Barunastra ITS: Nala Heroes

Khalif Aji Puspito
Team Barunastra ITS
Institut Teknologi Sepuluh Nopember
Surabaya, Indonesia
khalifaji10@gmail.com

Adhi Duta Baskara
Team Barunastra ITS
Institut Teknologi Sepuluh Nopember
Surabaya, Indonesia
adbaskara@gmail.com

Muh Hisyam Khoirudin
Team Barunastra ITS
Institut Teknologi Sepuluh Nopember
Surabaya, Indonesia
hisyamkhoirudin@gmail.com

Wikandhana Siddha Rajasa
Team Barunastra ITS
Institut Teknologi Sepuluh Nopember
Surabaya, Indonesia
wikandhana.rajasa19@gmail.com

Luthfi Halim
Team Barunastra ITS
Institut Teknologi Sepuluh Nopember
Surabaya, Indonesia
lhluthfihalim@gmail.com

Iqbal Mabruri
Team Barunastra ITS
Institut Teknologi Sepuluh Nopember
Surabaya, Indonesia
iqbal.mabruri@gmail.com

Alivza Sontonojaya
Team Barunastra ITS
Institut Teknologi Sepuluh Nopember
Surabaya, Indonesia
alivza.sontonojaya@gmail.com

***Abstract*— Nala Heroes is a fully autonomous surface vehicle (ASV) designed by Team Barunastra ITS with a custom modular catamaran hull made for entering the 2018 International Roboboat Competition. Compared with previous boats made for entering the competition, the Nala Heroes is far more enhanced and unique. This paper focuses on discussing the competition strategy, the design creativity of the boat and system, and the experimental results that the team has obtained through months of research and practice. With the innovative features the Nala Heroes possesses, and the time spent to research and practice the vehicle, it is hoped that the Nala Heroes can successfully finish all the missions in the competition.**

Keywords*— *Autonomous surface vehicle, modular, catamaranl, enhanced, strategy, creativity, results

I. Introduction

Figure 1. The Nala Heroes

Nala Heroes is Team Barunastra ITS' boat designed specifically for competing in the 2018 International Roboboat Competition. The Nala Heroes is made with improvements from previous entries in all aspects. This year, the mapping ability, algorithm, and sensors of the Nala Heroes have been significantly enhanced and are hoped to lead Team Barunastra ITS' victory.

This technical design report focuses on the competition strategy of the team, the design creativity, and the experimental results of Team Barunastra ITS' endless struggle. Details of the components specifications and the team outreach activities are explained in the Appendages. Through this technical design report, it is hoped that the readers get a better understanding of the team's strategic thinking, design and engineering decisions.

II. Pre-Competition Strategy

Being number one has always been the team's goal. Since this year is Team Barunastra ITS' third year in participating in this competition, the team targets to finish all the tasks with the best performance. Due to the limited amount of time for the preparation, Team Barunastra ITS had to find the best way to be able to finish all the missions. Team Barunastra ITS then came up with conducting parallel research. Research on image processing, user interface, data acquisition, machine learning, etc. have all been done parallel. This parallel research technique saves plenty of time and makes finishing all the tasks given possible.

Before carrying out research, Team Barunastra ITS arranges a well-planned strategy and timeline. After arranging the team strategy and the preparation timeline, mission 1 (Autonomous Navigation), 2 (Speed Challenge), and 4 (Find the Path) are researched simultaneously. From the research, a system is then developed. After the system has been developed, testing was then carries out. Mission 1, 2, and 4 were tested individually and then tested all at once to see the full-run performance. The results of the testing were satisfying, but the team keeps on testing the missions to see if there are any possible problems the team might encounter in the future.

Meanwhile testing missions 1, 2, and 4, the team carries out research and develops the system for missions 3 (Automated Docking) and 5 (Follow the Leader). Since Follow the Leader Task has a lower level of difficulty than the Automated Docking Task, the team prioritizes in finishing research on the fifth mission first. Testing of the fifth mission is then executed and, in that meantime, research on the third mission is carried out. After obtaining decent results from the fifth mission, the team then runs missions 1, 2, 4, 5 respectively in one run to see the overall performance of the Nala Heroes. Due to the complexity of mission 3, in this meantime, research on the third mission still runs.

