MAKARA-01 Autonomous Robotic Boat 2012 Competition

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Abstract

Universitas Indonesia has designed MAKARA-01; an ASV (Autonomous Surface Vehicle) to participate in the 5th annual competition organized for the Association of Autonomous Unmanned Vehicle Systems International. We focused on the following engineering concepts of; naval system, mechatronics, and electrical engineering. A catamaran made of high-density foam equipped with GPS, compass, Laptop, thermal sensor, and USB cameras was developed to function autonomously to pursue its directed tasks. These tasks are focused on image recognition as well as navigation and thermal sensing to do certain task needed thermal sensor.

1. Introduction

MAKARA-01 Robotic boat is the 2012 design of the Universitas Indonesia. The boat was designed in order to participate in the 5th Annual International AUVSI Competition (Autonomous Surface Unmanned Vehicle). With the dimension of 4.94ft x 2.96ft x 0.73ft and made of high-density foam, this design has a major purpose geared to achieve the missions of the competition. A key aspect of MAKARA-01 design is the ease of transportability from Indonesia to the United States and for the ability to assemble as well as disassemble easily.
With limited funds and the need of high-tech devices it was decided to create a control board to manage the output signal generated from anLaptop which analyzes and processes all the data. The controller system includes; 1) ATMEGA2560 and Laptop for CodeBlocks software as the main coding source, 2) USB cameras, compass, thermal sensor, and GPS as the sensory systems, 3) Wireless hub for communications and programming. Additionally, self-designed water cannon with a small conventional water pump and series of servo motors were added to find targets in different orientations. A Turnigy brushless motor thrust was included to generate the desire propulsion for greater speed.

2. Mechanical Design

The basic structure of the boat relies on a catamaran to avoid the usual problems of stability and reduce the amount of power needed to propel the boat. The boat contains two hulls connected together with two 3inch x 4inch fibers. Each hull has a combination of U shape for shallow draft and its smooth motion through the water and V shape for the speed. One of the major advantages of a catamaran design is the big platform that is providewithin the hulls; such platform was made of 0.6 mm fiberglass, in which we placed a small conventional water pump for the water cannon, wireless hub and the AUVSI judge's camera/wireless box, it can also support a payload of about 7kg.
On the middle part of each hull, a hole was made to put the entire electric and power system, so it was completely protected from any water contact. The protective cover was made by a combination of plywood and plastic. On the very front of the platform a 10 inch wide piece of plywood was placed to protect the other subsystems on the platform and also to accomplish one of the missions on the competition, which is to push a red button to stop a water fall. After a series of test we found out that the addition of a stiffener connected in between the front piece of the plywood and the hulls front stiffener was needed to provide a better altitude to the cameras and water cannon for better recognition of images and hitting targets.
Based on the V shape catamaran used last year, with little draft there was too much exposition to the lake water letting the electric part be exposed to danger. To counter this problem from last year, we made a double size boat with triple draft. The most challenging part of the design was to make a puzzle boat that is as lightweight as possible, due to the international shipping conditions. Each part of the entire boat, screws/bolts joining method was decided for facilitating assembling/dissembling process and transporting, without sacrificing the structure strength.

This is the hull specification:

- LoA = 150.84 cm
- BoA = 90.23 cm
- H = 22.35 cm
- Draft = 5.364 cm
- Displacement = DWT+LWT
- LWT = 15kg (fiber)
- DWT = 7kg (target)

