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GPS Navigation System on Autonomous Ship asAn Effort to Increase Fish Catch for Fisherman in Pamekasan Indonesia

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Abstract **- Currently most of the marine fishing in Indonesia uses traditional boats with navigation systems using compasses and mobile phones. Besides being ineffective, this fishing system also has a high risk, so a safer fishing system is needed, namely using an autonomous boat with a system capable of attracting fish. The use of the Autonomous Surface Vehicle (ASV) for monitoring and fishing purposes has been carried out by Aryusmal (2018)** [1] **, namely using GPS equipped with an Arduino Uno microcontroller to carry out ship movements, and an error of 1.5 m was obtained. Whereas Permana (2018)** [2]**made an ASV ship with GPS equipped with an APM microcontroller and Arduino Uno, an error of 30 cm was obtained. Referring to the need for a safe fish system and the results of previous research, this paper designed an autonomous ship with a GPS navigation system using a pixhawk microcontroller which is supported by the use of a brushless motor as the main propulsion of the ship and mission planner software to determine navigation waypoints. This system is able to monitor in real time and save the results of navigation and compass movements up to the last waypoint on the Pixhawk microcontroller. To find out the performance of the ASV, waypoint latitude and longitude tests were carried out on a laboratory and field scale. Laboratory test results have an error of 1.7%, while the results of field testing error errors that occur are 4.4% at longitude and the smallest error is 1.3% at latitude. This error occurred due to field conditions due to sea water shocks. However, this error did not really affect the movement of the ASV ship, because the shift was not too far.**

Keywodrs – Autonomous, GPS, Manuvering, Mission Planner, Navigation, Waypoint

I. INTRODUCTION[1]

The development of conventional public transportation technology has been implemented and developed by various countries. One of the transportation technologies developed is sea transportation [3]. One of the developments in marine transportation technology is the Unmanned Surface Vehcile (USV). USV are a sea transportation technology that can move automatically or autonomously which has the ability to achieve long-distance missions [4]. As a maritime country, the development of USV has the potential to be developed in Indonesia, seeing that the technology in the waters is less than optimal, especially in the field of fishing. Fishing at sea is currently still using traditional boats, where the navigation system on fishing boats only uses compasses and cellphones [5] [6]. So it is necessary to add a more modern navigation system to the ship.

The development of the ASV ship has been carried out by Permana [2] by making the Unnamed Surface Vehicle (USV) ship. This USV ship uses the ardupilot mega (apm) and arduino uno microcontrollers using mission planner software to set waypoints. Mission planner software has the advantage of being able to display movements directly when the ship moves in the waters. The testresults from the USV obtained accurate data with a shift in the ship's position of 30 cm. Meanwhile Saputra [7] has designed an ASV equipped with a bluetooth module, so it can monitor environmental conditions around the waters manually andautomatically. The ASV, which has carried out testson lake 8 ITS, obtained a position error of 2 meters, the error was caused by the program on the ASV used which had a position tolerance of 2 meters. Meanwhile Aryusmal [1] has designed and built a navigation ship for the movement of ships that follow certain trajectories. The resulting navigation ship is equipped with an arduino-based control system with GPS as a guide for the movement of the ship according to the specified waypoint. However, an error still occurs in the ship's trajectory of 0.2 meters

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when there are 8 waypoints. Meanwhile, when there are 4 waypoints, an error of 1.5 meters occurs. Besides, the process of maneuvering when turning one of the motors stops. This causes the movement of the ship's maneuvers to be less than optimal.

ASV has also been developed by Gan dan Xiang [8] namely this ASV ship is used to carry out shore monitoring, onboard control subsystems andwireless communication systems. This ASV isequipped with paddles and a single rudder, where the integrated navigation system uses INS/GPS, and uses the STM32F103ZET6 microcontroller as the CPU. ASV vessels acquire and process sensor data including position data based on the NMEA-0183 GPS protocol and data based on fixed protocols from the IMU. Then the status of the navigation system is sent by the coast monitoring subsystem via the ZigBee module. Meanwhile Joni dan Fiqi [9] developing an unmanned ship using a V hull shape and using an Android 2 Mpx camera can already trace the track properly. The color tracking method is appropriate for devices with not too high specifications. The placement of the rudder away from the center line provides the right response for the ship's turn so that it does not touch the track. Forfurther research, it is necessary to design a more aerodynamic ship shape because this ship is vulnerable to wind. For the motor, it is necessary to select the appropriate motor for the propulsion used in the water.

Therefore, through this research, a ship prototype with an Autonomous Surface Vehicle (ASV) system based on GPS sensors and a Pixhawk microcontroller which is equipped with a compass is designed. ASV components consist of a brushless motor, electrical speed control, servo motor, Pixhawk microcontroller and li-po battery. The working principle of this system is that the data obtained by the GPS and compass sensors will be sent to the Pixhawk microcontroller and processed to become a waypoint for the ship's destination. Furthermore, the microcontroller will give orders to the electrical speed control to control the movement of the brushless motor and the ship's servo motor to the intended waypoint.

II. METHOD

ASV ship design and control manufacture process needs some software to be done such as Maxsurf, AutoCAD, Inventor and Mission planner. Therefore, each software will be explained in the following sub-chapters.

A. Maxsurf

Maxsurf software is special software for shipdesign and analysis. There are various kinds of design and analysis in software. Maxsurf itself is one of the software products commercialized by Bentley, with special uses for carrying out ship designs and the like in 3D form, even being able to model the shape of the structure and the power requirements of the ship itself. To obtain the desired ship design, the parameters entered into the maxsurf software are length, sheet and height [10].