After research on the third mission is done, testing is then carried out, starting with testing out the hydrophone then testing the drone on land. The results obtained from the testing were very satisfying. Although the results were well, to this date, the team rarely tests the drone on the boat to prevent unnecessary problems from happening to the drone.

All the missions are then carried out in one run to see and get a visualization of how the Nala Heroes will perform in the competition. Although the results were decent, to date, the team is still perfecting running all the missions to obtain the maximum results. It is hoped that by the time the team arrives to Florida, all missions can be finished with the best performance.

To get a better understanding, the in-depth explanation of the experimental results will be explained in section five.

III. COMPETITION STRATEGY

In this 2018 International Roboboat Competition, Team Barunastra ITS plans to take and accomplish every single challenge in the competition. The team's strategy is to complete the easiest task first and the hardest last. Team Barunastra ITS' strategy in approaching every single mission will be described in the following section in the order of completion.

A. *Autonomous Navigation (Mission 1)*

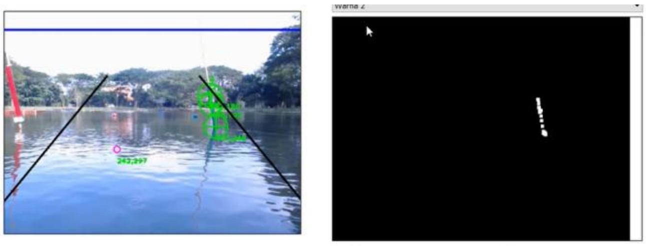

Figure 2. Autonomous Navigation Challenge trial

The first task taken by the team will be the mandatory Autonomous Navigation Challenge. Nala Heroes is to go from one waypoint to another. The team will predict the first waypoint before the first gate and the second waypoint after the second gate. The team also uses image processing algorithm to calculate the midpoint between the two gates. The boat is designed to prefer image processing over waypoint navigation, thus if the boat sees the two gates clearly, the boat will use image processing for navigation.

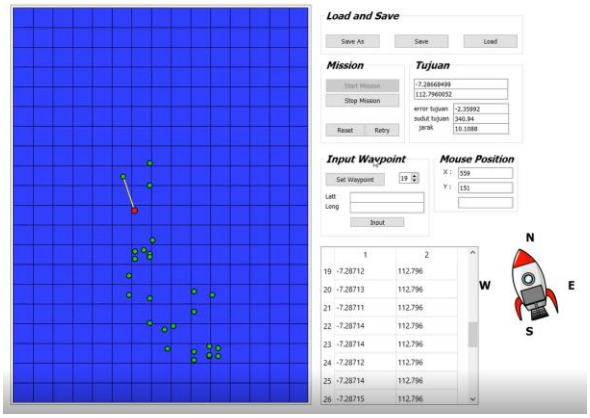

Figure 3. Waypoint navigation

The reason behind the combination of the two navigation methods is to increase the accuracy of navigation and to prevent the boat from navigating out of bounds.

B. *Speed Challenge (Mission 2)*

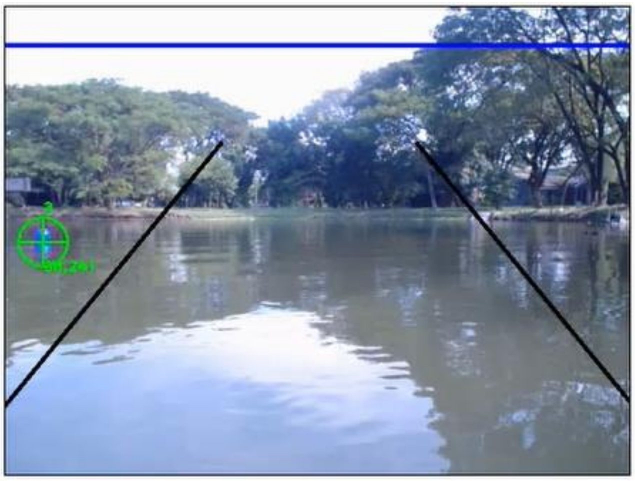

Figure 4. Running the Speed Challenge

The second task taken by Nala Heroes will be the the speed challenge. For this challenge, the boat will use the similar navigation techniques as the autonomous navigation task. The difference is that in this mission, the boat will go from one waypoint to another waypoint beyond the blue ball and go back the start waypoint. The boat will navigate with image processing alternately, where the boat is programmed to avoid the blue ball, making the ball always left of the boat. Since the team aims to be the fastest boat in this task, the additional middle thruster (explained in section 3) will be activated upon entering the task.