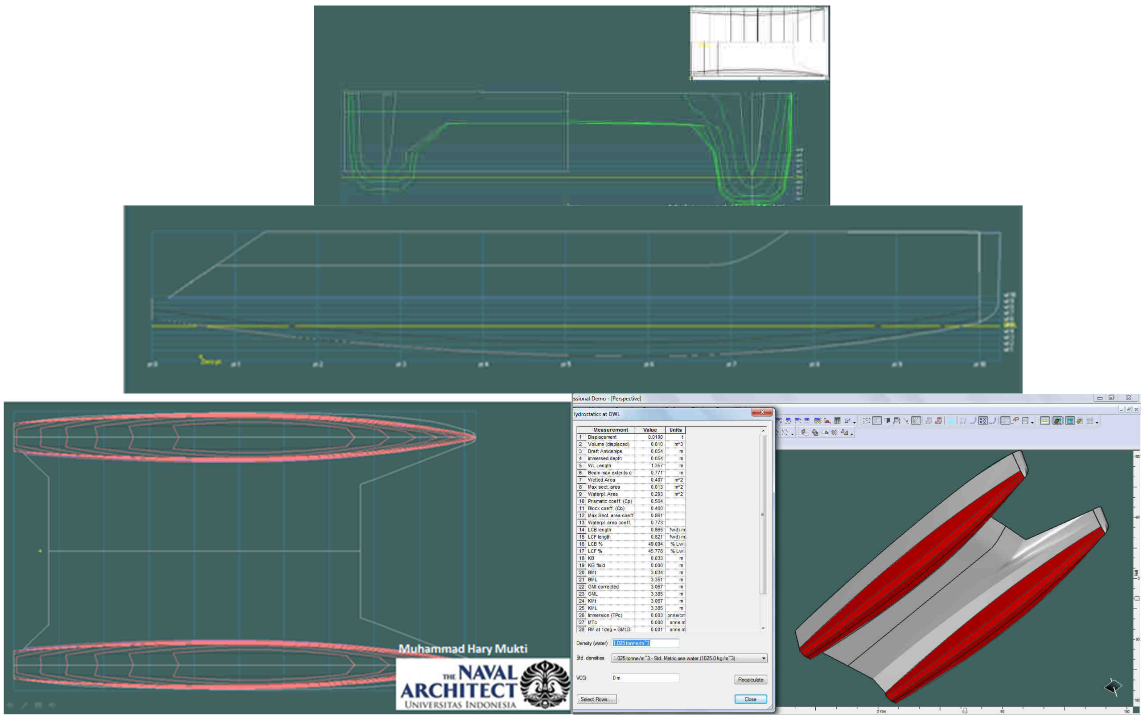

Fig.1. Hull Design 3D Maxsurf Professional

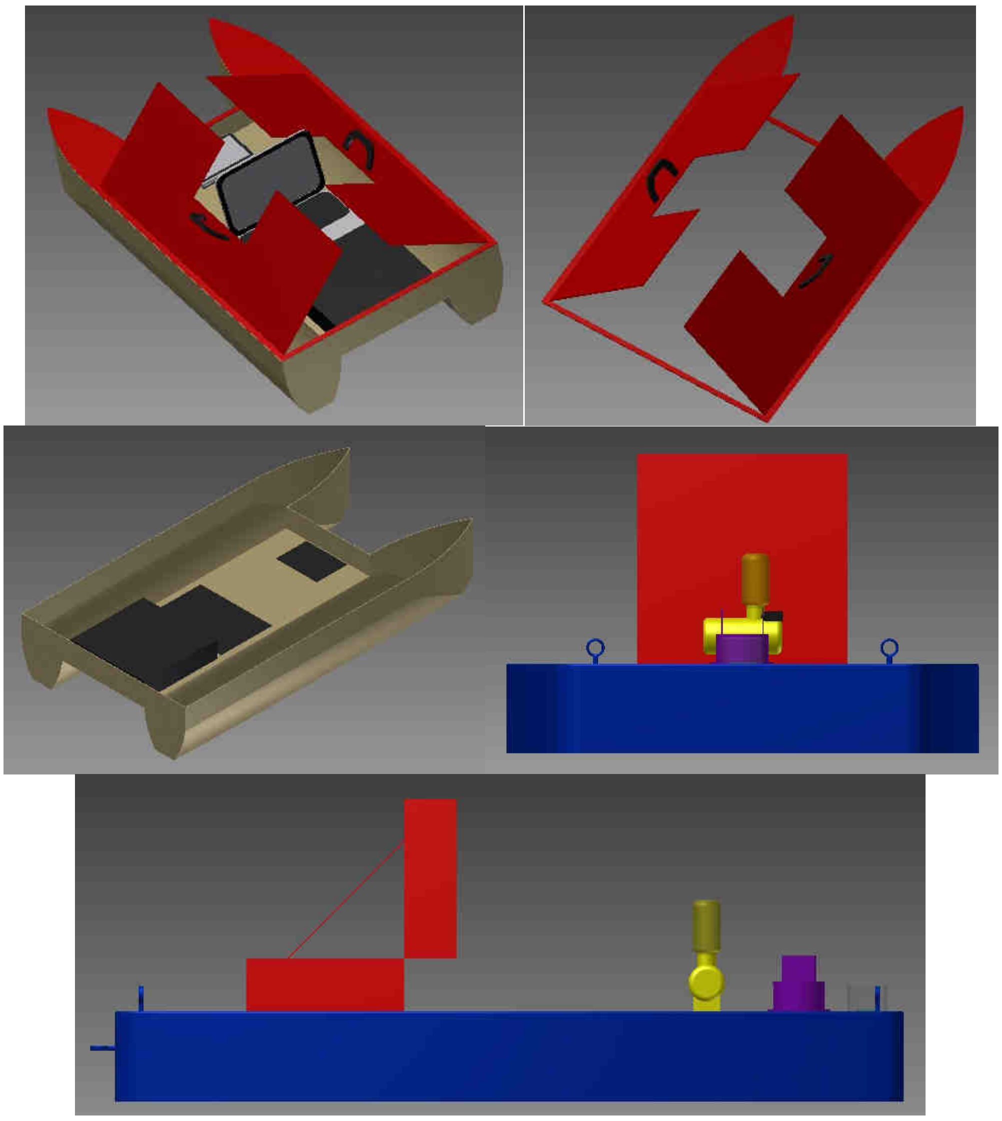

Fig.2. Inventor Autodesk Super Structure 3D model

2.1. Fabrication

Each hull was made of several frame that printed from body plan, then we can produce the master of the hull that can be used to create the fiberglass. This is one of example fiberglass hull models fabrication.

Fig.3. Hulls fabrication process

2.2. Propulsion

The propulsion system consists of two brushless motor. This XK3665-B-2700KV Brushless Inrunner is an engine give great power to the propellers. It's mounted in the 3/4 length of AP of the boat using its system, which is regulates the speed of the motor.

Table 1. 2815 Outrunner Brushless Motor-KV1520

Details	Specs	Details	Specs
# of poles:	4	Kv (rpm/v) :	1520
Max Amps:	90A	Weight (g)	275
Max Volt:	11.1V	Max Current (A)	90
Max Watts:	1000W	Resistance (mh)	8
Rpm/V:	1520kv	Max Voltage (V)	11
Resistance:	0.0075 ohms	Power(W)	1000
No-load Current:	2.7A(7.4V)	Shaft A (mm)	5
Dimension:	36.0mm x 65.0mm	Length B (mm)	65
Mounting hole depth:	6mm	Diameter C (mm)	36
Length of extend Shaft:	16mm	Can Length D (mm)	63
Shaft diameter:	5mm	Total Length E (mm)	81
Weight:	112g		

