Aterkia 07 : Autonomous Surface Vehicle

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***Abstract*—Aterkia 07 is an ASV made by the Aterkia team of Diponegoro University to participate in the International Roboboat Competition 2022. This report explains the details used by the ASV (the hull design, electrical system, and software integration). This report also contains explanation about the shape of the bow of an axe that we choose to reduce the resistance. Aterkia 07 uses AI and waypoint system navigation also combining AI and deep learning with Pixhawk 2 to complete the tasks.**

***Keywords*— Axe bow, catamaran, AI, waypoint, deep learning**

I. COMPETITION STRATEGY

Considering human and equipment resources, Aterkia 07 Diponegoro team will focus on completing 4 tasks, including The Mandatory Navigation Channel, Avoid the Crowds, Snack Run, and Water Blast.

A. *Navigation Channel*

The navigation channel is mandatory where the ship must be able to pass through two gates. The navigation system that will be used to complete this task is the waypoint. The waypoint control system on the ship is the determination of the destination point as a straight path that will be passed by the ship.

B. *Avoid The Crowds*

This obstacle mission was first tried in Aterkia 6 Diponegoro. This mission expected the ASV to find a way to maneuver through a defined path made of buoys while avoiding any contact with them. The one thing to be required is a ship that has reliable vision and a camera to detect object. For this mission, the team had several developments from the previous year. The team carried out addition of vision such as using Arduino configured vision for ASV control and added a small feature using an ultrasonic sensor to provide object detection accuracy so the ASV can avoid obstacles.

The navigation systems that will be used in this task are AI. The AI-enabled navigation system will use the camera as the ship vision that is integrated with deep learning to spot buoys. This method is the development of the Aterkia 6 navigation system that uses the PING-Parallax ultrasonic sensor instead of vision. The navigation system using the PING-Parallax ultrasonic sensor on the Aterkia 6 has drawbacks due to the speed of sensor readings, therefore the Aterkia 07 uses an AI navigation system and deep learning.

C. *Snack Run*

This challenge requires good maneuverability and the thrust speed of the ship. In this case, we design the shape of the catamaran hull to get high stability. The camera will be used to detect the position of the buoys.

Pixhawk 2 is a controller that has been integrated with the Mission Planner as a ground control system used by Aterkia 6, on the other hand the Pixhawk 2 has shortcomings in customization, due to lack of resources for research on combining AI and deep learning with Pixhawk 2. The Aterkia 07 uses Arduino Mega as a ship controller and will be integrated with GPS, compass, gyroscope, and accelerometer modules with specifications and capabilities similar to the Here 2 navigation sensor on the Pixhawk 2.

D. *Water Blast*

For this mission, we placed the sprayer water gun on the front of the ship. The arrangement of the pump is close to the water gun. This approach we carry does not impact speed or waterways on board. Once the ASV detects the presence of a water blast pipe, it will keep a minimum distance before shooting water into the pipe.

II. DESIGN CREATIVITY

A. *Hull Design*

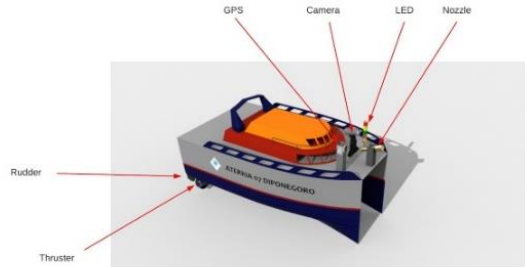

Figure 1. Aterkia 07 Design

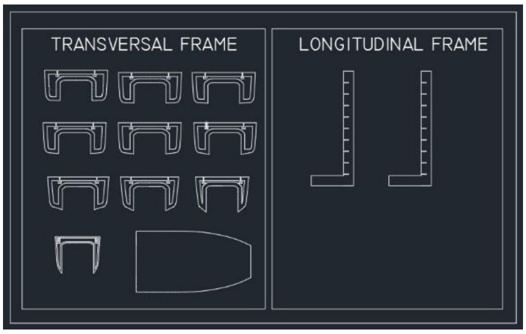

Figure 2. Framing Laser Cut Aterkia 07

For the competition, we chose the axe bow hull type. The bow itself is in the shape of the blade of an axe. The level of stability is the key to preventing the ship from being trimmed or sinking. The catamaran hull was later selected to enhance the stability.