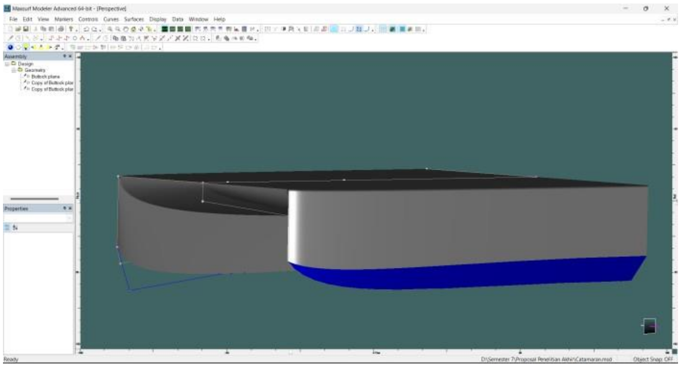


Figure 1. 3D Ship Body Hull Design in Maxsurf Modeler Advanced Software

B. Autodesk Inventor

Autodesk Inventor is a design application on computers/laptops for 3D mechanical design, simulation, visualization, and documentation developed by Autodesk. Inventor is primarily used for digital prototyping and designing mechanical and Engineering products. Inventor offers a variety of features that allow users to design, visualize product ideas before they are physically built. In Figure 2 is a ship design from Autodesk Inventor Software.

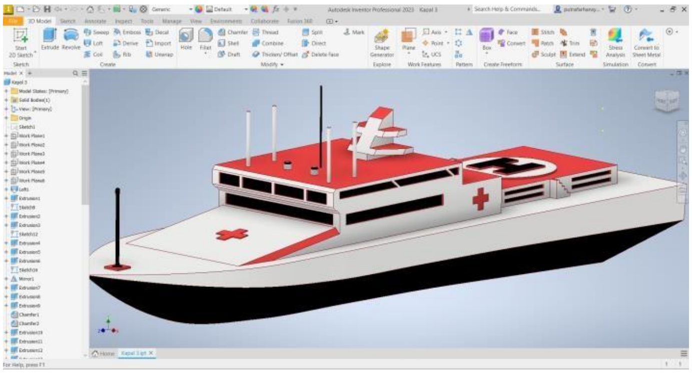


Figure 2. Ship Design From Autodesk Inventor

C. AutoCAD

AutoCAD is software available on computers/laptops for drawing 2 dimensions or 3 dimensions developed by Autodesk. AutoCAD products are the most widely used software. AutoCAD is widely used by civil engineers, land developers, architects, mechanical engineers, interior designers, and others. AutoCAD has its native formats DWG and the little-used DXF interchange which have become the de facto CAD data standards. However, AutoCAD has developed the DWF data format.

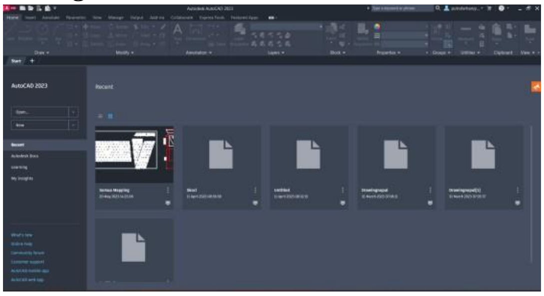


Figure 3. AutoCAD Software Home Display

D. Mission Planner

One application that has been adapted to the Pixhawk microcontroller is the mission planner software which is used as an application for setting and determining waypoint parameters for navigation routes. For example, the data entered is the coordinates of Longitude and Latitude A and gives the coordinates of Longitude and Latitude B, then the Pixhawk system will arrange the ship to move towards point A then towards point B automatically. The homepage display of the Mission Planner Software is as shown in Figure 4.

Figure 4. Display Homepage Mission Planner

Especially for this study used a body hull designthat has the shape of a catamaran or with two hulls. This method is considered more appropriate because thebody hull has very high stability to be able to move inthe waters. The main dimensions of the ship used as areference are taken from the data of the Aryasmal ship. The tests were divided into two, namely testing the navigation system which was carried out in a swimmingpool and testing the ship's maneuvers carried out at sea.

Based on the result which is obtained data from the results of ship navigation and maneuver testing. Then an analysis of the results of the effectiveness of the navigation system and maneuvering of the autonomous surface vehicle ship using the Pixhawk microcontroller is equipped with a compass and GPS sensor. Latitude and longitude data are variables used as dependent variables in the analysis and discussion ofthis study.

III. RESULTS AND DISCUSSION

This chapter discusses the testing and system analysis of the Autonomous Surface Vehicle (ASV) that was planned in the previous chapter. Figure 5 is the ASV used in this research research. Testing and analysis of this chapter is divided into various stages, by discussing sub-sections of the overall system design accompanied by tables and figures that support systemtesting and analysis.

Figure 5. Testing of Ship Navigation Systems

The design of the Autonomous Surface Vehicle (ASV) ship includes load assumptions on the ship, the body hull frame which has been designed in Maxsurf, AutoCAD, and Inventor software. ASV ship load weight planning is assumed through Table1 below.

TABLE 1
ASV VESSEL WEIGHT ASSUMPTION

No	Component	Amount	Weight(grams)
1.	Microcontroller	1	200
2.	Brushless Motor	2	500
3.	ESC	2	750
4.	Servo	2	120
5.	Baterai Li-Po	1	440
6.	Modul GPS	1	50
7.	VTX	1	50
8.	Camera	1	150
8.	Rudder	2	100
9.	Propeller	2	100
10.	Light Spectrum	1	1500
11.	Ship Deck	1	1000
	Total		4.960

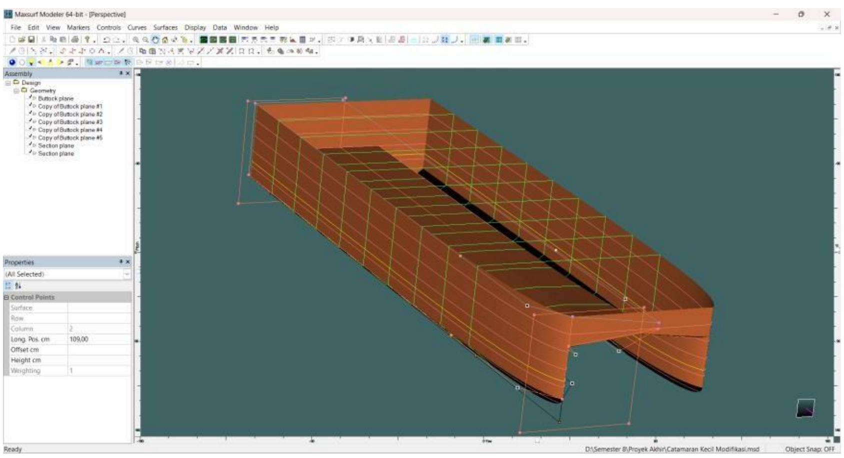


Figure 6. 3D Catamaran Body Hull Design in Maxsurf Software

Referring to table 1, the type of body hull used is the catamaran hull, because this type of ship is more stable with the presence of two hulls.