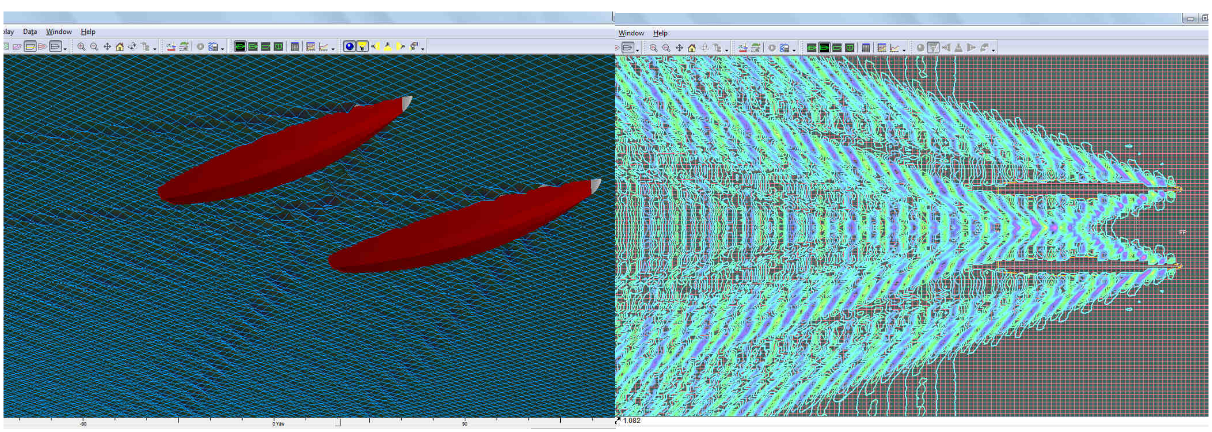

Fig.4. Hullspeed Maxsurf Preofessional

Before that we Use CFD, Hullspeed Maxsurf Profesional program to predict the waves and resistance that hull create. Thus we can choose what propulsion is the best for this hull. It provides 30lbs (13.6 kg) of thrust when a 360Watts is supplied. Because of the dimension of MAKARA-01, such power is not needed, so we only made use of 120Watts. A 11.1V LiPo battery provides enough power to the motor and water pump for about 1 hour.
This One of our strategy in naval technology is rotating ability for the ASV, use twin screw propellers at each hull which can make the boat rotating in the place such picture below:

Fig.5. ASV Rotation

And this is the hole supporting hardware for propulsion system. Aluminum Two-blade Propeller[Ø5mm]-463(D63*P1.4)

Fig.6. Propulsion System

Shaft and Prop set 4mm, includes couplings.
Specs.
Length: **269mm**
Diameter: **4mm**
Prop: **3 blade 28mm**
Motor Shaft: **3.175mm**
Suits sleeve 12925

Fig.7. Regulator

Programmable Settings;

Reverse		Battery:	**2-6SLipoly**
Low Voltage	(none/2.8v/3v/3.2v/3.4v)	BEC:	**3A/6v**
Brake:	(none/soft/hard)	Motor Type:	**Sensorless Brushless**
Timing	(0.00/3.75/7.50/11.25/15.00/18.75/22.50/26.25)	Size:	**94 x 33 x 18mm**
Constant Current:	**120A**	Weight:	**91g**
Burst Current:	**240A**	*Speed:	100,000+rpm(2 Pole)
Resistance:	**0.0007ohm**		

Red Aluminum Motor Heat Sink w/adjustable fan (top) 36mm Inrunner Motors for motor efficiency.

Fig.8. Red Aluminium Motor Heat Sink

3. Electrical and Electronic Subsystems

The electrical and Electronic Subsystems were designed to supply the power and do the automotion in MAKARA-01. The Electrical subsystem contains the Power Distribution System and Electronic Subsystem contains the Control board diagram, Communication Protocol, and Sensory Subsystem. Following is description of the Electrical and Electronic Subsystems.

3.1. Power Distribution System

To supply all the component in electronic system, power distribution system is needed to prevent the interrupt for the Control Board and supply the power what is needed. This power distribution system use 1 battery LiPo 11.1 V, 1 battery LiPo 7.4 V, and Lithium Battery in Laptop. This following is the Power Distribution Diagram to describe the power distribution system in Makara-01.

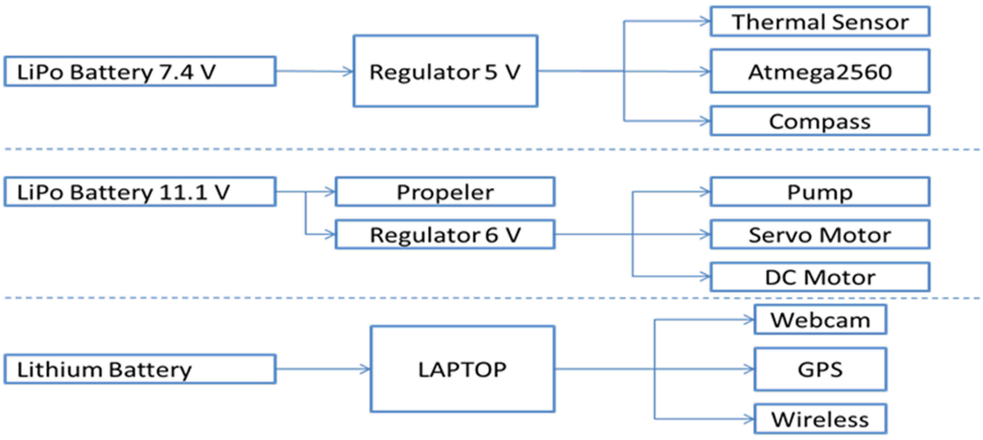

Fig.9. Power Distribution Diagram

LiPo Battery 7.4 V is used to supply the board Atmega2560, Thermal Sensor, and Compass after regulated with Regulator 5V. LiPo Battery 11.1 V is used to supply Propeler and regulated with Regulator 6 V to supply Pump, Servo motor, and DC Motor. This subsystem prevents the interrupting the power supply for Atmega2560 so that no reset occurs in Atmega2560. Lithium Battery take a role in supplying the power for the Laptop, webcam, GPS, and wireless is supplied by the USB port from Laptop. For establishing this power distribution system, the board power distribution is made from PCB to switch on or off easily.

