	49.7	59.0	67.7	76.0	83.9	91.5	98.8	105.9
18	KG mm	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0
19	BMt mm	0.0	3433.6	2148.7	1651.6	1371.6	1185.2	1049.7	944.5	859.5	788.6	728.1
20	BML mm	0.0	2445.1	1573.9	1234.2	1040.0	908.2	810.3	732.4	668.0	613.0	564.8
21	GMt mm	-512.9	3264.7	1988.7	1501.3	1230.6	1052.9	925.8	828.4	751.0	687.5	634.0
22	GML mm	-512.9	2276.2	1413.9	1083.9	899.0	775.9	686.4	616.4	559.6	511.8	470.7
23	KMt mm	-312.9	3464.7	2188.7	1701.3	1430.6	1252.9	1125.8	1028.4	951.0	887.5	834.0
24	KML mm	-312.9	2476.2	1613.9	1283.9	1099.0	975.9	886.4	816.4	759.6	711.8	670.7
25	Immersion (TPc) tonne/	0.000	0.002	0.003	0.003	0.003	0.003	0.004	0.004	0.004	0.004	0.004
26	MTc tonne.m	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
27	RM at 1deg = GMt.Disp.	0.0	284.9	347.0	393.0	429.5	459.5	484.6	506.0	524.3	540.0	553.3
28	Max deck inclination de	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
29	Trim angle (+ve by ster	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Figure 9: Water streamlines

	Speed (m/s)	Froude No. LWL	Froude No. Vol.	Holtrop Resist (N)	Holtrop Power (W)	Van Oortmerssen Resist. (N)	Van Oortmerssen Power (W)	Series60 Resist. (N)	Series60 Power (W)	Compton Resist. (N)	Compton Power (W)	Fung Resist (N)	Fung Power (W)	Kilt Barge Resist. (N)
9	0.6000	0.184	0.307	2.19	1.75	1.00	1.35	0.74	0.59	7.00	5.06	1.36	1.00	6.69
10	0.6750	0.207	0.346	2.73	2.43	2.14	1.93	1.07	0.98	9.00	8.10	1.39	1.25	8.48
11	0.7500	0.230	0.384	3.26	3.36	2.61	2.61	1.46	1.46	11.63	11.83	1.59	1.59	10.45
12	0.8250	0.253	0.422	3.87	4.25	2.89	3.17	1.93	2.13	14.83	18.31	1.85	2.03	12.64
13	0.9000	0.276	0.460	4.52	5.42	3.45	4.14	3.01	3.61	19.62	23.54	2.14	2.57	15.04
14	0.9750	0.299	0.499	5.22	6.78	7.12	9.26	4.23	5.50	26.34	32.04	2.46	3.20	17.66
15	1.0500	0.322	0.537	5.98	8.37	6.37	7.52	4.68	5.71	32.72	45.81	2.81	3.94	20.48
16	1.1250	0.345	0.576	6.79	10.18	1.19	1.79	5.59	8.39	41.44	62.17	3.18	4.77	23.51
17	1.2000	0.368	0.614	7.65	12.24	2.45	3.91	10.90	17.44	49.51	79.22	3.57	5.72	26.75
18	1.2750	0.391	0.652	8.58	14.58	10.13	17.22	–	–	57.88	98.38	3.99	6.78	30.19
19	1.3500	0.414	0.691	–	–	20.88	36.14	–	–	73.32	131.98	4.42	7.96	33.85
20	1.4250	0.437	0.729	–	–	38.03	53.36	–	–	95.80	182.32	4.87	9.28	37.72
21	1.5000	0.460	0.767	–	–	31.90	63.79	–	–	122.58	246.15	5.35	10.69	41.79
22	1.5750	0.483	0.806	–	–	31.54	66.24	–	–	154.47	324.48	5.84	12.27	46.08
23	1.6500	0.506	0.844	–	–	27.92	61.42	–	–	184.67	406.27	6.36	13.90	50.57
24	1.7250	0.529	0.882	–	–	22.28	51.24	–	–	197.79	464.88	6.89	16.04	55.27
25	1.8000	0.552	0.921	–	–	15.76	37.83	–	–	210.49	505.18	7.44	17.88	60.18
26	1.8750	0.575	0.959	–	–	9.23	23.08	–	–	217.20	542.99	8.01	20.04	65.30
27	1.9500	0.598	0.998	–	–	3.25	8.46	–	–	222.81	579.38	8.61	22.38	70.63
28	2.0250	0.621	1.036	–	–	–	–	–	–	–	–	9.22	24.09	76.16
29	2.1000	0.644	1.074	–	–	–	–	–	–	–	–	9.86	27.67	81.91
30	2.1750	0.666	1.113	–	–	–	–	–	–	–	–	10.50	30.44	87.87
31	2.2500	0.689	1.151	–	–	–	–	–	–	–	–	11.18	33.49	94.03
32	2.3250	0.712	1.189	–	–	–	–	–	–	–	–	11.85	36.74	100.40
33	2.4000	0.735	1.228	–	–	–	–	–	–	–	–	12.56	40.10	106.99
34	2.4750	0.758	1.266	–	–	–	–	–	–	–	–	13.28	43.83	113.78
35	2.5500	0.781	1.305	–	–	–	–	–	–	–	–	14.02	47.65	120.78
36	2.6250	0.804	1.343	–	–	–	–	–	–	–	–	14.78	51.75	127.99
37	2.7000	0.827	1.381	–	–	–	–	–	–	–	–	15.56	56.03	135.40
38	2.7750	0.850	1.420	–	–	–	–	–	–	–	–	16.36	60.64	143.03
39	2.8500	0.873	1.458	–	–	–	–	–	–	–	–	17.18	65.25	150.87
40	2.9250	0.896	1.496	–	–	–	–	–	–	–	–	18.01	70.25	158.91