TABLE 2
ASV VESSEL BODY HULL DIMENSION DATA

	Mark	**Unit**
Type Hull	Catamaran	
LOA	1500	mm
LPP	1300	mm
LWl	1150	mm
B	370	mm
T	80	mm
H	185	mm
Koefisien block (Cb)	0,347	
Koefisien Prismatic (Cp)	0,874	
Volume Displacement (V)	100491,2	mm^3
Displacement	10,05	kg

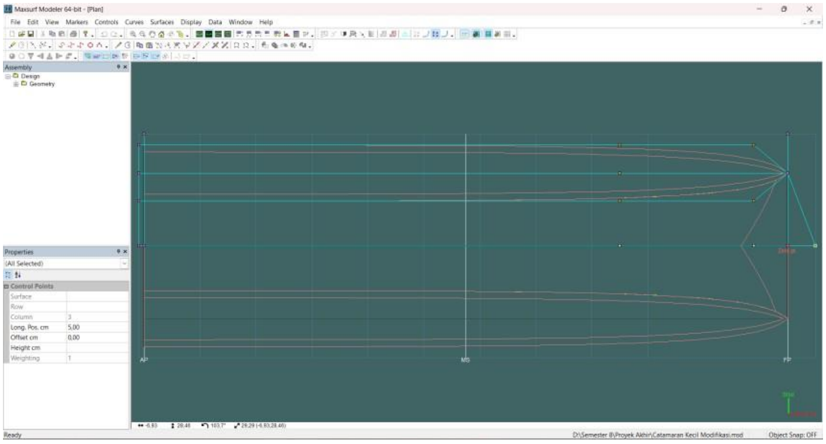


Figure 7. Top View of the Catamaran Body Hull in Maxsurf Software

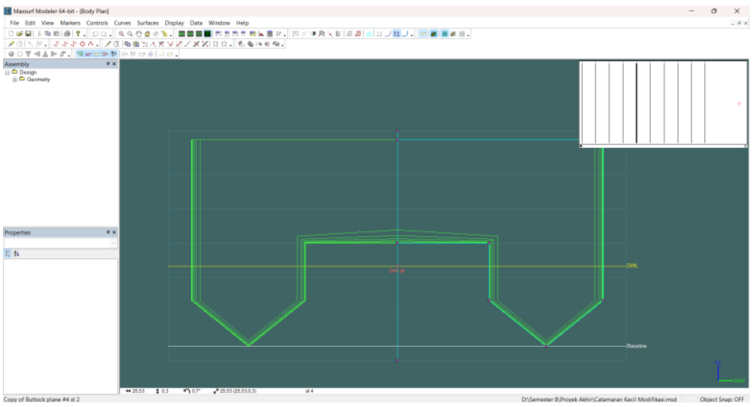


Figure 8. Front View Design of Catamaran Body Hull in Maxsurf Software

Figure 6 is a 3D body hull design that will be designed with the body hull specifications listed in Table 1 in mm units. Seen in Figure 7 is the top view of the hull body or outer skin of the ship. While Figure 8 is the front view of the body hull or hull design. After creating a design in the Maxsurf software, the design is then exported and entered into the AutoCAD software so that the design can be printed on paper as the main standard when cutting balsa wood later. Seen in Figure 9 is the upper deck design of the ASV hull.

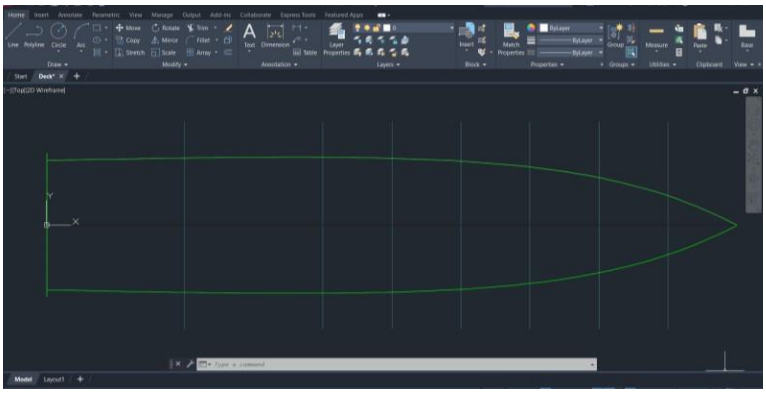


Figure 9. Right Side Ship Body Hull Deck Design in AutoCAD Software

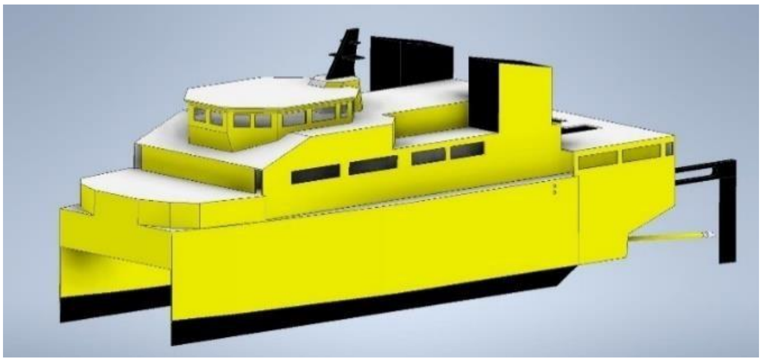


Figure 10. ASV Ship 3D Design

Figure 10 is a 3D design of the ASV ship that will be made. The design uses Autodesk Inventor software, which in this design has adjusted to the size of the design that has been adjusted to the design thathas been made in the Maxsurf software.

