Makara 09 Mark II - Autonomous Surface Vehicle

Alif Hikmah Fikri[1], Ahmad Mufin Rosyadi[2], Ardanto Finkan Septa[3], Atikah Syahidah[4], Auli Rahman[5], Bagus Arya Tjitrosoemarto[1], Fadhil Azharrisman@ui.ac.id[5], Fahmi Ismail Wibisono[5], Fahri Alamsyah[6], Farolina Rahmatunnisa[3], Fikih Muhamad[2], Goldy Tanjung Wijaya[6], Grace Missrani[2], Hansel Matthew[2], Irfan Rahadi Kurnianto[5], Joshua Alviando[2], Miftahul Khoir Shilahul Umam[2], Muhammad Arif Budiyanto[1], Muhammad Miftah Farid[6], Nathaniel Faustine[6], Ones Sanjerico Sitanggang[2], Pratama Prananda Rachmat[7], Radityo Fajar Pamungkas[2], Ricad Ragapati[5], Suryadi[2], Yoga Dwi Adityaputra[5]

1. Naval Architecure, Department of Mechanical Engineering, Univesitas Indonesia
2. Electrical Engineering, Department of Electrical Engineering, Faculty of Engineering, Universitas Indonesia
3. Computer Science, Faculty of Computer Science, Universitas Indonesia
4. Chemical Engineering, Department of Chemical Engineering, Faculty of Engineering, Universitas Indonesia
5. Mechanical Engineering, Department of Mechanical Engineering, Faculty of Engineering, Universitas
6. Computer Engineering, Department of Electrical Engineering, Faculty of Engineering, Universitas Indonesia
7. Physics, Department of Physics, Faculty of Mathematics and Natural Science, Universitas Indonesia

alif.hikmah@ui.ac.id[1], ahmad.mufin@ui.ac.id[2], ardanto.finkan@ui.ac.id[3], atikah.syahidah@ui.ac.id[4], auli.rahman@eng.ui.ac.id[4], bagus.arya@ui.ac.id[1], fadhil.azharrisman@ui.ac.id[5], fahmi.ismail71@ui.ac.id[5], fahri.alamsyah@ui.ac.id[6], farolina.rahmatunnisa@ui.ac.id[3], fikih.muhamad@ui.ac.id[2], goldy.tanjung@ui.ac.id[6], grace.missrani@ui.ac.id[2], hansel.matthew@ui.ac.id[2], irfan.rahadi@ui.ac.id[5], joshua.alviando@ui.ac.id[2], miftahul.khoir@ui.ac.id[2], arif@eng.ui.ac.id[2], muhammad.miftah81@ui.ac.id[6], nathaniel.faustine@ui.ac.id[6], ones.sanjerico@ui.ac.id[2], pratama.pananda81@ui.ac.id[7], radityo.fajar71@ui.ac.id[2], ricad.ragapati@ui.ac.id[5], suryadi76@ui.ac.id[2], yoga.dwi61@ui.ac.id[5]

Abstract—Makara 09 Mark II is an autonomous surface vehicle designed and built by students of Universitas Indonesia to participate in 12th AUVSI International RoboBoat Competition 2019 which is held by AUVSI Foundation in Reed Canal Park, South Daytona, Florida, on 17-23 June 2019. This journal explains the details of the technologies used by the ASV: the hull design, electrical system, software integration and sensors used. The journal also elaborates the innovations made in the ASV like the rotational propeller design using servo and the use of machine learning to enhance image processing of the ASV.

Index Terms—Makara 09 Mark II, Autonomous Surface Vehicle, Technology details, Rotational Propeller, Machine Learning.

I. Introduction

Makara 09 Mark II is an autonomous surface vehicle designed and built by the students of Universitas Indonesia from various major that are joined in the research team of Autonomous Marine Vehicle Universitas Indonesia (AMV UI). The design of Makara 09 Mark II is the latest and the most sophisticated design in order to accomplish the missions on AUVSI Roboboat Competition 2019. This is the fourth time for Universitas Indonesia to compete in AUVSI Roboboat Competetion in which AMV UI have participated in 2012, 2016, 2017, and 2019. In 2018, AMV UI became the runner up on the National Roboboat competition in Indonesia. The Achievement courages us to develop better ASV and then participate in the 12th AUVSI International Roboboat Competition this year.

