BARUNASTRA AUTONOMOUS SURFACE VEHICLE

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***Abstract*—This paper describes the design and implementation of the Barunastra autonomous surface vehicle for entry into the 9th Association for Unmanned Vehicle Systems International Foundation's 2016 RoboBoat Competition, held in Virginia Beach, Virginia. Barunastra is an autonomous surface vehicle developed by Institut Teknologi Sepuluh Nopember's students to complete the autonomous mission tasks in the competition. Barunastra Team has developed innovative features to complete the challenge, these features are hull and propulsion design, rudder system, android smartphone for image processing and GPS, and custom deck deployment system for interoperability mission task.**

***Index Terms*—Barunastra, Autonomous Surface Vehicle, Triple blade rudder, Android smartphone, crane equipped deck system**

I. INTRODUCTION

Barunastra is a Catamaran style autonomous surface vehicle designed and developed by students at Robotic Lab, Institut Teknologi Sepuluh Nopember. This is our first entry participating AUVSI Roboboat Competition, though the research team has been established since 2012. In 2015, Barunastra became the winner at the regional roboboat competition in Indonesia. It makes the team had the courage to participate in International AUVSI 2016 Competition. Barunastra ITS team consists of undergraduate students majoring Electrical Engineering, Mechanical Engineering, Naval Architecture and Shipbuilding Engineering, Marine Engineering, and Information System. The goal of the team is accomplish all mandatory tasks, such as buoy navigation, obstacle avoidance, automated docking, acoustic beacon positioning, also launch and recovery an Autonomous Underwater vehicle from the ASV's deck.

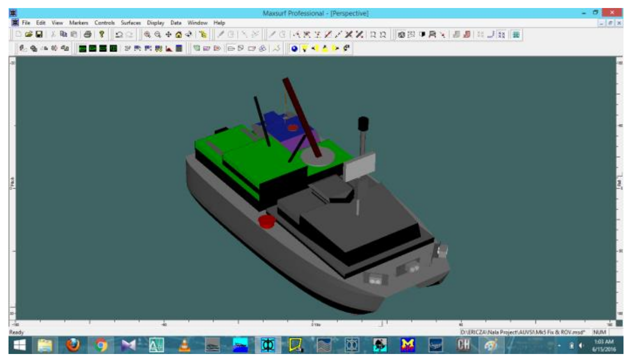


Figure 1.1. Barunastra ASV (2016)

The final Design of Barunastra was developed with solutions to achieve these tasks, including a stable and maneuverable catamaran hull platform, UUV sub vehicle and its deployment deck, and Android integrated system.

II. DESIGN STRATEGY

Barunastra ITS team is divided into 4 divisions, they are Electronic division, Mechanical division, Software Programming division, and Official division. Due to the limited funding that is divided into research and team accommodation for the competition, the team has to spend it wisely and overcome the limited fund by using Android Smartphone camera, GPS, and compass feature as the robot sensors to substitute the expensive electronics hardware and sensors. The team working time is spent by developing ASV capability until it is mechanically ready then is tested in field to improve reliability for each mission.

III. MECHANICAL

Barunastra was designed to achieve speed maximum at 14 knots. To reduce the planning, some heavy hardware such as battery placed in the forepeak as ballast.

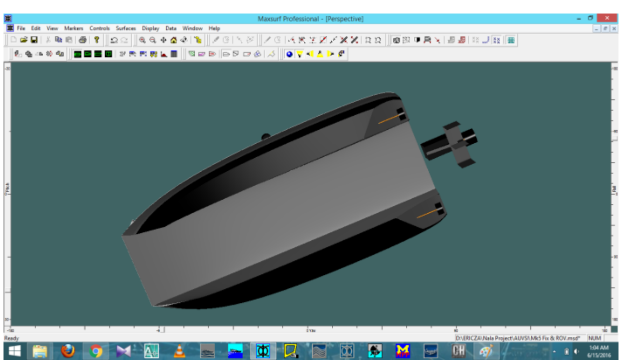
A. Design Process and Methodology

The design processes of the ASV are research, establishing design requirement, feasibility study, conceptualization, preliminary design, detailed design, and production plan.