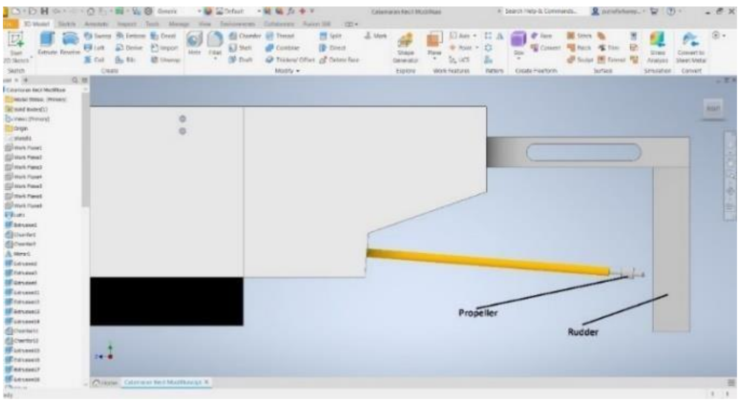
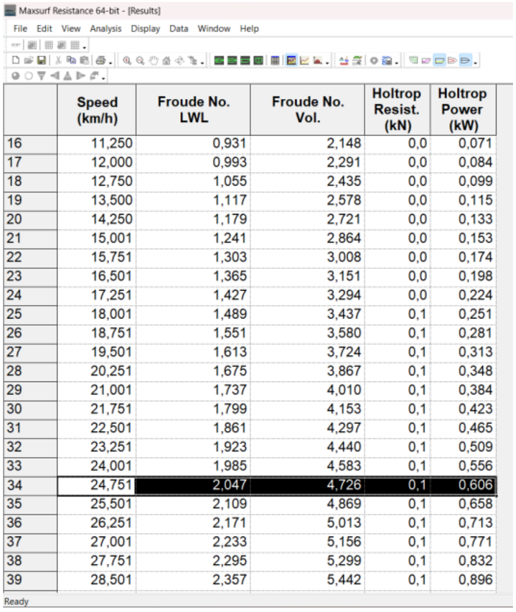


Figure 11. Ship Propulsion and Rudder Laying Design in Inventor Software

Figure 11 is a design for placing the thrust or propeller and placing the position of the ship's rudder orrudder using the Autodesk Inventor software. By planning the design of the ship, it is estimated that the ship's weight is 8 kg, so it still has a tolerance to reach a maximum weight of 2.05 kg. Based on the amount ofload used, the placement of the ship's propeller and rudder adjusts to the existing load, so that the propulsion and steering of the ship can work optimally.


Maxsurf Resistance 64-bit - [Results]
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	Speed (km/h)	Froude No. LWL	Froude No. Vol.	Holtrop Resist. (kN)	Holtrop Power (kW)
16	11,250	0,931	2,148	0,0	0,071
17	12,000	0,993	2,291	0,0	0,084
18	12,750	1,055	2,435	0,0	0,099
19	13,500	1,117	2,578	0,0	0,115
20	14,250	1,179	2,721	0,0	0,133
21	15,001	1,241	2,864	0,0	0,153
22	15,751	1,303	3,008	0,0	0,174
23	16,501	1,365	3,151	0,0	0,198
24	17,251	1,427	3,294	0,0	0,224
25	18,001	1,489	3,437	0,1	0,251
26	18,751	1,551	3,580	0,1	0,281
27	19,501	1,613	3,724	0,1	0,313
28	20,251	1,675	3,867	0,1	0,348
29	21,001	1,737	4,010	0,1	0,384
30	21,751	1,799	4,153	0,1	0,423
31	22,501	1,861	4,297	0,1	0,465
32	23,251	1,923	4,440	0,1	0,509
33	24,001	1,985	4,583	0,1	0,556
34	24,751	2,047	4,726	0,1	0,606
35	25,501	2,109	4,869	0,1	0,658
36	26,251	2,171	5,013	0,1	0,713
37	27,001	2,233	5,156	0,1	0,771
38	27,751	2,295	5,299	0,1	0,832
39	28,501	2,357	5,442	0,1	0,896

Ready

Figure 12. ASV Vessel Propulsion Needs Calculation Results Using Maxsurf software

In Figure 12 using the maxsurf software using the ship design and dimensions in Table 2, it can be seen that the thrust or motor that will be used on the ASV ship for this research research. Then the ship will be able to move starting at 0.251 kW or at a speed of 18.001 km/h until the maximum speed required is0.896 kW or at a speed of 28.501 km/h

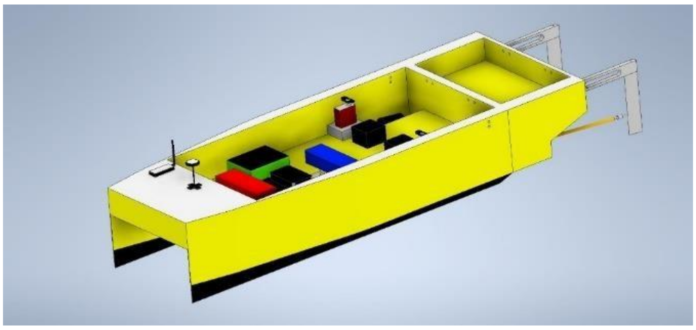

Figure 13. Ship Navigation System 3D Design

The Pixhawk microcontroller on the ASV requires several other components to program it, namely the Global Positioning System, Pixhawk microcontroller, receiver, brushless motor, electronic speed control, servo motor, and li-po battery. These components are assembled and connected to the Pixhawk microcontroller according to Table 3 .

TABLE 3
IN OUT PIN PIXHAWK USED

No	Pin Pixhawk	Component	Information
1.	PWM IO 1	Motor Servo	IN motor servo
2.	PWM IO 2		
3.	PWM IO 3	ESC	IN motor brushless
4.	PWM IO 4		
5.	SER 3	GPS	IN module GPS
6.	I2C		
7.	RC IN	Receiver	IN module transmiter
8.	Power	Power Module	IN baterai li-po