C. *Find the Path (Mission 4)*

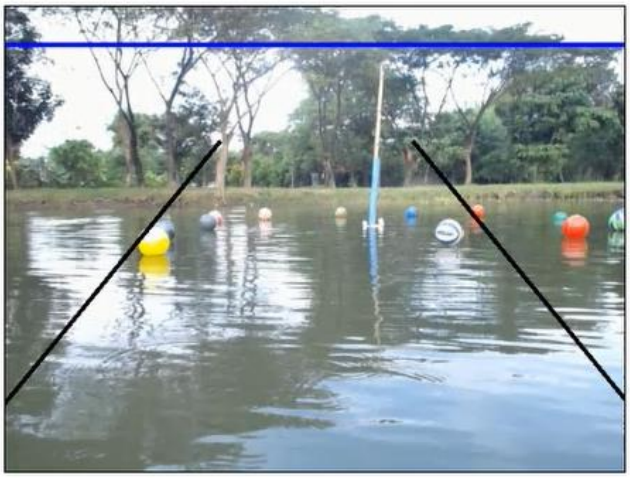

Figure 5. Entering the Find the Path Challenge

The third mission taken by Nala Heroes will be Find the Path. For this mission, the boat will use the proximity sensors (located at the forecastle of the boat) and waypoints to navigate through the course. The boat will use waypoints to enter, circle, and exit the course. The proximity sensors are used simultaneously to avoid the obstacles inside the course.

D. Follow the Leader (Mission 5)

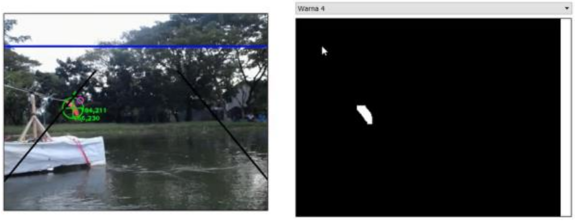

Figure 6. Find the Path testing

The fourth mission taken by Nala Heroes will be Follow the Leader. After entering the mission, the boat will use image processing to track and follow the red flag. A wall-tracer algorithm is then used to follow the wall of the floating platform. To make sure the boat does not go too fast or too slow, the speed of the boat is determined by the image processing of the flag by the boat.

E. Automated Docking (Mission 3)

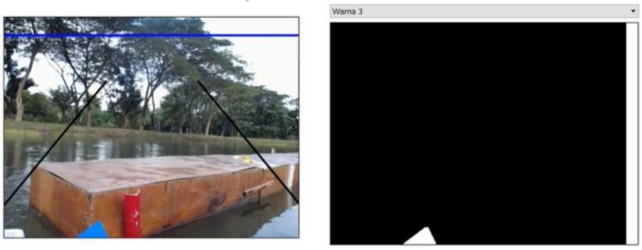

Figure 7. Automated docking testing

The Automated Docking mission is planned to be taken last because of its complexity and difficulty. The boat is to find the active pinger, launch the drone to take a picture of the number on the platform, and navigate to with the corresponding dock.

To start, the boat will be using a wall-follower algorithm to follow the platform wall. Using a hydrophone, the boat will determine the dock with an active pinger. The boat will then dock and activate the drone to launch to the platform. The drone then will use a built-in camera to take a picture of the platform and fly back to the boat. To process the picture, machine learning algorithm is used. After obtaining the correct number, a timer (which has been set prior to the competition) is used to move forward or backwards to the designated dock.

IV. DESIGN CREATIVITY

This section focuses more towards the new innovations and the creative aspects of Nala Heroes' system. The team's experience in making both architectural/ design decisions and system engineering decisions will also be discussed in this section.