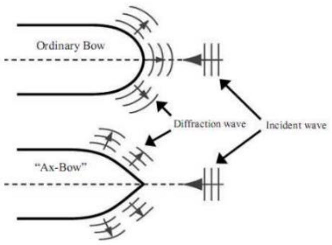

Figure 3. Axe Bow Principle

The advantages of using this type of hull it reduces ship resistance and wave reflections. The small shape of the bow angle reduced the resistance. After splitting the waves, it will create an aerodynamic force and help speed up the ship. Studies show that sharpening the shape of the bow is most effective. Wave test results show that the axe bow decreases by 20% to 30% above 166 amps over the entire wavelength range. This can reduce by 4% to 6% of house power or fuel consumption [1]. Another advantage is the material. This ship also uses the same material as the Aterkia 6 which uses carbon material. The advantage of carbon that it is lighter than balsa wood or fiberglass.

The innovation that we brought to the Aterkia 07 is also the usage of composites and wood. We pay close attention to the important details of the material, as it has a significant impact on the final result in terms of the weight and the quality of the ship.

B. *Sensors and Vision*

Aterkia 07 uses Arduino IDE as software to develop the main program. Aterkia 07 will focus on developing vision with AI and elements for accurate and stable sensing. In vision, a camera embedded with a deep learning system is used to detect obstacles and give the result of the distance between the ship and the obstacle. The ship vision will be strengthened with three sensing elements 1) GPS module, to know the coordinates of the boat position accurately. 2) Magnetometer, as a compass that will provide information related to the direction of the boat. 3) Accelerometer, used to detect the speed of the ship's displacement with respect to the z-axis. Equipped with 3 detection elements and reinforced by AI as vision, Aterkia 07 has a navigation system that is capable of performing waypoint and AI navigation systems.

C. *Software Architecture*

To integrate each component so the ship can complete each task smoothly, the Aterkia 07 uses a software architecture consisting of two parts.

The first is PID Avoid the Crowds to control the rudder and motor to avoid obstacles with distance input detected by AI. Furthermore, is the PID Turn and Go. PID Turn works to regulate motor motion so the ship can change direction. PID Go adjust the ship's speeds to reach the designated coordinate. PID Turn and Go ensure the ship can get through a specified location.

D. *Electrical Architecture*

The electronics used in the Aterkia 07 prioritize efficiency in both power and space. Electronic components are integrated into the printed circuit board to minimize space requirements. The components on the board are the Arduino, GPS, magnetometer, receiver and relay, and the connection between the motor and servo.

The power in the Aterkia 07 is divided into three parts. First is a 10Ah lipo battery that powers the ship's motion system, motors via ESC, rudder servos, and the Ardunio that is connected to GPS, magnetometer, receiver, and relay. Second, a battery with a capacity of 2.5 Ah to power the NUC which is connected to the camera to support vision on the boat. Lastly, is another battery with 2.5 Ah to power the LEDs and pumps through a voltage regulator.

E. *ASV Perception*

Computer vision requires a custom object detection model for detecting balls and waterjet targets. In this case, we complete model training using the YOLOv5s architecture.

We use about 2000 sets of data from red, yellow, green, blue, and target balls. Using this number of datasets expected to improve the accuracy of mean accuracy performance (mAP). After training the dataset, we calculated the distance between the two balls and tried to find the center so that the ship could pass between them.