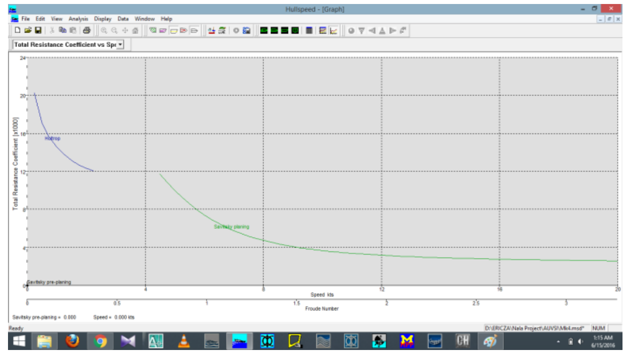
The research of the ASV has begun since 2012, from that year the team has already researched on catamaran-style and trimaran-style type hull. Based on the research, the team concludes that the catamaran is the most suitable design because its balance both in stability and maneuverability, especially for roboboat competition missions. The design requirement for this ASV is based from the missions that the need of 360 degree maneuver need the 360 degree maneuver and high stability. The preliminary design include the hull design that impact to the placement and maximum weight of the ASV components.

After the preliminary design, the team conducting detailed design of the ASV by determining what is the most suitable component of the ASV and adding detailed system specification for the design.

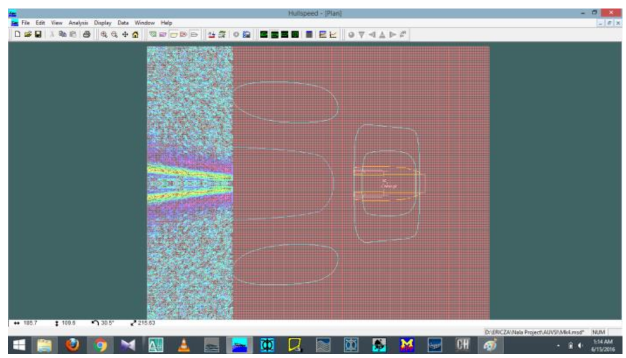
B. Hull Design



The hull design of Barunastra is a Catamaran-style. The advantages of catamaran are low resistance and high stability. Barunastra needs high stability for the great accuracy of sensors. Catamaran is also designed as for easy maneuver

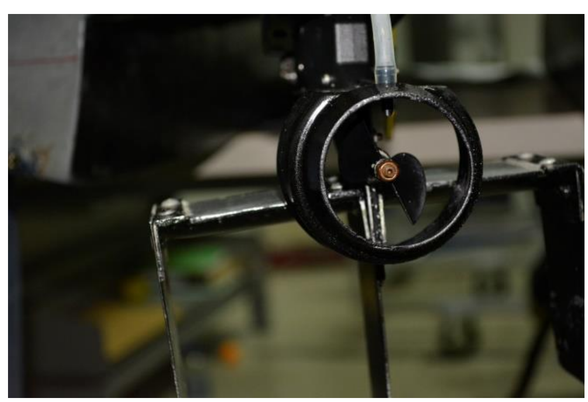


From the picture above we can see the speed (x) VS resistance coefficient (y) of catamaran also has a great value.



The picture above explains the effect of *wave making* from this boat. We can see that the *wave making* does not disturb the boat so the resistance will not increase because of the increasing of the speed.

C. Steering System



Barunastra Nala steering system is a combined differential and outboard motor. It uses outboard motor to direct the flow of water to make the boat turn. The outboard motor is operated by directing the propeller so the thrust from propeller will make the boat turn.. The outboard motor is the main steering system of Barunastra Nala and the differential thrust used for turning by 360 degree. The mechanism of this system is using propeller that is located in both portside and starboard-side of the boat to thrust it with difference direction that causes the boat to turn by 360 degree. The steering system of Barunastra Nala is also supported by the M configuration rudder below the main propeller. It helps the boat to turn by increasing the drag in one side of the boat to make the boat turn beside of the direction the flow of water by outboard motor. Furthermore, the M configuration rudder helps the system to decrease the high of rudder to have the same amount of drag that Barunastra Nala needs.

D. Propulsion System

Barunastra Nala has 2 propulsions, these are the main propulsion and the secondary propulsion. The main propulsion is located in the center of the while the secondary one is located in both portside and starboard-side of the boat. The main propulsion is used for the whole missions and the secondary just used for turning by 360 degree and boosting the boat for navigation gate mission. The secondary propulsion system uses 4.5cm diameter twin-mirrored 2 blades propeller. It is the most efficient and suitable to hull. We have used 3 blades but the result is not good as the 2 blades propeller. This propulsion system has main contribution to the steering system. Without this propulsion system this boat can't turn. This propulsion also has difference shafting. It is difference from the main and the secondary propulsion. The main propulsion uses 1.19:1 reduction gear as a joint and a flexible shaft. Each of secondary propulsion system uses a flexible joint and a fixed shaft. The flexible joint helps the system to increase the reliability of fixed shaft, because it usually breaks when the configuration is sloppy.