3.2. Control board diagram

Control Board diagram contain two controller that establish the automotion system, namely Laptop and Atmega2560. Laptop is used to do image processing, GPS System, and wireless communication and Atmega2560 is used to control all actuators and sense the temperature and electronics compass. The following diagram shows the control board/computer communication system:

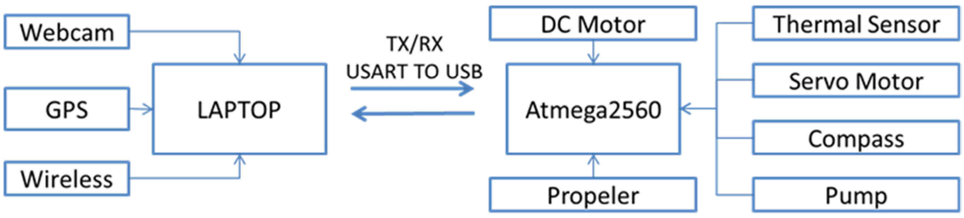

Fig.10. Control Board Diagram

The Atmega2560 features the following main control; 1) Controling Propeler and all actuator, such as Servo motor and DC Motor, 2) Sensing temperaature task with thermal sensor, 3) Navigating with Compass, 4) Communicate with Laptop to ask for the data from Laptop about image processing, wireless, and GPS. This board was programmed using C language.
The Laptop features the following control; 1) image processing, 2) GPS module, 3) Wireless Communication. This Laptop has Linux OS to operate OpenCV to do good image processing with Webcam. Image processing in Laptop yields the command for Atmega2560 to navigate as well as the navigation. For GPS System, Laptop will send data from GPS Module to operator after the command from Atmega2560 received. There is the description about communication protocol.

Atmega2560 also is essential in controlling servo motors which allow webcam and water cannon to move in X-Y direction. Two servo motors were added to the water gun to increase the strength on moving it upwards and downwards for better focus on the target.

To prevent water from getting into the Laptop and Atmega2560, an acrylic plate was placed on top of the electronic system. All the electrical components are totally covered and kept away from contact with water.

3.3. Communication Protocol

MAKARA-01 uses a signal combined with 2 bytes. Communication protocol between Laptop and Atmega2560 allow the control to synchronize each other.The following table describes MAKARA-01 communication protocol.

Table 2.Communication Protocol

Laptop-Atmega2560	CMD/DIR	DATA/PWM

Atmega2560-Laptop	A/M

CMD/DIR	Description
0X01	forward
0X02	backward
0X03	Turn Left
0X04	Turn Right
0x05	Manual
0x06	Auto

DATA/PWM
PWM VALUE
DATA JOYSTIK

A/M	Desc
A	Auto
M	Manual

3.4. Sensory Subsystems

3.3.1. GPS Module

GPS Module in this project use RXM-SG GPS Module made by Parallax. The RXM-SG GPS Module provides a high quality, highly sensitive GPS receiver with an external antenna to provide a complete GPS solution for both microcontroller and PC applications. The high-performance SiRFstar III chipset features 20 parallel satellite tracking channels for fast acquisition of NMEA0183 data for robotics navigation, telemetry or experimentation. This GPS Module can connect to a microcontroller or even a PC (via USB). A Windows application provides a graphical display of the GPS data and can even show the location on Google Maps (internet connection required). Four general purpose I/O pins provide expansion for pin-intensive projects.

