Barunastra ITS: Nala G.4

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***Abstract*— Nala G.4 is a catamaran autonomous boat designed by Barunastra ITS Roboboat Team in order to compete in the Annual International Roboboat Competition 2019. This technical design report contains the plan, process, and trial error during the preparation. All the reasons behind every decision have been carefully thought out by the team to reach the goal that Nala G.4 is able to give the best performance in the competition.**

***Keywords*— Autonomous, Barunastra ITS, catamaran, Nala G.4, roboboat.**

I. Introduction

Figure 1. Nala G.4 at the premiere launch

Nala G.4 is an autonomous vessel designed by Barunastra ITS Roboboat Team to take part in the 12th International Roboboat Competition. The word of Nala itself stands for Naval Autonomous, which Barunastra ITS Roboboat Team always puts the Nala word as the first name of the boat. While the meaning behind G.4 itself is that Nala G.4 is the fourth boat by the team to participate in the international competition.

Technically, there has been a lot of improvement on Nala G.4 compared to the previous boats. Starting from the boat's hull base material to the object detection algorithm used. This report will discuss in more depth about the preparation, strategies, and reasons behind other technical decisions.

II. Competition Strategy

A. Autonomous Navigation

The first mission that must be carried out by Nala G.4 is to able to navigate automatically or known as autonomous navigation. Overall, the system used was adapted from the system used last year. The difference is that we do not use image processing anymore but is improved by object detection using a camera placed on the ship's forecastle. The first thing to do in this mission is to determine two waypoints using a GPS placed in the superstructure of the front of the ship. Waypoints are used for positioning the ship and determining the destination point. Object detection is useful for detecting the first pole/gate, then the ship is controlled to pass the pole by taking the midpoint of the second pole (at the first gate).

B. *Speed Challenge*

The second mission is speed challenge. To do this mission, the method used is almost the same as the autonomous navigation mission. There are two waypoints, which are in the entrance gate and around the blue ball object. The first waypoint is before the red and green balls as the gate, and then by using object detection the midpoint of the gate is obtained. The second waypoint is intended for the boat to go to the blue ball. When the boat is close enough to the blue ball, with object detection the boat is required to turn around the blue ball counter-clockwise, as the blue ball positioned on the left side of the boat until the boat faces one waypoints. The boat returns to the gate by detecting one waypoints and object detection to determine the midpoint.

Figure 2. Detection on Turning Point

C. *Automated Docking*

The next mission is automated docking. We use waypoint and wall-follower algorithms. First, the boat has to go to the initial waypoint in front of the dock; the boat approaches the dock and plays it using a wall-follower algorithm to get the emitted signals by the beacon. Once the active beacon is found, the boat stores the waypoint based on that location and continues to circle the dock until the forecastle leads to the initial waypoint, then it starts to dock by going to the waypoints where the active beacon is located.

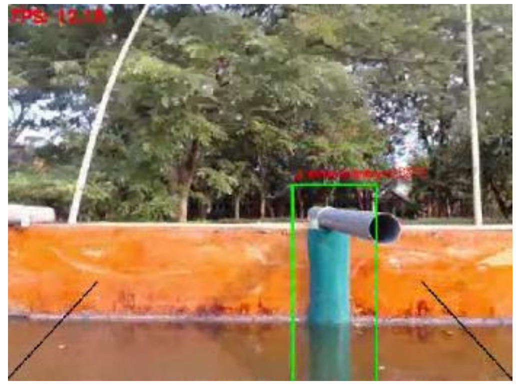

Figure 3. Object Detection on the Dock

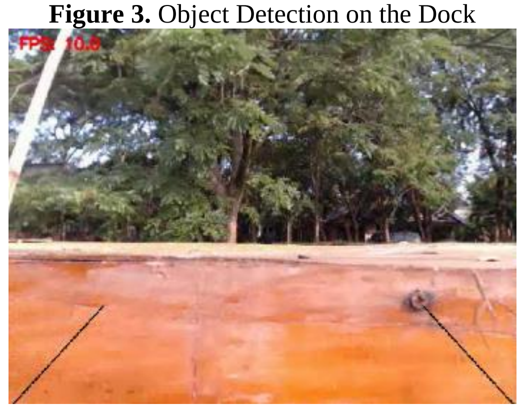

Figure 4. Trial on Automated Docking Mission

D. *Raise the Flag*

Raise the Flag is the fourth mission that must be completed. This mission is quite challenging for us because this is the new one and needs the drone to finish the mission. In order to complete this mission, we used wall-follower algorithms, camera and waypoint to detect the dock. First is the drone was flown to detect 7-segment module below. Once detected, the 7-segment module is classified to find out the actual number. Then, the boat turning round the dock with the wall-follower algorithm to find the flag that corresponds to the 7-segments.