E. Final Specification

These are the final hull specifications of the ASV.

no	Measurement	value	unit
1	Displacement	9.56	kg
2	Volume	8351.61	cm^3
3	Draft	9	Cm
4	Immersed depth	9	Cm
5	Lwl	97.39	cm
6	Beam wl	49.63	cm
7	Wsa	3667.33	cm^2
8	Max CSA	114.33	cm^2
9	Waterplan are	1914.78	cm^2
10	Cp	0.75	
11	Cb	0.524	
12	Cm	0.699	
13	Cwp	0.841	
14	Lcb from zero pt	-4.549	Cm
15	Lcp from zero point	-5.94	Cm
16	KB	4.44	cm

IV. ELECTRICAL

A. Hardware Architecture

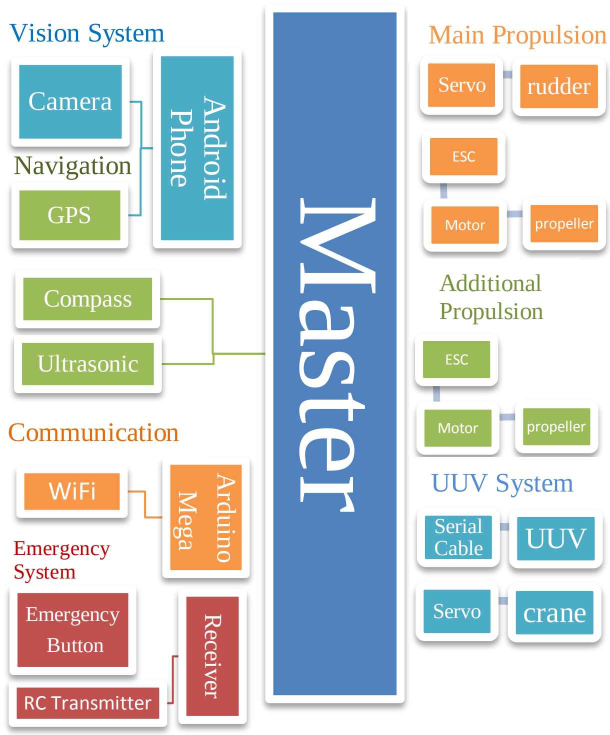


Figure 4.1. Hardware Architecture

Figure 4.1 describes the hardware architecture of Barunastra. Barunastra uses Master ARM microcontroller STM32 Discovery and several slaves. The slaves are for vision and communication system to the server. The first slave is vision system that uses an android phone while the communication slave uses Wi-Fi shield equipped with arduino mega. Barunastra also uses additional sensors aside from Vision based sensor for navigation. These are GPS, compass, and ultrasonic sensor. The actuators are the main propulsion system, additional propulsion system, steering system, UUV deployment system, hydrophone deployment system, and logo attachment system for automated docking.

B. Computer and Communication System

Barunastra computational system can be divided into 3 parts. The main part is the master ARM microcontroller STM32F4 Discovery to process the sensor data and the algorithm, and command the actuators.

The second computational system is Android smartphone. Aside from camera and GPS sensor, Barunastra uses android smartphone for image processing. The android sends 8-bit processed data to the ARM microcontroller through serial communication via Bluetooth.

The other computational system is Arduino Mega equipped with Wi-Fi module to communicate with server.

C. Sensors and Actuators

The sensor suite used on Barunastra is including: Camera and GPS built in on an Android phone for object identification and navigation, compass for direction, and ultrasonic for range measurement.

The main reason of using an Android phone is to substitute digital camera, GPS sensor, and on-board processing to overcome limited fund. Beside, Android built in camera is more powerful than any other average webcam for the same price because it has additional useful features such as autofocus, white balance, and auto exposure. The most useful feature is auto exposure because it can automatically adapt the change of lights intensity of an environment, so the image data will not become too bright or too dark when the light intensity changes.

Barunastra uses the camera to identify objects by size, shape, and color. The android phone processes the image data then send it along with GPS data.

The GPS is used to navigate through mission. The compass sensor combined by the GPS is used to determine its movement direction. Additional 3 ultrasonic sensors are used to avoid an obstacle when it’s too close and camera fail to detect the object.

For detection of submerged sonar pings, a hydrophone sensor will be deployed when the mission begins. Ranging to the activated sonar pings is achieved using a combination of *time-of-flight* calculation.

D. Emergency System

Barunastra has 2 emergency systems to ensure safety for safe operation, those are on-board and wireless. An emergency stop button is installed on the vessel to terminate both power to the system and the on-board thruster. Other than that, a wireless manual control was developed via remote control to interrupt any process. The manual control signal is sent directly to the master microcontroller.