II. MECHANICAL

A. Hull Design

The hull concept that is used by Makara 09 Mark II is the catamaran concept, the concept of using two hulls symmetrically on the both side of ASV. The decision of using the catamaran concept was based on past experience of designing and literature study.

Fig. 1 Makara 09 Mark II ASV

The catamaran concept is currently being adopted and researched worldwide for the perfection and development of patrol boats and navy vessel. Compared to the mono hull concept, the catamaran concept has many advantages. Less energy used at high speed, greater stability which caused by the side hulls that support the main hull, larger deck area due to the larger beam of the ship, those are the advantages of the catamaran concept compared to the mono hull concept [1]. In Makara 09 Mark II ASV, the material used for the ASV is balsa wood. The decision of using that material was based on its good strength-to-weight ratio and also it is malleable so it could easily use to produce the ASV body. This ASV was designed using Bentley Maxsurf 20 application for designing the concept of the ship. The configuration of the hulls was placed in such way to reduce more drag [2].

B. Propulsion
Furthermore, to move the ASV, two T200 Bluerobotics thrusters are used. To get maximum performance, those thrusters are placed on the back of the lower hull. A servo is also installed in each thruster with the azimuth propeller so it will have a shaft to move. The servo-controlled shaft is useful for helping thruster movements when turning so that the turning radius of the ship are not too large.

Fig. 2 Propulsion Makara 09 Mark II

C. Cooling System
The cooling system that used in the Makara 09 Mark II ASV is aimed to transfer heat that were produced by the electronic hardware inside of the ASV to outside of the ASV. On this ASV, the air-cooling system was chosen because it was considered more efficient. Air circulation in Makara 09 Mark II is supported by 6 ventilators, of which two ventilators are on the front, two on the top side of the electrical board, and two other ventilators are on the back of the ASV. This USV is also implementing a fan for the air circulation. Ventilators located on the front function as a place for incoming air flow. The presence of a ventilator on the front helps electrical components and computers (NUC) get air that helps reduce heat in that section. Air that has been mixed with heat released by electrical components and the NUC is released through two ventilators on the back of the ASV.

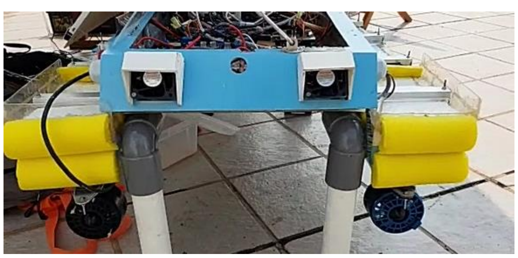

Fig. 3. Cooling System of Makara 09 Mark II

ASV Specification		
Length	1.04	m
Beam	0.70	m
Height	0.35	m
Draft	0.12	m
Displacement	14	kg