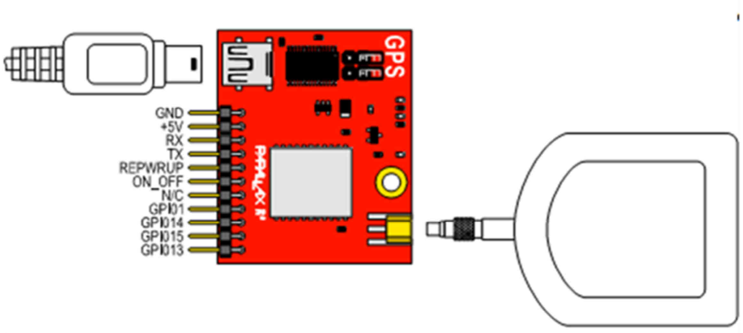

Fig.11. RXm-SG GPS Module w/ Ext. Antenna

Global Positioning System (GPS) is a space-based global navigation system providing location and time information anywhere on or near the earth. The system was created by the United States Department of Defense and consists of 24 satellites orbiting the earth. With an unobstructed view of the sky the GPS system will attempt to acquire and lock on to three or more satellites to provide a position fix using trilateration. Time information is provided by atomic clocks aboard each satellite. This information is provided to the user in UTC format.

3.3.2. Electronic Compass

The CMPS03 digital compass was added to the sensory system as a flux gate detector for the reading of the earth's magnetic field so we could determine the direction of travel. It uses 5VDC 15 mA. This compass module has been specifically designed for use in robots as an aid to navigation. The aim was to produce a unique number to represent the direction the robot is facing. The compass uses the Philips KMZ51 magnetic field sensor, which is sensitive enough to detect the Earths magnetic field. The output from two of them mounted at right angles to each other is used to compute the direction of the horizontal component of the Earths magnetic field.

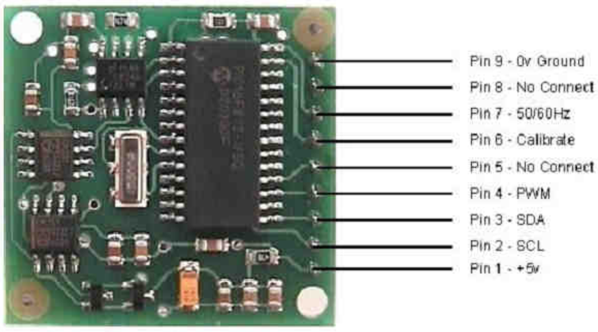

Fig.12. Compass Sensor (CMPS03)

The Compass communicates with Atmega2560 using I2C (Inter Integrated Communication) or PWM (Pulse Width Modulation). In MAKARA-01, CMPS03 communicates with Atmega2560 with I2C because simply usage with SDA, SCL pin in Atmega2560. The direction of MAKARA-01 can be determined from data of CMPS03.

3.3.3. Vision Camera

Webcam Logitech is used as sensor on MAKARA-01. This Webcam is used to acommodate the image processing which is done by Laptop. This webcam is placed above the water cannon that has the servo motor that allow the Webcam moves X-Y direction. This webcam placed together with water cannon in front of the boat in order to get the image clearly to get the best image processing.

Fig.13. Webcam Logitech

4. Supplementary Features

Instead of the main system in MAKARA-01, such as, naval, mechanics, electrical and electronic, and sensory subsystem, MAKARA-01 has the supplementary features used to do some task in the competition. The following are the supplementary features that were in MAKARA-01.

4.1. Water Cannon

As requirement for the one of the missions, we included a water cannon mounted on a series of R/C servo motors connected to a small water pump. The servo motors are all controlled from the onboard computer. Using input from the connected computer, it can aim and fire a stream of water to the selected target fromthe USB camera.

4.2. Crane

Crane was designed to do certain task taking poker chip in certain zone. This crane was designed with Servo Motor to rotate the crane and DC Motor in gripper to take poker chip. The material used for the crane is aluminium and steel in order to get the strong crane.

5. Conclusion

For less than a year preparation, MAKARA-01 is able to accomplish the tasks proposed for the AUVSI 2012 competition. A well engineered design allows it to have a great autonomous control, stable power distribution, naval architecture performance, and assemble/disassembly design.
Our group is appreciative to the AUVSI for allowing our team to participate in this competition. The tasks asked from our group were challenging and seen opportunity that most university students are not presented with. It helped us to improve our robotic and naval knowledge. The skills attained through this process are invaluable and will be taken with us into our workplaces.