E. Power Management

Energy storage is provided by 3 units of four cells. They are 16.8 Volt Lithium Polymer batteries for thruster that provide up to 20 Amp hours, 1 unit of Two cell 8.4 Volt Lithium Polymer batteries for system and sensors, and Lithium-ion battery for android phone. Power regulation is provided through the regulator control board at 12V and 5V to power the on-controller system, sensors, and other on-board electronics.

V. SOFTWARE

A. Software Managemant

The software management of Barunastra is shown in figure 5.1

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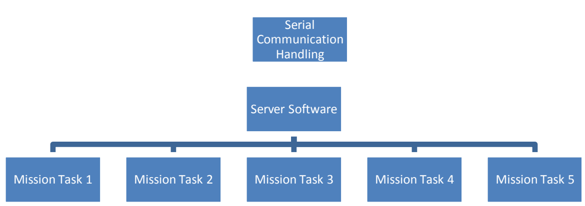

Figure 5.1. Software Architecture

The serial communication handling for this system is the arduino and its Wi-Fi shield that make communication to committee and Software server. The server software makes decision which mission should be conducted based on what's is in the server data.

B. Heading Control System

The heading control system uses digital compass. The compass data is processed in master microcontroller to make set point heading. After the ASV determines the set point heading, the ASV will use PD control.

C. Navigation System

The navigation system uses GPS data from android, then it is processed in master microcontroller to determine where the ASV position and where the ASV should navigate based on the data sent via server.

VI. COMPETITION CHALLENGES

The Multiple Challenges of The Roboboat competition are designed to evaluate the capability and reliability of the ASV platform. These challenges include Gate Navigation Test, Obstacle avoidance, Automated Docking, Deploying Sub-vehicle, localization of submerged acoustic beacon, and interaction with the judge's network. The algorithm to navigate near the mission is similar for every mission. Barunastra utilizes GPS to locate the ASV near the given mission location, then uses image processing to detect the parameters for mission identification.

A. Gate Navigation Test

The purpose of this task is demonstrating the hydrodynamics, controllability and basic sensing abilities of the vehicle. The ASV must pass the entrance gate then speed through the speed gate as fast as possible. Once the ASV enters the mission, it will attempt to go straight using compass sensor to control the vessel with conventional PD controller until the camera detects the speed gate. Once camera detects the speed gate, the Android phone will send a dot representing the center of the gate then those data will be added as a compensation of the compass sensor for set point of the PD control.

B. Obstacle Avoidance

The purpose of this task is demonstrating the ability of plotting a course and correctly classify similar looking buoys as obstacles or navigation buoys. For this mission, the ASV uses additional ultrasonic sensors. The ASV will navigate use compass as the heading set point. The camera and ultrasonic sensor is used to detect buoys.

C. Automated Docking

Barunastra will run the vision algorithm to identify the sign after navigating the coordinates of the docking challenge. Afterwards, the ASV will execute a sequence of docking maneuvers. To make sure the ASV is successfully docked, a servo-based actuator is installed to the vessel to attach team name into the hooked side of the dock.

D. Interoperability Challenge

The purpose of this task is to launch, recover, and communicate ASV to AUV sub-vehicle in the designated area. After the ASV enters the mission, the ASV will navigate to the launch point using image processing and compass. It will launch the AUV by using the crane system on deck. Once the AUV launched, it will navigate itself to reach the underwater display then detect the number using camera and send the data to the ASV. After that, the AUV will go back to the ASV. The ASV later will recover the AUV using the crane system.

E. Acoustic Beacon Location

The purpose of this task is demonstrating the ASV ability to navigate based on underwater acoustic beacon even when multiple beacons are active in the same vicinity. Barunastra only has one hydrophone sensor, so the strategy is to encircle each buoy then give report when it receives some signal from the acoustic beacon.

VII. CONCLUSION

This year, the team focuses on the hull, propulsion system, and software management. After the development of the most suitable mechanics system of the ASV, the team then focuses on the electronics and software management. The result is an ASV with high stability, maneuverability, and capability to complete the missions given from the Roboboat 2016 competition.

VIII. ACKNOWLEDGEMENT

The Barunastra ITS Team would like to thank everyone that has supported us through years on this project, including: Institut Technologi Sepuluh Nopember Robotics Lab, Robotics club, Hydro-modeling club, and Marine Technology and Innovation club.

We also would like to thank to our sponsors, including: Pertamina Lubricants, Garuda Indonesia, Pertamina Shipping, PT KAI, IKOMA ITS, PT Jasa Marga, PP (Pembanguan Perumahan), Daya Radar Utama, Petrokimia Gresik, BKI, and Saligading Bersama for supporting us to make this project success.

IX. REFEERENCE

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