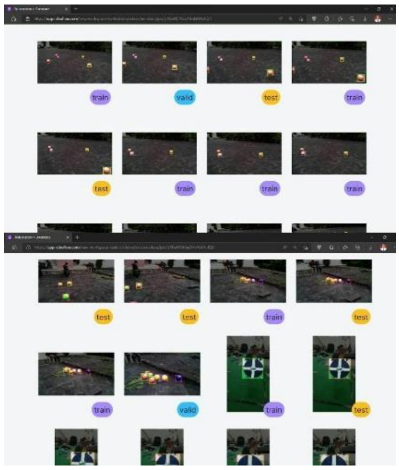

Figure 4. Data Training with Roboflow

F. *Water Blast Control*

For waterblast mission we use the integration of Arduino and computer vision. This combination allows the water shooter accurately shoot the target. When the camera begins to detect the presence of the target, the camera calculates the distance [2]. Using a simple calculation, we calculated the target diameter to be 25 inches and the target width to be 558 pixels. From this data, calculations are carried out.

$$F = (P \times D)/ R \quad (1)$$

With F is the local length, P is pixel, D is the distance from target to the camera, and R is the real diameter of the target. From the simple calculation we get the value of F is 1.138. The value of F will be constant as the camera moves and the target pixel value changes. Now we have an F number, we can determine the distance from the target to the camera using the formula

$$D' = (R \times F)/ P \quad (2)$$

III. EXPERIMENTAL RESULTS

A. *Hull Stability*

TABLE I. PRINCIPLE DIMENSION ATERKIA 07

Principle Dimension	
Length	90.75 cm
Breadth	50 cm
Height (Hull)	33.5 cm

Principle Dimension	
Height (Full)	45.5 cm
Draft	18.5 cm

Item Name	Quantity	Mass (Kg)	Total Mass (Kg)	LC (m)	TC (m)	VC (m)
Lightship	1	4	4	0,28	0	0
NUC	1	0,5	0,5	0,455	0	0,15
Arduino	1	0,2	0,2	0,455	0	0,15
LED	1	0,8	0,8	0,835	-0,076	0,15
Camera	1	0,4	0,4	0,835	0	0,15
Nozzle	1	0,6	0,6	0,88	0	0,15
Seater	1	0,5	0,5	0,835	0	0,15
Water Pump	1	1	1	0,643	-0,086	0,072
PCB	1	0,3	0,3	0,555	0	0,15
Voltage Regulator	1	0,3	0,3	0,38	0	0,072
Relay	1	0,3	0,3	0,34	0	0,072
Battery 4 Cells 5000 mAh (L)	1	0,6	0,6	0,291	-0,082	0,072
Battery 4 Cells 5000 mAh (R)	1	0,6	0,6	0,291	0,082	0,072
Exhaust Fan	1	0,6	0,6	0,165	0	0,15
Terminal	1	0,8	0,8	0,455	-0,072	0,15
Battery 4 Cells 10000 mAh	1	1,2	1,2	0,245	0	0,072
GPS	1	0,2	0,2	0,835	0,076	0,15
Total Loadcase			12,9	0,438	-0,015	0,078

Figure 5. Electric Component Loadcase

We calculated the center of gravity used the Maxsurf Stability application by inserting the electrical components placed on the ship.

TABLE II. CENTER OF GRAVITY

Longitudinal Center (m)	Transverse Center (m)	Vertical Center (m)
0.438	- 0.015	0.078

To find out the value of the stability we carried out an analysis of the static and dynamic stability of the ship. The value of the GZ enforcement arm indicates the stability value. GZ is the enforcing arm of the ship to return to its original position described by the displacement of point G when the balance changes to point G` after experiencing a collision.