This year, based on various considerations, Team Barunastra ITS takes a different approach in designing the boat. Team Barunastra ITS prioritizes functionality over aesthetics, thus compared with previous boats, the Nala Heroes is designed with a higher complexity.

A. Boat

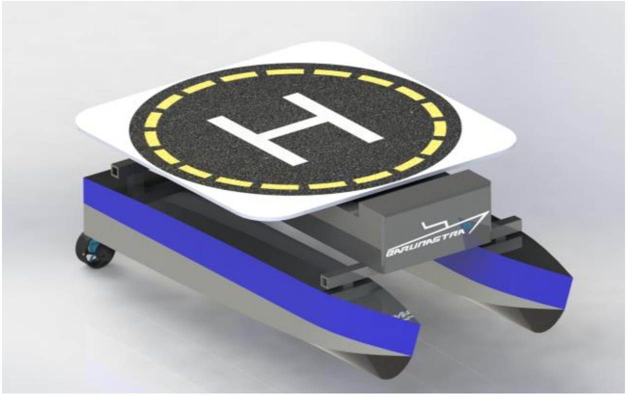

Figure 8. The Boat Design

The hull design applied by Team Barunastra ITS is a symmetrical catamaran hull. As previous years, the team prefers a catamaran hull over any other hull type due to the added stability and the additional space. Also, like the previous year, the Nala Heroes is made modular so that it can easily be taken apart and transported. Nala Heroes uses a wave interference bow to prevent the boat from planing. Being even keel at operational speed helps the sensors to read the terrain with minimal problems.

A design innovation that the team came up with and is very different from previous boats is the separated middle superstructure. The middle superstructure is where all the electronics are placed. With the middle superstructure, the component layout can be neater, and electronics short-circuits can be avoided even if water enters the hull. The separation of hull and superstructure/ a central processing unit also helps the boat to be more modular.

This year, the Nala Heroes has improved propulsion system. Unlike previous years, instead of using a traditional rudder, Nala Heroes uses a T200 propulsion system to have increased maneuverability. Since Nala Heroes is rather heavier than other contestants and the T200 only adds maneuverability, the team figured that to score high and win the speed challenge, more speed is needed. To solve the problem, the team chooses to add an additional propulsion in the middle of the boat to add more speed specifically for the speed challenge. It is hoped that with the added propulsion, Nala Heroes can be up to par, if not, faster than other boats.

B. System

For the 2018 International Roboboat Competition, the system of the boat has gone through major improvements. Overall, the system and component layout are well organized. Learning from previous experience, the team also sees that there are additional components that may be needed suddenly. The team provides extra slots in every sensor so that in case an electronic component must be added, it can be added with ease, without having to unplug other components. The power distribution board of the Nala Heroes is also centralized, making the system more concise.

Data collection is taken from each sensor on the boat and is spread out to various microcontroller, avoiding interference and lag from the data collected. Since all data processing is centralized in the mini PC, the data from the microcontrollers will all then be sent to the mini PC.

The main navigation method of the Nala Heroes is waypoint navigation, meaning that smooth GPS data is needed. To obtain a smoother and higher accuracy data, the Nala Heroes utilizes two GPS'. These two GPS correct one another, giving a more optimized result than using one GPS.

V. Experimental Results

Team Barunastra ITS divides the testing/ experimental phase into two phases. The first is the seldom phase and the second is the intense phase. The seldom phase is from months November through February and the intense phase is from months March through June.

Months November through December, Team Barunastra ITS focuses more towards the production of the boat. As last year, the team experiments more with the block construction method. After various experiments, the results of the block design were very satisfying as there was no leakage in the hull and the connection were all watertight.

January, the team began to develop the user interface and began testing system. The team started testing with the GPS. Testing of the GPS Ultimate Adafruit were conducted and the results obtained were not very pleasing. The GPS data obtained were very unstable. To solve the problem, the team changed the GPS used for the boat.

February, the team tried the first and second mission. While running the first mission, the team found that the GPS data were not too accurate, and the data obtained were still not stable. Seeing this problem, instead of changing the GPS, Team Barunastra ITS added one more GPS, with the hopes of increased accuracy. For the second mission, the team ran it well the first few tries but observed that the boat needed more speed, thus the team planned to add more thrusters.