E. *Find the Path*

The next mission that the boat must do is Find the Path. In order to complete this mission, we use the SRF or proximity sensor placed on the boat's bow section and waypoints as its navigation. First, the boat heads to the initial waypoints around the obstacle arena. First, the boat is required to find an entrance using proximity sensors and object detection to avoid obstacles until the buoy is detected. Once detected, the boat turning around the buoy (counter-clockwise) until the forecastle of the boat leads to the initial waypoints.

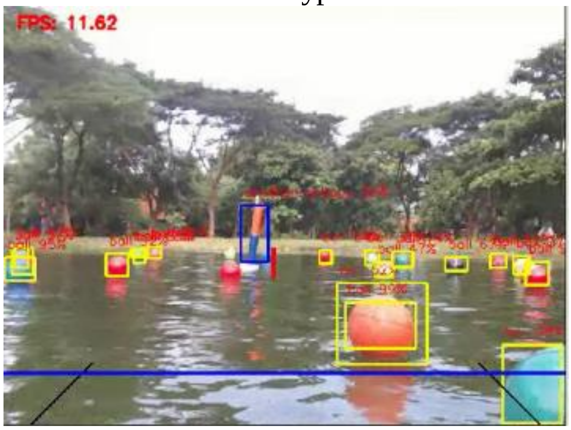

Figure 5. Detecting the Balls Colour

F. Return to Dock

The last mission that must be carried out by Nala G.4 is to be able to be back home after the long voyage crossing the ocean. Return to dock is a new mission, but the algorithm has been used in previous missions. Waypoints are used for positioning the boat and determining the destination point, while to avoid obstacles in front of the boat, we use SRF as a sensor.

Figure 6. Detecting Objects

III. Design Creativity

In this chapter, will discuss more deeply about technical matters relating to the boat and electronic systems.

A. Hull Design and Construction

The catamaran hull is once again the choice for the Nala G.4 boat after several previous competitions have been used. In choosing the form of the hull, we always adjusts the needs and functions of the boat. At this International Roboboat Competition, we see that we need the smooth manoeuvres and high stability for the boat, thus we choose the catamaran hull to be able to carry out the mission more easily and provide more space on the deck.

Our goal in Nala G.4 design is to prioritize the functional and dimensions of the boat's body. Compared to its predecessor, Nala G.4 has smaller dimension with a wider space on the deck by not separating the two hulls, simplifying several systems, and giving some improvements to the boat's base material. The material we chose for Nala G.4 is the carbon fibre reinforced plastic composite which is used on the hull and the superstructure building. The carbon fibre we use has reduced boat weight by 73.3% when compared by using glass fibre. In addition, carbon fibre also tends to be stronger than fibre glass [1].

Table 1. Length, Width, Height, Draught, and Displacement Maximum Capacity of Nala G.4

Measurement	Value	Unit
Length	0.88	m
Width	0.49	m
Height	0.30	m
Draught	0.15	m
Displacement Max.	20.99	kg

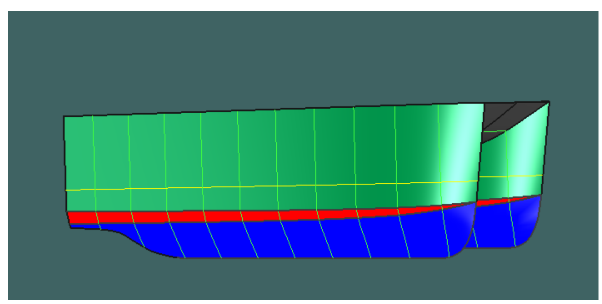

Figure 7. The Boat Design by Maxsurf

In the boat designing process, we used Maxsurf and SolidWorks to do the design. Figure 7 shows the visualization of 60% progress of the entire design of Nala G.4 with Maxsurf.

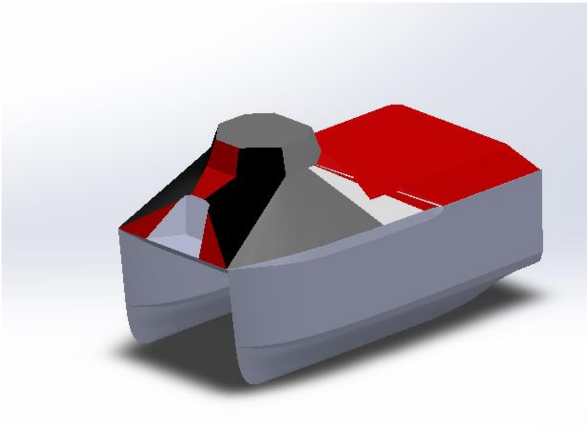

Figure 8. Nala G.4 on SolidWorks

Specifically, the type of catamaran hull we choose is the symmetrical catamaran because, in addition to having more space, the symmetrical catamaran has a bigger displacement instead of the asymmetric. Also, the axe bow type that we have considered can reduce the planning effect caused by collisions with waves [2].