Table 1. Makara 09 Mark II Specification

III. ELECTRICAL

A. Power Management

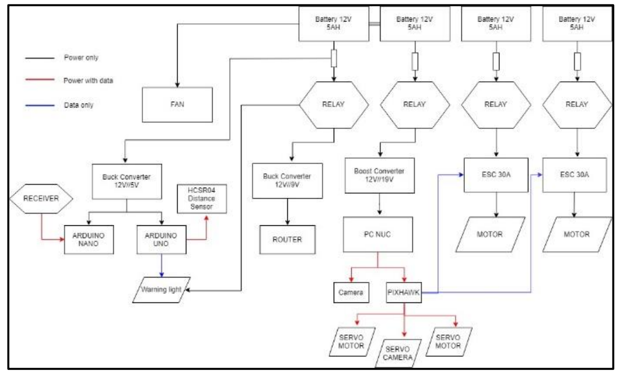

Fig. 4 Power Distribution Diagram of Makara 09 Mark II

Makara 09 Mark II has electrical resources derived from four Lithium Polymer (LiPo) batteries with capacity of 3 cell 5000 mAh and works at a voltage of 12 V and produces an output current of 30 A. The four batteries are connected to a fuse that functions as a circuit breaker in the circuit if the current is too large. Then, fuse is connected to a relay that functions to turn on or turn off the electronic circuit of the ASV from the remote control when remoted mode. The current from the relay is then divided into five lines. The first line is a buck converter that converts the voltage to 5 V, which then used by router. There is another line where the current flows to the 12V/5V buck converter. The buck converter is connected to Arduino Nano, on which attached the receiver and Arduino Uno, on which attached HCSR04 ultrasonic sensor for distance detection, and warning light.

In addition, the second line is connected to the step-up transformer. The task is to increase the voltage to 19 Volts. The voltage is used by NUC, camera and Pixhawk on the Makara 09 Mark II. The power and data from NUC flow to the camera and pixhawk. From the pixhawk, power and data are flown to the kill-switch and servos to work. Servos (left and right) are used to move the azimuth propeller on the thruster. Furthermore, on another two lines, the current flows to ESC 30A which regulates the movement of the thruster.

There is a connection which directly flows from the battery and not using the fuse and relay, which is the connection to the fan. The fan is used for the cooling system, which works on 12A current. The operation of the boat is fully enabled by using the student-developed circuit boards and some commercial off the-shelf technology.

B. Control System
In order to have all of the mission tasks done properly, the Makara 09 Mark II boat must implement a reliable control system. It uses a combination of Intel NUC, camera, Pixhawk, Arduino nano, navigation system, and propulsion system, all achieve the favoured control system.

Intel NUC is the place where all of the programming of high-level language is compiled as well as executed, and it has a full-featured ground station application software namely Mission Planner which is used as a configuration utility or as a dynamic control supplement for the boat when put in autonomous mode. Intel NUC stores all of the activities recorded by the camera, either it be pictures or videos, into the computer database that is used for further processing which is the image processing. Processing of images implements mathematical operations by using any form of signal processing for which the input is an image, a series of images, or a video, such as a photograph or video frame, and that the output of image processing may be either an image or a set of characteristics or parameters related to the image. The results of the data of the image processing is then sent to the Pixhawk.

Pixhawk is an open source flight controller platform that is able to control autonomous vehicles. It acts as the low machine language that is able to control the actuators in correspondence with the output signals of Pixhawk by means of electronic speed controls (ESCs). ESC is an electronic circuit that serves the purpose of an electric motor's speed, its direction and possibly also to act as a dynamic brake. The Pixhawk is tuned by using a PID (Proportional-Integral-Derivative) algorithm which is a technique of a closed-loop control system that try to get the actual result closer to the desired result by adjusting the input in the hope of achieving stability.

There are three algorithms in a PID controller consisting of P, I, and D respectively. P depends on the present error, I on the accumulation of past errors, and D is a prediction of future errors, based on current rate of change. These controller algorithms are eventually translated into software code lines. Then there is Arduino Nano is used in the system as well. The Arduino Nano is a microcontroller board based on the ATmega328 and it has 14 digital input/output pins in which 6 can be used as PWM outputs, 6 analog inputs, an onboard resonator, a reset button, and holes for mounting pin headers. In this system, Arduino Nano plays an essential role. It is used to process the data transmitted by the remote control which is given to the relay of the system.

In order to enhance its safety, Ultrasonic sensors HCSR04 are implemented on the USV. If the distance of the HCSR04 is close to the edge of the pond or another object, the warning light will be turn on.

C. Wireless Kill Switch

The Makara 09 Mark II boat should be able to be stopped whenever there is an emergency signal with diagram of the signal shown 5. The wireless kill switch system is basically a system implemented in the boat so that the boat itself can have an emergency stop by instantly cutting out the power of the controller unit circuit and driver unit circuit. Kill switch system using a PWM signal. The pulse of signal had previously been measured so that the range could be gain when it is low and high. After the pulse had been determined, the codes are then constructed according to the range that had been specified. Based on the pulse measured (+/-1000 up to +/-1900), a variable is set to have a value of 1500 so that the on and off state for the system. By default, on the RC, +/-1000 is set when the position is down while +/-1900 is set when the position is up and the parameter used for all the pulse measured is 9600 baud rate. All of the pins are correctly connected already according to our favor. The RC receiver is connected to the channel pins placed on the microcontroller as the corresponding input pins. On the other side, the output pins are then connected to each appointed component.