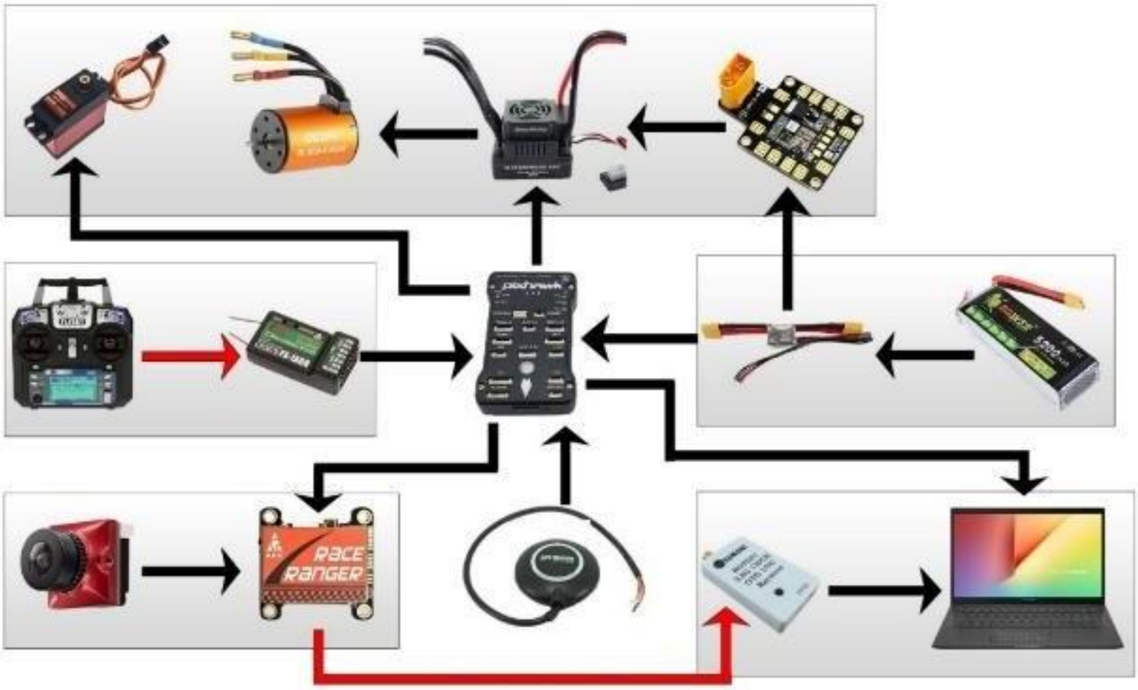

Figure 14. ASV Ship Navigation Control System Wiring

Figure 14 is the ASV ship navigation system wiring. Where the Pixhawk microcontroller is a component that can adjust the ship's movement manually and automatically. For the voltage divider, a power distribution board is used which has been supplied with a Li-Po 3 Cell battery. The 12V voltage is used to supply electronic speed control, while the 5V voltage is used to supply the Pixhawk microcontroller and servo motor. By using 2 motors, a power module is also used which functions to connect two ESCs to a Li-Po battery. Furthermore, the method for changing manual and automatic ship movements has been set onchannel 5 on the remote control, namely the SWD button.

Figure 15. Placement of Ship Navigation Systems

Figure 15 is the placement of the navigation system on the ASV ship. Where the placement of the microcontroller and GPS must be in a position far from components that can cause vibration, one of which is the vibration generated by brushless motors. Because the Pixhawk microcontroller and GPS are the main sensors that determine the ship's movement towards predetermined waypoints and the results will later be stored on the microcontroller. The Pixhawk microcontroller must also avoid cables that can generate hot temperatures, including cables from the battery power connected to the Electric Speed Control (ESC), because they can interfere with thetemperature of the Pixhawk itself.

A. Testing of Ship Navigation Systems

In this test is done by testing the movement of the ship manually and automatically. ASV can move automatically with the help of waypoint navigation on GPS. The waypoint navigation works based on the selected location points, so that the ASV will move towards the point to the point that has been determined automatically. Ship navigation system testing is carriedout in waters that have no currents or big waves and thelocation chosen in this test is a swimming pool.

Figure 16. Testing of Ship Navigation Systems

Testing of ship navigation systems is very importantto ensure that ships can operate safely and efficiently in waters. Some of the tests carried out on the navigation system include:

1. Main Control Equipment Testing

Testing control devices such as microcontrollers. This test aims to ensure that the tool functions in providing accurate data.

2. Electronic Device Testing

Testing of electronic devices such as Brushless Motors, Electronic Speed Control, and Servo Motors. The purpose of this test is to ensure that the electronic device functions properly and can work optimally.

3. System Integration Testing

The system integration test involves all systems on board the ASV, such as gauges and electronic devices. This test is carried out to ensure that the system works synergistically and can interact well with each other.

4. Positioning Accuracy Testing

Testing the accuracy of the ship's position by using apositioning system such as GPS and Compass. This test is carried out to ensure that the ship can follow the position of a predetermined waypoint.

Figure 17. Testing of Ship Navigation Systems

Shown in Figure 17 is a waypoint for testing the ship navigation system automatically to determine the ship's performance using 5 points of interest. Where to use 5 points of interest because the track field conditions are not too big.

The results of testing the ship's navigation system are as shown in Table 4. It can be seen that the ship has a latitude and longitude waypoint target.While the results of the GPS ASV are real data on the movement of the ship. The difference between the target and the real condition is the error expressed asa percentag.

TABLE 4

NAVIGATION SYSTEM TEST RESULT DATA

Destination Point	**Waypoint Targets**		**GPS ASV**		**Error (%)**	
	Latitude	**Longitude**	**Latitude**	**Longitude**	**Latitude**	**Longitude**
1	-7.1401075	113.4865580	-7.1401075	113.4865580	0	0
2	-7.1402246	113.4865487	-7.1402246	113.4865487	0	0
3	-7.1402952	113.4865594	-7.1402951	113.4865592	1.5	1.7
4	-7.1403098	113.4865031	-7.1403097	113.4865030	1.4	8.8
5	-7.1402459	113.4864803	-7.1402459	113.4864803	0	0

The graph related to ship navigation system testing is shown in Figure 18

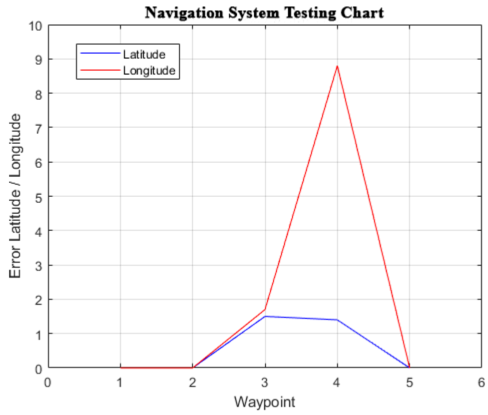

Figure 18. Navigation System Testing Chart

From Figure 18 it shows that the error that occurred during the maneuvering test of the ASV ship's navigation system was the biggest increase at the 4th longitude waypoint. The results of testing this navigation system found that the control system contained on the ship can work optimally and has followed the predetermined waypoints even though the track at the time of testing had wide limitations. However, it is sufficient to test the ship's navigation system.