B. System

In 2019 International Roboboat Competition, we use electronic components that are not much different from the previous. We use SRF US10 and Lidar Tfmini for the sensors. As the main electronic component, STM 32F407, Servo, T-Motor on drone, T-200 for the boat propulsion systems, and USB TTL FTDI. We use a USB cable as the PC and STM connector thus the commands from PC can drive motor and servo. Meanwhile DSSS/FHSS Receiver retrieves the data processed on a microcontroller. We send data from GPS and compass to PC using Pixhawk 2 PX4 while sending data from SRF to our laptop using Arduino.

In order to make troubleshooting easier, we are now no longer using mini PC as our motherboard but we have decided it into MSI GL63 8SE and Nvidia Jetson TX2, the other reason is that we need the GPU for object detection. We use Ubiquiti M5 as our networking system to connect the boat and the team base. Ethernet connects the rocket (Ubiquiti M5) to the laptop and we use power-over-Ethernet as the power supply. More about the system architecture will be shown in the appendix.

IV. Experimental Result

In this section, we will explain our processes in the face of trial and error and our work plan a few months ago.

We had started manufacturing the boat hull by designing the boat moulding since the end of December 2018 and began purchase materials that would be needed. The process of design, moulding, until the boat is ready for the trial was complete in the second week of March 2019. It was quite time-consuming because we tried new basic material that is carbon fibre. We were still adjusting so there were some mistakes that we made it as the learning process.

Moving to the electronics and programming side, research on object detection has been carried out since the Q4 of 2018. Errors in classification certainly occurred before finally achieving stability in detecting the objects. In our mission experiments, we focused on allowing the boat to run smoothly on Speed Challenge missions, Find the Path, Return to Dock, and Automated Docking. After the four missions went smoothly we did an intense training for the Raise the Flag mission during the month of May and did many exercises for 7-segment classifying with various numbers, colours and fonts. As part of the training process, we also moved the challenge arena to make sure the boat really could carry out the mission under different conditions. In an effort that we have done in the last few months, of course, we hope that Nala G.4 can compete very well.

V. Acknowledgements

Our participation in this year competition is certainly not separated from the support of our advisors, Mr Rudy Dikairono, S.T., M.T. and Mr Andhika Estiyono, S.T., M.T. who gave us such constructive advice and motivation from both technical and non-technical aspects.

Also, PT Telekomunikasi Indonesia, an information and communication company; PT PLN, electricity company; PT Nindya Karya; PT Perta Arun Gas; IKOMA ITS, and 17 other companies that have become our sponsors.

We would also like to thank the Bayucaraka ITS Team, a team that focuses on unmanned aerial vehicles, who has given the guidance regarding the design of our team's drones.

VI. References

[1] C.-M. Lee, J.-W. Yu, J.-E. Choi and I. Lee, "Effect of bow hull forms on the resistance performance in calm water and waves for 66k DWT bulk carrier," *International Journal of Naval Architecture and Ocean Engineering*, vol. 11, no. 2, pp. 723-735, 2019.