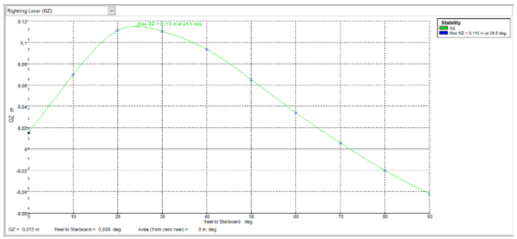

Figure 6. GZ Graphic

	Heel to Starboard deg	0,0	10,0	20,0	30,0	40,0	50,0	60,0	70,0	80,0	90,0
1	GZ m	0,015	0,069	0,111	0,110	0,093	0,065	0,034	0,006	-0,020	-0,042
2	Area under GZ curve f	0,0000	0,4245	1,3532	2,4878	3,5155	4,3130	4,8063	5,0018	4,9261	4,6121
3	Displacement kg	12,86	12,86	12,86	12,86	12,86	12,86	12,86	12,86	12,86	12,86
4	Draft at FP m	0,207	0,206	0,213	0,223	0,206	0,153	0,065	-0,080	-0,451	n/a
5	Draft at AP m	0,143	0,142	0,122	0,064	0,001	-0,069	-0,172	-0,376	-0,981	n/a
6	WL Length m	0,910	0,910	0,912	0,918	0,921	0,919	0,915	0,913	0,912	0,912
7	Beam max extents on	0,481	0,486	0,474	0,451	0,441	0,274	0,254	0,262	0,265	0,315
8	Wetted Area m^2	0,504	0,501	0,468	0,438	0,413	0,394	0,391	0,383	0,368	0,349
9	Waterpl. Area m^2	0,170	0,170	0,137	0,123	0,128	0,137	0,158	0,181	0,198	0,214
10	Prismatic coeff. (Cp)	0,773	0,772	0,767	0,754	0,703	0,689	0,694	0,702	0,727	0,745
11	Block coeff. (Cb)	0,139	0,126	0,120	0,120	0,131	0,259	0,384	0,533	0,619	0,504
12	LCB from zero pt. (+ve	0,447	0,448	0,452	0,464	0,471	0,470	0,466	0,462	0,460	0,459
13	LCF from zero pt. (+ve	0,383	0,388	0,437	0,436	0,414	0,386	0,380	0,388	0,421	0,457
14	Max deck inclination de	4,0141	10,7733	20,6873	31,1074	40,9885	50,5790	60,2780	70,1286	80,0514	90,0000
15	Trim angle (+ve by ster	-4,0141	-4,0905	-5,7441	-9,9503	-12,721	-13,722	-14,633	-18,072	-30,243	-90,000

Figure 7. Stability Data Characteristic

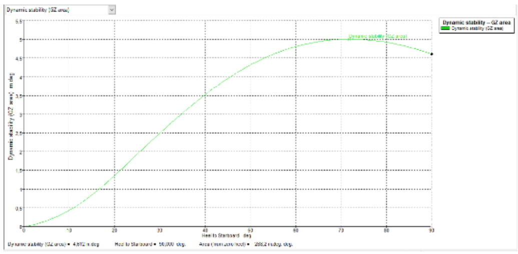

Figure 8. Dynamic Stability Graphic

From the curve above, the ship is highly stable and reaches a maximum GZ arm of 0.115 m at an angle of 24.5 degrees at full load. This means that once the ship has passed a slope of 24.5 degrees, it will not be able to return to its original position. In addition to stability analysis, we also conduct a seakeeping analysis.