B. Ship Manuver Tests

Ship maneuver testing is the process of testing the ship's ability to maneuver in various conditions andsituations. The purpose of this test is to ensure that the ship is able to operate safely and efficiently at sea. In testing the ship's maneuvers, the results obtained were that the ship was able to move automatically or manually.

a. Manual Mode ASV Vessel Maneuver Testing

In testing with manual movements, several types of tests were carried out before testing the automatic modeship maneuvers. The following are several types of shipmaneuver tests carried out:

1. Stability Testing

This test is carried out to ensure that the ship has adequate stability at sea with various loads. The test involves several changes in payload and a shift in the weight of the load on the ship.

2. Rudder Testing

This test aims to ensure the ship's steering system functions properly. The tests involve steering maneuvers such as turns, changes of course and emergency maneuvers to test the ship's response.

3. Maximum Speed Testing

This test is carried out to determine the maximum speed that an ASV ship can achieve while at sea. This test involves gradually increasing the ship's speed and observing the ship's response, stability, and engine performance.

4. Braking Test

This test involves testing the ship's braking system to ensure the ship can stop safely and at an appropriate distance. This test includes an emergency braking test and a braking test under various load weight and speed conditions.

5. Emergency Maneuver Testing

This test is carried out to check the ship's response in emergency situations, such as avoiding maneuvers from obstacles or other ships. This test aimsto ensure the ship has the ability to deal with emergency situations effectively. In manual mode ship testing, theresults obtained are that the ship is able to move based on commands sent by the remote control. To control the ship, a remote control is used which is connected to thereceiver on the ship with a limited distance of approximately 500 meters.

b. Automatic Mode ASV Vessel Maneuver Testing

In the automatic mode ship maneuver test, the ship is expected to move according to a predeterminedwaypoint. The difference between the aiming point and the maneuver that occurs will determine the maneuvering performance of the ship.

a) First Test of Auto Mode

The first ASV test was carried out on the Pamekasan Coast. In this test using 7 destination pointson the GPS waypoint navigation system. The destination point can be seen in Figure 19.

Figure 19. Ship Maneuver First Test Waypoint

From this test, the data obtained is in the form oflongitude and latitude ASV location coordinates. In this test the smallest shift in latitude position occurred at point 2 of 0.000002 and the largest at point 4 of 0.000004 because it turned slightly to the right. Meanwhile, the shift in the ship's longitude position is the smallest at point 6 of 0.000002 and the largest at point 2 of 0.000004. The data obtained is as shown in Table 5.

TABLE 5

FIRST TEST DATA RESULTS

Destination Point	Waypoint Targets		GPS ASV		Error (%)	
	Latitude	Longitude	Latitude	Longitude	Latitude	Longitude
1	-7.2240832	113.4503388	-7.2240835	113.4503391	4.1	4.4
2	-7.2240885	113.4499338	-7.2240883	113.4499334	2.1	3.5
3	-7.2236069	113.4499365	-7.2236066	113.4499362	4.1	2.6
4	-7.2233355	113.4497890	-7.2233359	113.4497893	5.5	2.6
5	-7.2233382	113.4503978	-7.2233379	113.4503981	4.1	2.6
6	-7.2237985	113.4504032	-7.2237982	113.4504030	4.1	2.6
7	-7.2239582	113.4505507	-7.2239582	113.4505507	0	0

The graph related to ship maneuver performancetesting is shown in Figure 20. Figure 20 shows the error that occurred during the first maneuver test, the biggestincrease was at the 4th latitude waypoint.

Figure 20. First Maneuver Testing Chart

b) Second Test of Auto Mode

The second test using 6 destination points on the GPS waypoint navigation system or is almost circular because it adjusts to the shape of the terrain.

The destination point can be seen in Figure 21.

Figure 21. Ship Maneuver Second Test Waypoint

In this test the smallest shift has latitude occurred at point 5 of 0.000002 and the largest at point 4 of 0.000004 because it turned sharply to the right. Meanwhile, the shift in the ship's longitude position is the smallest at point 1 of 0.000002 and the largest at point 4 of 0.000005. The data obtained is as shown in Table 6.

TABLE 6
SECOND TEST DATA RESULTS

Destination Point	Waypoint Targets		GPS ASV		Error (%)	
	Latitude	Longitude	Latitude	Longitude	Latitude	Longitude
1	-7.2242056	113.4504032	-7.2242053	113.4504030	4.1	1.7
2	-7.2238225	113.4501645	-7.2238228	113.4501642	4.1	2.6
3	-7.2235723	113.4501135	-7.2235726	113.4501133	4.1	1.7
4	-7.2234153	113.4503067	-7.2234157	113.4503072	5.5	4.4
5	-7.2237373	113.4506795	-7.2237375	113.4506798	2.7	2.6
6	-7.2243493	113.4506741	-7.2243493	113.4506741	0	0

The graph related to ship maneuver performancetesting is shown in Figure 22. Figure 22 shows the error that occurred during the second maneuver testing, the biggest increase was at the 4th waypoint, latitude and longitude.

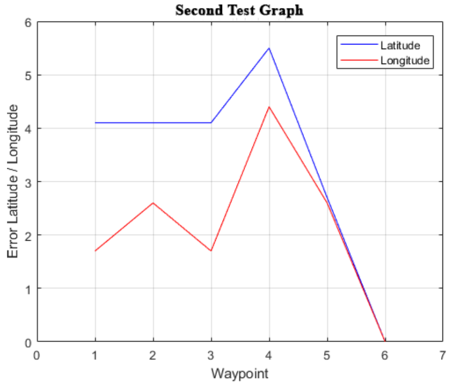

Figure 22. Second Maneuver Testing Chart

c) Third Test of Auto Mode

This third test uses 8 destination points on theGPS waypoint navigation system or in the form of a zig-zag line. The destination point can be seen inFigure 23.