March, Team Barunastra ITS tried to run the fourth mission. The results were satisfying, so the team decided to add more buoys. After adding the buoys, the boat struggled to finish the course as it always got stuck and hit the buoys. Seeing this problem, Team Barunastra ITS added an additional proximity sensor. The results were better, but the aft part of the boat kept hitting the buoy. No solutions were found seeing this problem. In this month, the team also installed an additional thruster mid of the boat and ran a few tests. The results of the runs were more satisfying than before as the boat ran faster.

In April, Team Barunastra ITS tested the fifth and third mission. The image processing ability of the boat was tested for the fifth mission. The results were good, but the boat tends to hit the platform and go out of bounds. With the help of the proximity sensors, the team added an algorithm for the boat to keep distance from the platform. The results were not too pleasing, so the team added a LIDAR to add a wall follower algorithm. The testing done for the third mission in this month was trying to obtain the pinger data using the hydrophone and the results were good.

May through June the team tried the automated docking mission. The wall follower algorithm was used to circle the dock and find the pinger but the boat often docked from behind because the boat read the pinger from behind. The team then tried to read the red color in front of the dock so that the boat can differentiate the front side and the back side. The results were satisfying as the boat successfully docked for the first time. A timer was used for the second docking attempt and the results were satisfying, but adjustments with the timing were needed.

Since Team Barunastra ITS plans to run the third mission, the team also experiments with the drone. The team wanted to make a waterproof drone, thus fiberglass was used. The results were not pleasing as the drone was too heavy and unstable. The team then tried to experiment with balsa as the material of the body, but the drone was still unstable. The team assumed that the problem lies in autopilot, so the team changed the autopilot from APM to Pixhawk. The drone was still unstable; thus, the team concluded the problem lied in the material of the body. The material of the drone cabin was then changed into Styrofoam. The results were satisfying so the team proceeded to testing the drone on water. The testing was a success.

With the testing results so far, Team Barunastra is optimistic that the Nala Heroes will do great in the 2018 International Roboboat Competition.

Acknowledgments

The participation of Team Barunastra ITS in the 2018 International Roboboat Competition is possible due to support from various parties. First, Team Barunastra would like to thank ITS and IKOMA for giving the team moral and financial support as well as facility to run the research. The team research would not be possible without the support of ITS.

Second, Team Barunastra ITS would like to thank the sponsors of the team. Big thanks to PT. Waskita Karya dan PT. Saligading Bersama for being the main sponsor of the team. The team would also like to thank PT. Krakatau Steel, PT Pertamina, and other sponsors for supporting Team Barunastra ITS.

We would also like to thank other parties that have helped made participating in the competition possible such as Team KRTI for helping the team's drone, ITS Robotics, and other parties that cannot be mentioned one by one.

References

[1] Setyawan, D. *et. al*. (2010, Nov). Development of catamaran fishing vessel. *The Journal fo Technology and Science*.[Online]. *21(4)*. pp. 167-174. Available: iptek2.its.ac.id/file/Development%20of%20Catamaran%20Fishing%20Vessel.pdf

[2] Catamaran boat hull construction, by N.R. Hesher Etal. (1962, Dec 11). *Patent 3,067,711* [Online]. Available: www.fiberglassics.com/library/images/5/51/Duopatent.pdf

[3] Luhulima, R. B. *et. al.,* "Selecting monohull, catamaran and trimaran as suitable passenger vessels based on stability and seakeeping criteria", presenterd at The 14th International Ship Stability Workshop (ISSW), Kuala Lumpur, Malaysia, Sept. 29- Oct. 1, 2014