Figure 10: Water streamlines

V. Acknowledgment

The Idea of creating the team and making it able to participate in this competition wouldn't have become a fact without all the generous contributions and support of our college Administrations, Staff members, and supervisors of the team. It helped us by providing funds and the necessary equipment to the team, so they are one of the main reasons for what we have reached so far.

Thank you for your support

References

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[2] Lentin Joseph (2015) Mastering ROS for Robotics Programming.

[3] Hydrodynamic modeling of planning catamarans with symmetric hull.

[4] 2023-RoboBoat_Team-Handbook_v3

[5] RoboBoat submission Reviews

Appendix A: Component List

	Vendor	Model/Type	Specs	Custom/Purchased	Cost	Year of Purchase
ASV Hull Form/Platform	Local	CATAMARAN	withstand high lo	Custom	600$	2023
Waterproof Connectors	BLUEROBOTICS	ENCLOSURE VEN	O-RING WATERT	Purchased	400$	2023
Propulsion	BLUEROBOTICS	T200	-	Purchased	200$	2023
Power System	Amazon	Lead Acid	432 Wh	Purchased	70$	2023
Motor Controls	BLUEROBOTICS	BASIC ESC	30AMP/26V	Purchased	36$	2022
CPU	INTEL	NUC 11 PRO	CORE I7 11th GEN	Purchased	500$	2021
Teleoperation	Tp-Link	EAP110-Outdoor	External 2x5dBi c	Purchased	90$	2021
Compass	VectorNav	vn-100	-	Purchased	1200$	2023
Inertial Measurement Unit (IMU)	VectorNav	vn-100	-	Purchased	1200$	2023
Camera(s)	logitech	C930s	pro HD webcam	Purchased	130$	2023
Hydrophones	Aquarian Audio	H2A HYDROPHO	-	Purchased	170$	2023
Vision	SLAMTEC	RPLIDAR A2	25 m RANGE RED	Purchased	200$	2021
Localization and Mapping	EMLID	REACH RS+	9DOF IMU / 9-CHA	Purchased	800$	2021
Autonomy	IMPLEMENTED	ROS	-	Custom	-	2023
Open Source Software	Ubuntu	16.04 LS	-	Custom	-	