IV. System Integration

A. Navigation

The boat uses Garmin GPS HVS 17x as the data GPS receiver. Max232 is used to convert RS232 data that produced by Garmin GPS HVS 17x to TTL data protocol. Pixhawk is receiving the TTL data that contains GPS data directly from Max232. A Pixhawk is used to receive waypoint data uploaded by source code that developed by our team. Mission Planner is used to validate waypoint that had been uploaded to the Pixhawk. The boat's movement is controlled by Pixhawk that connected to ESC. Pixhawk receive the data from Intel NUC and GPS, afterwards Pixhawk will process the data and control the speed and direction of the boat with PID method. PID Method is a conventional and effective method to control boat's speed.

B. Image Processing

Color Detection

Makara 09 Mark II using OpenCV library for image processing, especially for color detection. OpenCV uses color threshold for color detection. Object must have significant color difference with the background in order OpenCV can detect object's color.

OpenCV usually capture images and video in 8-bit, unsigned integer, RGB (Red, Green, Blue) format. RGB format then will be converted into HSV (Hue, Saturation, Value) format. Hue represents the color, saturation represents the amount to which that respective color is mixed with white, and value represents the amount to which that respective color is mixed with black. Hue is unique for that specific color distribution of object. Saturation and value may be varied according to the lighting condition of that environment. Object HSV value will be matched with the color HSV configuration. If the HSV value matched, then OpenCV will do some noise reduction method.

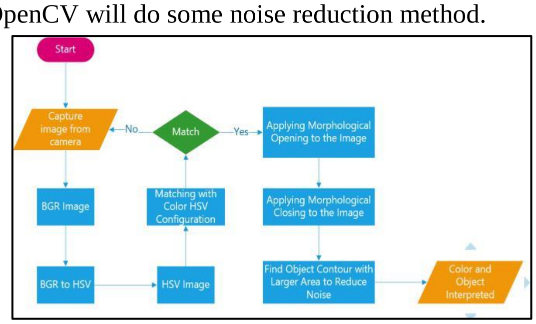

Fig. 5 Color Detection

This can be done by applying morphological opening and then morphological closing to the image. Then program will find object contour with larger area. Thus, color and object will be interpreted. In order to interpret the color detection, the step is shown in figure 5.

Shape detection

Shape detection will be required to support the docking mission. Logitech C920 Camera obtain the visual image and processed by OpenCV. OpenCV will obtains only the contrast color and change to be black and white image. Canny feature is required to emphasize some images which taken by the camera. Also, the FindContour and IsConvex features functions as the filter of the visual image. And then, some contours will be available to specified which one is triangle or cross by matching the contours based on side appropriate using approxPolyDP feature. Then, FindAngle feature is used to ensure that OpenCV obtains the image accurately by specifying the contours. The step on how to obtain the image is shown on figure 6

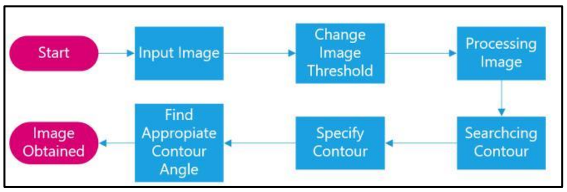

Fig. 6 Shape Detection Algorithm

C. Communication

The Makara 09 Mark II boat uses an Ethernet based communication backbone for the implementation of its onboard systems communication, control, and health monitoring. The main on-board computer, which is the Intel NUC platform, controls the communications with the judges and the task the boat is executing. To ensure the Makara 09 Mark II boat has remarkable external communication that connects with the ground station systems and the judge's network, a NanoStation M5 (NSM5) manufactured by Ubiquiti Networks (UBNT) technology company is used. It is a 5GHz Hi-Power 2x2 MIMO AirMax TDMA Station [3]. It packs some phenomenal performance with a revolutionary design combining a high gain antenna system, advanced radio architecture, and highly researched and developed firmware technology. It has great performance by providing 150+ Mbps real outdoor throughput and up to 15km+ range.