APPENDIX A: COMPONENT SPECIFICATIONS

No	Component	Vendor	Model/Type	Specification	Cost Each (USD)	Total (USD)
Ship Mechanics and Electrical System						
1	ASV Hull Form/Platform	Handmade, with fiberglass as basic materials	Catamaran Ponton	LOA = 1.35 m, D = 0.25 m T = 0.12 m, B = 0.75 m	0	315
2	Waterproof Connector	-	-	-	0	0
3	Propulsion (3 Motor)	Blue Robotics (with Modification)	Azipod T200 Propulsion System	Each: Thrust 5.1 kgf and Power 350 watts	310	930
4	Power System (6 Batteries)	FLOUREON	Lithium Polymer	2-4s 5200mAh 30 - 35C	50-70	400
5	Motor Control (microcontroller)	STMicroElectronics	STM32F4VGT6	1 Mbyte of on-chip Flash memory, 192 Kbytes of SRAM, ART Accelerator, 32-bit,	42	42
6	CPU	Gigabyte	GB-BSi3A-6100	Intel(R) Core(TM) i3-6100U CPU @ 2.30GHz (4 CPUs), ~2.3GHz RAM 8 GB	510	510
7	Teleoperation	Ubiquiti Network	GP-B240-100	5 Km range, 150Mbps, 27dBm, 5.8Ghz	700	700
8	Compass		Cmps11	3-axis (magnetometer,gyro,accelerometer) with kalman filer, 16bit Data, 0.1 accuracy degree	42	42
9	GPS	Ublox	NEO 7M GPS Module	1.5m accuracy	25	50
10	LiDar	SeedStudio	TF Mini LiDar	12m distance 2-degree accuracy	80	80
11	Proximity Sensor (UltraSonic)	-	US-100	4.5m distance, 40Khz Ultrasonic wave	5	20
12	Camera	Logitech	logitech Webcam c930	3MP, 1080 30 fps	76	76
13	Hydrophone					

No	Component	Vendor	Model/Type	Specification	Cost Each (USD)	Total (USD)
			Drone System			
14	Aerial Vehicle Platform	Tarrot	Tarrot Frame FY650	Fiber Carbon	130	130
15	Motor and Propeller (4 Motor)	Tarrot	Tarrot	2814/700KV	150	600
16	Power System (1 Batteries)	FLOUREON	Lithium Polymmer	5500 mAh 35C 4S	70	70
17	Microcontroller	Arduino	Arduino Mega 2560	16 Mhz, 16 analog Pin, 54 D I/O, 256KB Flash Memory	25	25
18	CPU	Pixhawk	Pixhawk 2.1	Include Here GPS, Nice Flight Controller	400	400
19	Camera	Xiaomi	Smartphone Camera	HD 720	150	150
20	AutoPilot	Mission Planner	Mission Planner			
			Algorithm and Strategy			
21	Algorithm	GPS + Compas Navigation System, Wall Follower, Object Avoidance				
22	Vision	Image Processing OpenCV Library				
23	Acoustics	STM32 Oszi Library				
24	Localization and Mapping	GUI and Mapping with QT Creator				
25	Autonomy	Combine All of that				
			Team			
26	Team Size	21				
27	Expertise Ration (hardware vs software)	3vs2				
28	Simulation	2 months				
29	Test in water	3 months				
30	Inter-vehicle-communication	basic wiring and soldering, schematic design				
31	Programming Language	C/C++				

APPENDIX B: OUTREACH ACTIVITIES

Team Barunastra ITS does not only focus on the competition. The team itself participates in and holds various activities. Activities that the team participates in is joining various exhibitions and fairs to educate the society about autonomous surface vehicles/ roboboats. The last activity Team Barunastra ITS joined was a small exhibition in a grand iftar event for foster children held by the alumni of ITS. The purpose of the exhibition was to educate the foster children so that they get motivation to continue their studies. Team Barunastra ITS presented and taught the children about boats and robots so that the children get a better understanding of the excitement of higher education. The team hopes that what the team has conveyed can motivate the little children.

Besides participating in events, Team Barunastra ITS holds an annual internship program for freshmen. The main purpose of the internship is to select the few that have potential to continue Team Barunastra ITS, but the team also aims to educates all the freshmen through the process. The team sees that once a freshman is accepted into the internship program, they cannot leave empty-handed, thus every day the freshmen are taught and trained different things. Based on the division they chose; the freshmen are taught everything that has to do with the division. The electroprogrammers are taught programming and how to handle the electronics of the boat. The mechanics are trained to design and build a mini boat throughout the internship. Whereas the officials are trained and taught how to present, handle sponsorship, etc.