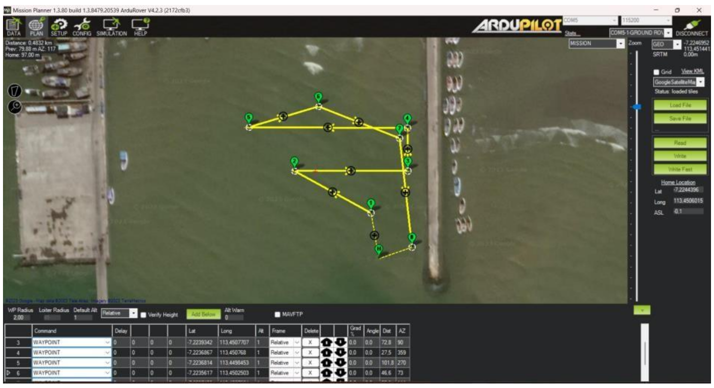

Figure 23. Ship Maneuver Third Test Waypoint

In this test the smallest shift has latitude occurred at point 1 of 0.000002 and the largest at point 2 of 0.000006 because it turned very sharply to the right. Meanwhile, the shift in the ship's longitude position is the smallest at point 1 of 0.000002 and the largest at point 2 of 0.000004. The data obtained is shown in Table 7.

TABLE 7

THIRD TEST DATA RESULTS

Destination Point	Waypoint Targets		GPS ASV		Error (%)	
	Latitude	Longitude	Latitude	Longitude	Latitude	Longitude
1	-7.2241764	113.4505561	-7.2241762	113.4505559	2.7	1.7
2	-7.2239342	113.4501109	-7.2239348	113.4501113	8.3	3.5
3	-7.2239342	113.4507707	-7.2239339	113.4507704	4.1	2.6
4	-7.2236867	113.4507680	-7.2236864	113.4507677	4.1	2.6

5	-7.2236814	113.4498453	-7.2236819	113.4498456	6.9	2.6
6	-7.2235617	113.4502503	-7.2235620	113.4502506	4.1	2.6
7	-7.2237453	113.4507224	-7.2237456	113.4507227	4.1	2.6
8	-7.2243733	113.4507948	-7.2243733	113.4507948	0	0

The graph related to ship maneuver performancetesting is shown in Figure 24. Figure 24 shows the error that occurred during the third maneuver test, the biggest increase was at the 2nd latitude waypoint.

Figure 24. Third Maneuver Testing Chart

d) Fourth Test of Auto Mode

The fourth test, 9 destination points are used onthe GPS waypoint navigation system and tracks are traversed more broadly to determine the performance strength of the ship's navigation system. The destination point can be seen in Figure 25.

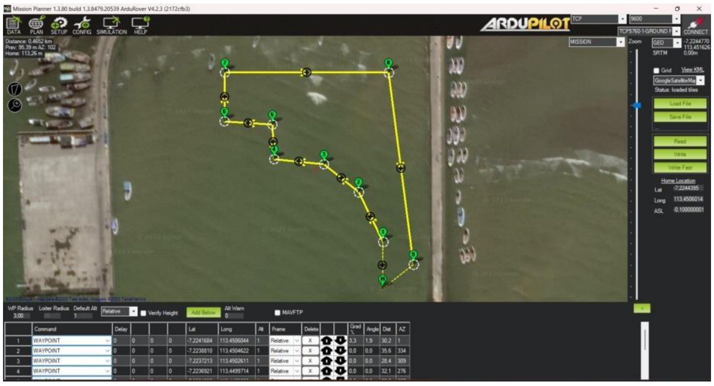

Figure 25. Ship Maneuver Third Test Waypoint

In this test the smallest shift has the latitude position occurs at point 1 of 0.000001 and the largest atpoint 5 of 0.000004. Meanwhile, the shift in the ship's longitude position is the smallest at point 1 of 0.000002and the largest at point 4 of 0.000004. The data obtained is as in table 8.

TABLE 8

FOURTH TEST DATA RESULTS

Destination Point	Waypoint Targets		GPS ASV		Error (%)	
	Latitude	Longitude	Latitude	Longitude	Latitude	Longitude
1	-7.2241684	113.4506044	-7.2241683	113.4506042	1.3	1.7
2	-7.2238810	113.4504622	-7.2238808	113.4504619	2.7	2.6
3	-7.2237213	113.4502611	-7.2237211	113.4502608	2.7	2.6
4	-7.2236921	113.4499714	-7.2236924	113.4499719	4.1	4.4
5	-7.2234925	113.4499606	-7.2234921	113.4499603	5.5	2.6
6	-7.2234739	113.4496817	-7.2234741	113.4496820	2.7	2.6
7	-7.2231918	113.4496844	-7.2231921	113.4496847	4.1	2.6
8	-7.2231918	113.4506366	-7.2231921	113.4506369	4.1	2.6
9	-7.2242988	113.4507814	-7.2242988	113.4507814	0	0

The graph related to ship maneuver performancetesting is shown in Figure 26. Figure 26 shows the error that occurred during the fourth maneuver testing, the biggest increase was at the 4th longitude and 5th latitude waypoints.

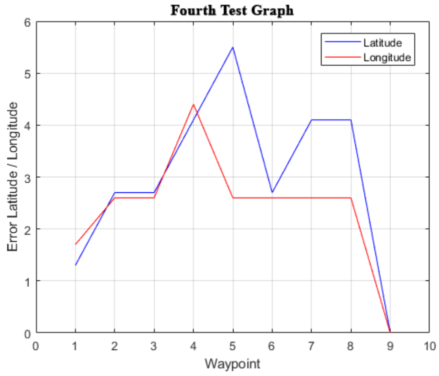

Figure 26. Fourth Maneuver Testing Chart

Based on Tables 5 to 8, this is the result of comparing data from waypoint targets that have been programmed in the Pixhawk microcontroller with GPSon the ASV when it is already running at sea. ASV moves automatically according to the intended

waypoint. However, there is a difference between the Waypoint Targets and the results of GPS data obtained while the ship is running.