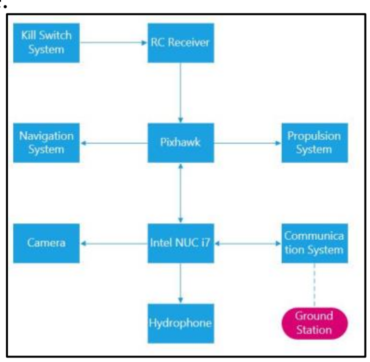

Fig. 7 Communication Diagram

Alternatively, the Makara 09 Mark II boat can be controlled remotely by using a 2.4GHz commercially available radio control system that allows an independent direct command and control link. This system implements an emergency stop functionality as well as a switch that can change the control of the boat from manual to autonomous and vice versa.

V. Software Architecture

This year, Robot Operating System (ROS) framework as the software on the robot is chosen, because Robot Operating System (ROS) is open source and supported by many developers. Moreover, the advantages of using this framework is able to integrate with many libraries such as OpenCV, Pixhawk, and Arduino [5]. So, a system to complete the mission sequentially was designed as shown in Fig 8.

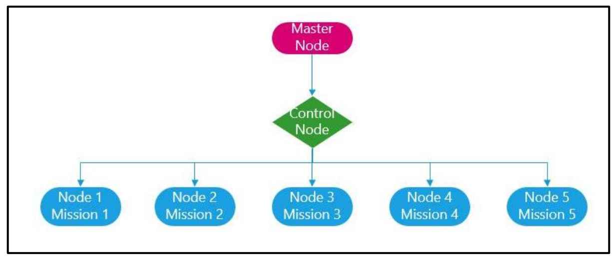

Fig. 8 Software Architecture

In completing the autonomous missions, the master node receives a command from a response server. And then, the master node will process the data based on the payload from data response server to decide which node will be run. Master node will control all of node missions. On the first node (node 1), the image processing program will be run to detect both of the speed gates. After obtaining speed gate data location, the boat will go through the speed gate for completing the mandatory mission.

After running the node 1, master node is waiting to receive a command from the response server to run the node 2. Node 2 receive the GPS location data of speed challenge arena. In the sequel, the boat will go to the speed challenge arena GPS coordinate. In this step, image processing is used to detect the buoy and the system will build path to circle the buoy and complete the mission.

While the mission 2 has been finished, Intel NUC will send http request to response server and receive a command to run node mission 3. Mission 3 is automated docking mission which its node will be run by two programs, there are image processing and AUAV controller. The image processing program is aimed to detect the shape of the dock. After the first dock is reached, AUAV controller program will be triggered to release the AUAV. Then, AUAV will search for the seven-segment shape, take a picture and back to the boat. Thereupon completing mission 3, master node will run he node mission 4 that is find the path. Image processing is used to detect which side of find the path arena is accessible to enter the find the path arena. The last mission is followed the leader. As soon as the boat arrived in the follow the leader arena, AUAV controller program is triggered to activate the AUAV and do the mission.

The whole program is written in C++ Language. The Intel NUC with Ubuntu 16.04 LTS Linux Operating System is used to process all of high-level programming such as image processing and ROS. Pixhawk is aimed to process all of low-level programming such as controlling the boat's movement and actuator.

VI. Aero Makara mark II

Automated Docking Challenge and Follow the Leader is mission that will AUAV to do. For this last challenge, a customized student-developed AUAV shown on figure 9 will be used.