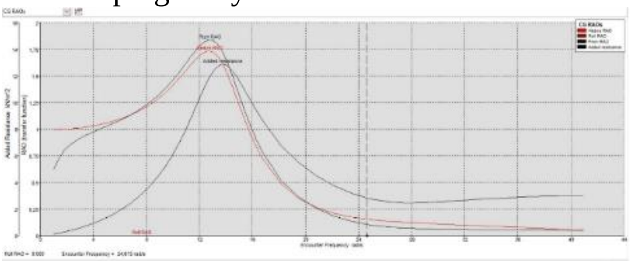

Figure 9. RAO Graphic

10 kn; HEAD SEA, 180 deg; JONSWAP: 17,922 s, 2 m

	Item	m0	units	RMS	units	Significant amp	units	Modal (peak) T_0 (w_0)	Mean (centroid) T_bar (w_bar)	Mean zero-crossing T_z (w_z)	Period units (Frequency units)
1	Modal period	17,926	s	--		--		--	--	--	
2	Characteristic w	2,000	m	--		--		--	--	--	
3	Spectrum type	JONSWAP		--		--		--	--	--	
4	Wave heading	180,0	deg	--		--		--	--	--	
5	Vessel Speed	10,000	kn	--		--		--	--	--	
6	Vessel displace	0,013	m^3	Monohull		--		--	--	--	
7	Vessel GMt	0,311	m	--		--		--	--	--	
8	Vessel trim	-4,0	deg	--		--		--	--	--	
9	Vessel heel	0,0	deg	--		--		--	--	--	
10	Transom method	No transom term		--		--		--	--	--	
11	Wave force meth	Arbitrary wave		--		--		--	--	--	
12	Added res. meth	Salvesen		--		--		--	--	--	
13	Pitch gyradius	0,227	m	--		--		--	--	--	
14	Roll gyradius	0,200	m	--		--		--	--	--	
15	Wave spectrum	0,251	m^2	0,501	m	1,001	m	17,925 (0,35)	15,008 (0,42)	14,124 (0,44)	s (rad/s)
16	Encountered wa	0,251	m^2	0,501	m	1,001	m	15,158 (0,41)	12,027 (0,52)	10,776 (0,58)	s (rad/s)
17	Added resistanc	0,055	kN	--		--		15,158 (0,41)	10,794 (0,58)	8,664 (0,73)	s (rad/s)
18	Heave motion	0,248	m^2	0,498	m	0,996	m	15,158 (0,41)	12,016 (0,52)	10,751 (0,58)	s (rad/s)
19	Roll motion	0,00000	deg^2	0,00000	deg	0,00000	deg	14,755 (0,43)	3,384 (1,86)	2,835 (2,22)	s (rad/s)
20	Pitch motion	0,41	deg^2	0,64	deg	1,29	deg	14,755 (0,43)	3,109 (2,02)	2,685 (2,34)	s (rad/s)
21	Heave velocity	0,085	m^2/s^2	0,291	m/s	0,582	m/s	14,930 (0,42)	6,393 (0,98)	4,924 (1,28)	s (rad/s)
22	Roll velocity	0,00000	(rad/s)^2	0,00000	rad/s	0,00000	rad/s	1,417 (4,43)	1,982 (3,17)	1,893 (3,32)	s (rad/s)
23	Pitch velocity	0,00069	(rad/s)^2	0,02625	rad/s	0,05250	rad/s	1,417 (4,43)	1,992 (3,15)	1,910 (3,29)	s (rad/s)
24	Heave accelerati	0,138	m^2/s^4	0,371	m/s^2	0,743	m/s^2	14,688 (0,43)	2,555 (2,46)	2,300 (2,73)	s (rad/s)
25	Roll acceleration	0,00000	(rad/s/s)^2	0,00000	rad/s/s	0,00000	rad/s/s	1,417 (4,43)	1,716 (3,66)	1,687 (3,72)	s (rad/s)
26	Pitch acceleratio	0,00745	(rad/s/s)^2	0,08634	rad/s/s	0,17268	rad/s/s	1,417 (4,43)	1,741 (3,61)	1,711 (3,67)	s (rad/s)

Figure 10. Seakeeping Calculation

Based on the table and graph above, our ship has good movement at 10 knots and 180 degrees wave angle.

B. *Material of The Hull*

In recent years, the presence of wood has become dominant as the main material for RC hulls and autonomous vessels. But since 2021, our team has decided to choose composites to build the hull. A composite material is a material formed from a combination of two or more materials that form through a non-uniform mixture (alloy) with different mechanical properties of each material [3]. From a mechanical point of view, this material is durable as it has considerable tensile and bending strength. It offers benefits such as strength, porosity resistance, and a longer life span.

The printing process of two main materials is fiber mat as the inner layer and carbon fiber as the outer layer of the hull. Carbon fiber is used on the outside of the material due to its strong properties with lightweight construction. Since the inside uses a fiber mat material, the hull is reinforced by the hardness of the material. This material requires another material to bond, using a Feller element (glass fiber booster) and catalyst in the form of a polyester resin material (Yukalac 157 BQTNEX) in comparison 1:10.

Fiberglass composites are made from a mixture of these materials. Fiberglass is a combination of two materials that have different physical properties and complement each other [4]. Fiberglass has the same strength as metal but the strength is affected by the combination and dose of the composition of the matrix and the feller element.

C. *PID Stability*

In Aterkia 07, the search for PID parameters is done by adjusting trial and error.

TABLE III. PID PARAMETER

Component	Parameters		
	Kp	**Kd**	**Ki**
Motor	4	2	1
Servo	2	1	0.5

Each parameter is used to drive the servo and motor in PID Avoid the Crowd and PID Turn and Go. The results can make the ship work as expected and have a good stable result.