How to find out how long the GPS error rate is in meters, you can convert from Degree Decimal (DD) units as in the table above to Degree Minute Second (DMS) units then convert them to meters using the method below.

Referring to the calculations Hajar [11] and Monroe [12] So to calculate the distance between 2 points can be done using the following formula:

1˚ (degrees) latitude/longitude = 113.322 meters1' (minute) latitude/longitude= 1885.37 meters

1” (second) latitude/longitude = 30.9227 meters

1˚ (degrees) latitude/longitude = 60' (minutes = 3600 (seconds)

1' (minutes) latitude/longitude = 60" (seconds)

Degree Decimal (DD) To Degree Minute Second (DMS)

D (D value is taken from an integer value that is positive because it is in east longitude) or (D value is taken from an integer value that is negative south latitude) and is expressed in degrees.

$$M = Pnd \times 60$$

$$S = PnM \times 60$$

Where,

Pn : Personal Navigation

D : Degrees

M : Minutes

S : Second

Distance Coordinate

$$JK = KT - KA$$

Where,

JK : Coordinate Distance

KT : Destination CoordinatesKA : Origin Coordinates

Error GPS

$$Error = \frac{\text{Coordinate Distance}}{\text{GPS ASV}} \; 100\%$$

The first comparison is the smallest data difference,namely in the fourth test data at the waypoint 1 latitude:

- Convert DD to DMS point -7.2241684:
  The number before the comma is changed to 7˚
  The number after the decimal point multiplied by 60is:

  M = Pnd x 60 (1)
  = 0.2241684 x 60
  = 13.450104 or it can be called 13'

  The number behind the comma from the result above is multiplied by 60 again, namely:

  S = PnM x 60 (2)
  = 0.450104 x 60
  = 27.00624 or it can be called 27”

  With the results above, the DMS coordinates are7˚13'27" (3)

  7˚ x 111,322 meters = 779,322 meters
  13' x 1,885.37 meters = 24,509.81 meters
  27” x 30.9227 meters = 834.9129 meters

- Convert DD to DMS -7.2241683
  The number before the comma is changed to 7˚
  The number after the decimal point multiplied by 60is:

  M = Pnd x 60 (4)
  = 0.2241683 x 60
  = 13.450098 or it can be called 13'

  The number behind the comma from the result above is multiplied by 60 again, namely:

  S = PnM x 60 (5)
  = 0.450104 x 60
  = 27.00588 or it can be called 27”

  Analyzing the results above, the DMS coordinatesare 7˚13'27" (6)

  7˚ x 111,322 meters = 779,322 meters
  13' x 1,885.37 meters = 24,509.81 meters
  27” x 30.9227 meters = 834.9129 meters

Based on the results of the comparison above, the difference in coordinates of 0.0000001˚ does not really affect the performance of the ASV ship.
The comparison of the two biggest data differences is in the second test data at the 4-longitude waypoint:

- Convert DD to DMS point 113.4503067:

  The number before the comma is changed to 113˚

  The number after the decimal point multiplied by 60 is:

  M = Pnd x 60 (7)
  = 0.4503067 x 60
  = 27.018402 or it can be called 27'

  The number behind the comma from the resultabove is multiplied by 60 again, namely:

  S = PnM x 60 (8)
  = 0.018402 x 60
  = 1.10412 or it can be called 1"

  With the above results, the DMS coordinates are 113˚27'1" (9)
  113˚ x 111,322 meters = 12,579,386 meters
  27' x 1,885.37 meters = 50,904.99 meters
  1" x 30.9227 meters = 30.9227 meters

- Convert DD to DMS 113.4503072

  The number before the comma is changed to 113˚ The number after the decimal point multiplied by 60is:

  M = Pnd x 60 (10)
  = 0.4503072 x 60
  = 27.018432 or it can be called 27'

  The number behind the comma from the resultabove is multiplied by 60 again, namely:

  S = PnM x 60 (11)
  = 0.018432 x 60
  = 1.10592 or it can be called 1"

  With the above results, the DMS coordinates are 113˚27'1" (12)
  113˚ x 111,322 meters = 12,579,386 meters
  27' x 1,885.37 meters = 50,904.99 meters
  1" x 30.9227 meters = 30.9227 meters

Based on the results of the comparison above, the difference in coordinates of 0.0000005˚ does not really affect the performance of the ASV ship. With all the experiments carried out, it can be concluded that theASV in testing this final assignment can be said to be accurate even though there is a difference in latitude coordinates of 0.0000001˚ and longitude of 0.0000005˚.The difference could be caused by the specifications ofthe GPS, or the GPS is too hot due to receiving signalsfrom satellites.
Find out the length of the GPS error rate in percent by using the formula below:

$$\text{Error} = \frac{\text{Coordinate Distance}}{\text{GPS ASV}} \times 100\%$$

The first comparison is the smallest data difference, namely in the fourth test data at waypoint 1 latitude.
Difference in Distance = Target waypoint – GPS ASV
= 7.2241684 – 7.2241683
= 0.000001

$$Error = \frac{0,000001}{7,2241683} \times 100\%$$
$$= 1.38\ \% \quad (13)$$

Comparison of the two biggest data differences is in thesecond test data at waypoint 4 longitude.
Difference in Distance = Target waypoint – GPS ASV
= 113.4503067 – 113.4503072
= 0.000005

$$Error = \frac{0,000005}{113,4503072}\ 100\%$$
$$= 4.4\% \quad (14)$$

IV. CONCLUSION

Based on the process of planning and discussingthe research entitled "Design and Build of an Autonomous Flying Dutchman Ship with a GPS Navigation System as an Effort to Increase the Quantity of Grouper Fishing on the Pamekasan Coast" it can be concluded that:

1. ASV ship with overall dimensions of 150 cm in length, 40 cm in width, 50 cm in height, 8 kg in weight and has a maximum speed of 28 km/hour hasbeen obtained.
2. An automatic ship maneuvering control system has been obtained using a Pixhawk microcontroller and a Brushless Motor by following predetermined coordinates or trajectories.

A navigation system has been obtained using the waypoint method to determine the path traversed by the Autonomous Surface Vehicle (ASV) with the help of aGPS sensor with an error rate of 1.38% at latitude and 4.4% at longitude.

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