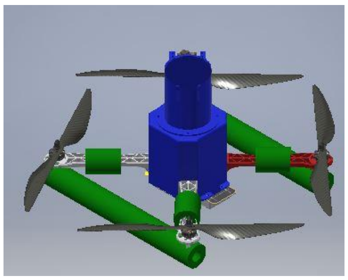

Fig. 9. Aero Makara Mark II AUAV

The Aero Makara Mark II AUAV is a quadcopter which has 4 rods on its frame. In order to land safely on the surface of the water, the rods are covered with cork to provide the AUAV's buoyancy. For keeping the electric component of the AUAV safe, it also uses protective electrical components made of PLA material printed in three dimensions. Furthermore, on the protector there is a parachute that can expand when the AUAV loses control and is forced to make an emergency landing.

This AUAV use a 5000mAH LiPo battery that works at 12V voltage. The current from the battery is divided into two: the 12V converter to 5V and the relay converter. The current from 5V source is used by Arduino nano, connected to the receiver and servo. The receiver is also connected to PPM Encoder, which will send data to ESC 30 A as a signal regulator for BLDC motor movement. While the current from the relay flows to ESC 30A which will be used to drive the motor. In addition, the current from the relay will flow to 12V/5V buck converter, which will be used by Odroid. It is also connected with pixhawk which functions to regulate work from ESC 30A.

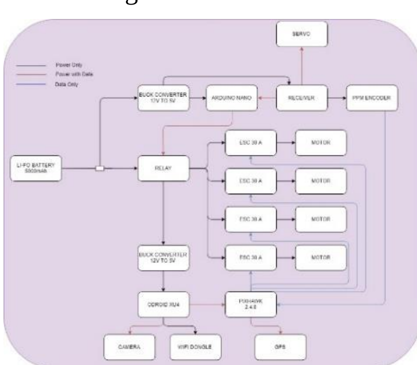

Fig. 9. Aero Makara Mark II AUAV

The Odroid flows data that becomes a pixhawk reference to determine the signal that is forwarded to ESC. Another function of Pixhawk is as a GPS on a AUAV.

VII. Conclusion

Makara 09 Mark II is an autonomous surface vehicle with specification of dimension length 105 cm, beam 70 cm, draft 12 cm and displacement 14 kg which has catamaran hull design, robust electrical, control, communication system and innovative rotational propulsion. Along with Aero Makara Mark II, our team believe that we are capable to accomplish the mission in AUVSI Roboboat Competition 2019 and become the winner.

ACKNOWLEDGEMENTS

AMV UI would like to thanks to:

- Associate Dean for Cooperating Students Affair (Direktorat Kemahasiswaan UI).
- Alumni and Venture Faculty of Engineering Universitas Indonesia.
- Robotics Team Universitas Indonesia (Tim Robotika Universitas Indonesia).
- Dr. Agus Hasan Sulistiono Reksoprodjo
- Dr. Eng. Muhammad Arif Budiyanto., S.T, M.T.
- PT. Perusahaan Listrik Negara (Persero)
- PT. Perusahaan Gas Negara, Tbk
- PT. Telekomunikasi Indonesia, Tbk
- PT. Nusantara Regas

that have contributed and help AMV UI Team on accomplishing Makara 09 Mark II

References

[1] Yanuar, Ibadurrahman, Kurniawan T. Waskito, S. Karim and M. Ichsan. Interference Resistance of Catamaran Ship Model with Asymmetric Outrigger Configurations. J. Marine Sci. Appl. (2016) 15:1.

[2] Yanuar, Gunawan, Talahatu, Indrawati and Jamaluddin. Resistance analysis of unsymmetrical trimaran model with outboard sidehulls configuration. Scopus. Volume 12, Issue 3, September 2013, Pages 293-297

[3] Nanostation M/ Nanostation Loco M Quick Start Guide. Canada. 2011-2016.

[4] Kodai Ishikawa. "Open Source Computer Vision in Microsoft Visual Video". 2014. Available: http://www.egr.msu.edu/classes/ece480/capstone/spring14/group05/ECE480_DT5_OpenCV_AN.pdf

[5] Shah Sunil. "Real-time Image Processing on Low Cost Embedded Computers". Electrical Engineering and Computer Sciences University of California. Berkeley. 2014.Available: http://www.eecs.berkley.edu/Pubs/TechRp \ts/2014/EECS-2014-117.pdf