D. *Computer Vision Performance*

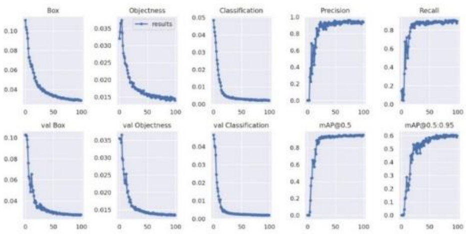

Figure 11. Training Dataset Performance

Figure 12. Object Detection with YOLOVv5s

The training data set uses Google Colab provided by Roboflow. In computer vision performance testing using object detection algorithms, the Yolov5s architecture achieved good results on the Epouch 100 with Map, precision, and recall close to 1.

TABLE IV. VALUE OF EACH TEST

mAP	Precision	Recall
95.6%	94.2%	90.1%

The values in the table above are sufficient to find the object accurately, so we can detect the object under different conditions without any errors.

E. *Water Blast*

Figure 13. Water Target Detection

In water blast testing, computer vision can detect the presence of the water target and calculate the distance between the computer and the water target. Distance values can also be transmitted to the Arduino for processing by PID.

IV. ACKNOWLEDGMENTS

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(Translation from P. Agustinus, S. Agoes, J. Edy, “Analisis Penerapan Bow Tipe Axe untuk Konsumsi Bahan Bakar pada Utility Vessel 48 Meter”. Jurnal Teknik PMOITS, Vol. 2, No. 2)

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APPENDIX A: Component Specifications

Component	**Vendor**	**Model/Type**	**Specs**	**Custom/ Purchased**	**Cost**	**Year of Purchase**
ASV Hull form/platform	Aterkia Diponegoro	Catamaran Hull	Carbon fiber and fiberglass LPP = 90,75 cm; Breadth = 50 cm; Height (Hull) = 33,5 cm; Full Height = 45,5 cm; Draft = 18,5 cm	Custom	NN	2022
Waterproof Connectors	-	-	-	-	-	-
Propulsion	Blue Robotics	T200 Thruster	https://bluerobotics.com/store/thrusters/t100-t200-thrusters/t100-p-bracket-r1/	Purchased	NN	2021
Power System	Tattu	Lipo Battery 4s 14,8v 10000mah 25c, Lipo Battery 4s 14,8v 2500mah 25c	https://www.genstattu.com/tattu-10000mah-14-8v-25c-4s1p-lipo-battery-pack-without-plug.html	Purchased	$280	2020
Motor Controls	Flycolor	ESC Flycolor 150A	http://en.flycolor.net/index.php?c=category&id=149	Purchased	NN	2020
CPU	Intel	NUC7i 5BNH	https://ark.intel.com/content/www/us/en/ark/products/95067/intel-nuc-kit-nuc7i5bnh.html	Purchased	$280	2020
Teleoperation	Flysky	Flysky Fs-i6	https://www.flysky-cn.com/fsi6	Purchased	$52	2022
Compass	Osoyoo	QMC5883L	https://osoyoo.com/driver/QMC5883L-Datasheet-1.0.pdf	Purchased	$143	2022
Inertial Measurement Unit (IMU)	-	-	-	-	-	-
Doppler Velocity Logger (DVL)	-	-	-	-	-	-
Camera(s)	Microsoft	Microsoft Lifecam Studio	https://www.microsoft.com/en-id/accessories/business/lifecam-studio-for-business?activetab=overview:primaryr2	Purchased	$100	2020
Hydrophones Algorithms	-	-	-	-	-	-

Vision	Yolo	Yolov5s	-	-	-	-
Localization and Mapping	U-Blox	Neo-M6N GPS	https://www.u-blox.com/sites/default/files/products/documents/NEO-6_DataSheet_%28GPS.G6-HW-09005%29.pdf	Purchased	$5	2022
Drone	Bhinneka	DJI Mavic Mini 2 Basic	https://www.bhinneka.com/dji-mavic-mini-2-basic-sku3335953288	Purchased	$496	2022
Autonomy	-	-	-	-	-	-
Open Source Software	Arduino IDE, Visual Studio Code	-	-	-	-	-

APPENDIX B: Software and Electrical Diagram