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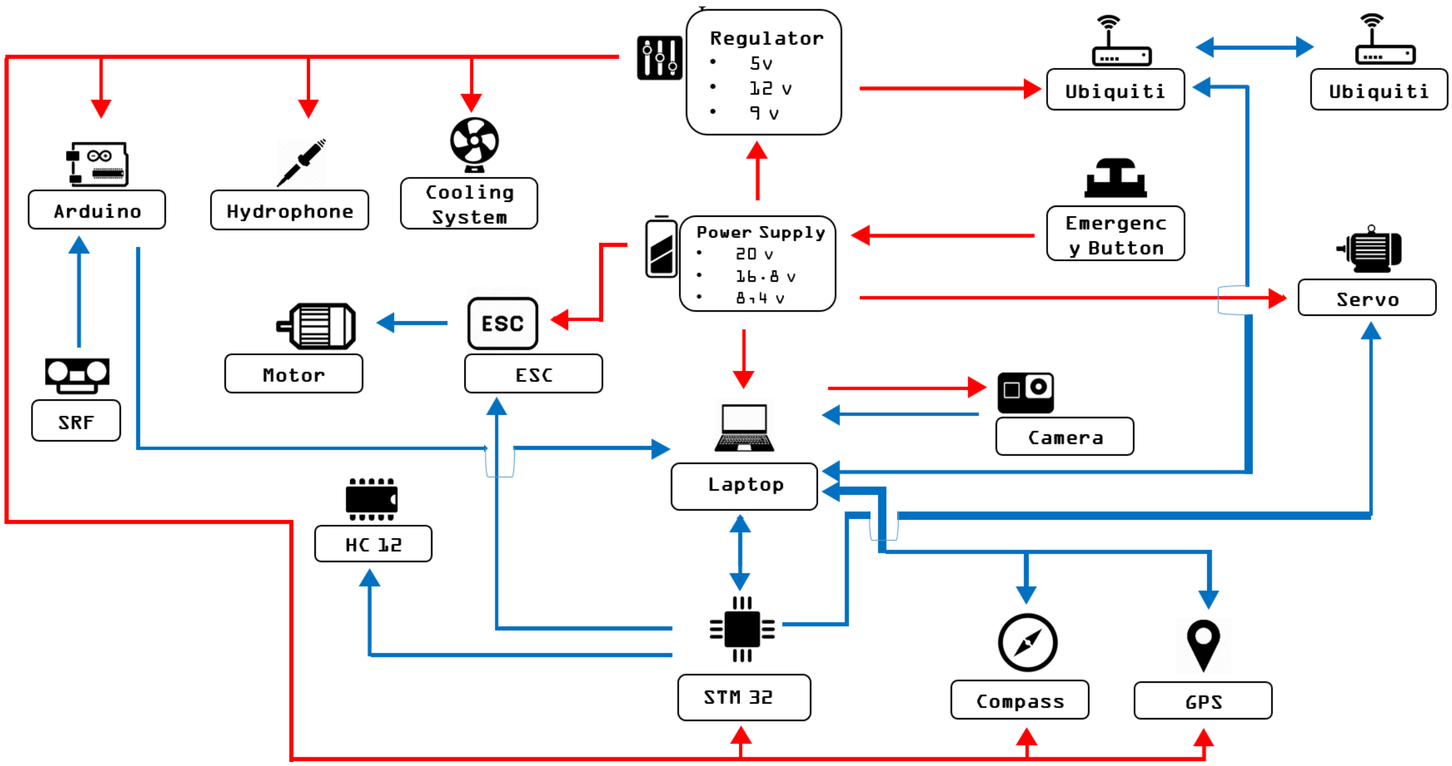
APPENDIX A: ELECTRICAL SYSTEMS



APPENDIX B: COMPONENTS SPECIFICATION

No	Component	Vendor	Model/Type	Specification	Qty	Cost per each (USD)	Total (USD)
Drone System							
1	Aerial Vehicle Platform	DJI	DJI Frame F450			11	11
2	Motor and Propeller (4 Motor)	T-Motor	T-Motor	2212/920KV		30	120
3	Power System	FLOUREON	Lithium Polymmer	5500 mAh 35C 4S 16 Mhz, 16 analog Pin, 54 D I/O, 256KB Flash Memory	1	70	420
4	Microcontroller	Arduino	Mega 2560	16 Mhz, 16 analog	1	15	15
5	CPU	Pixhawk	Pixhawk 2.1	Include Here GPS, Nice Flight, Controller, Compass	2	300	600
6	AutoPilot	Mission Planner	Mission Planner				
Mechanics and Electrical Systems							
7	ASV Hull	Handmade, Semi vacuum with *Carbon Fibre*	Catamaran Flat Side Inside	LOA = 0,9 m D = 0,3 m T = 0,15 m B = 0,5 m			568
8	Waterproof Connector						
9	Propulsion	Blue Robotics	Azipod T200 Propulsion System	Each : Thrust 5.1 kgf and Power 350 watts	2	310	620
10	Azimuth Systems	Hand Made		Gear Type		107	321
11	GPU	MSI	GL63 8SE		1	1600	1600
12	Microcontroller	STM	STM32F407	10 x 10 mm, Cortex -M4 core, 168 MHz	2	35	70
13	Teleoperation	Ubiquiti Network	GP-B240-100	5 km range, 150 mbps, 27 dBm, 5.8 GHz	1	700	
14	Camera	Logitech	C922	HD 1080		97	97
15	Hydrophone	Aquarian Hydrophone	H1A		1	159	159

No	Component	Vendor	Model/Type	Specification	Qty	Cost per each (USD)	Total (USD)
16	Light Detection and Ranging	TFMini LiDAR				50	
17	CPU	Nvidia	Jetson TX2		1		
Algorithm and Strategy							
18	Algorithm	Global Navigation Satellite System, Wall Follower, Object Avoidance, YOLOv3 Object Detection, Image Classification					
19	Vision	1 Camera-Logitech C922			1	105	105
20	Acoustics	STM32 Oszi Library					
21	Localization and Mapping	GUI and Mapping with QT Creator					
22	Autonomy	Combine All of that					
Team							
23	Team Size	18					
24	Expertise Ration (hardware vs software)	7 vs 5					
25	Simulation	2 months					
26	Test in water	3 months					
27	Inter-vehiclecommunicatio n	basic wiring and soldering, schematic design					
28	Programming Language	C/C++, Python					