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Automatic Fish Feeder on Unmanned Surface Vehicle with Automatic Control and Navigation

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Abstract

Fish farming is common in Indonesia. The farmers usually use ponds with a large size for cultivation which have constraints on feeding due to their size. An automatic feed system with An Unmanned Surface Vehicle (USV) can be the solution to overcome this problem. The USV moves to the predetermined position and direction using GPS and compass. When it has arrived at that point this USV feeds the fishes according to the predetermined amount. In this study, the Pixhawk is used to control the USV to accomplish the given mission. It uses mission planner software for determination of the waypoint points, the calibration of components, and the control of PID. The Pixhawk also serves as a ground control station (GCS) for monitoring the motion and position of the USV using radio communication of 433MHz telemetry connected to the GCS and computer. The fish feeding system uses a load cell sensor to measure the weight of the feed to be thrown and two servo motors as a feed production system. Both sensor and servo motors are controlled by an Arduino UNO. The feed tank has a maximum capacity of 7.5 liters with 0.41 cm per kilogram buoyant force of the USV. The test was carried out on a pool of 10 × 10 m by placing 4 Waypoints. The USV has an average speed of 0.65 m/s and reaches a total distance of 55.5 m in 88 seconds. Before releasing to the pond, the feed weight is measured using a load cell sensor which has an accuracy of 98.99%. The difference between the set point and the feed released by the USV is very close, where the average error value is about 4.98%. The error value becomes smaller when more weight is set.

Keywords: Unmanned Surface Vehicle; Fish Feeder; Cultivation; Pixhawk; Arduino UNO; Mission Planner; Load Cell; Servo Motor.

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1. Introduction

Indonesia is the largest maritime country in the world, with the potential for a wealth of natural resources spread across various regions. The potential of fishery resources, both capture fisheries, marine aquaculture, public waters and others is estimated at US$ 82 billion per year [1]. Globally, aquaculture contributed to 44.1% of the world's total fish production in 2014 and this percentage continues to increase every year. Asia countries dominate 88.91% and Indonesia is in second place with a contribution of 5.77% of the world's aquaculture production. The condition of Indonesian aquaculture itself tends to significantly increase in production since 2003, with a production volume of 13.7 million tons in 2013 [2].

Feeding aquaculture in Indonesia is still widely used in a simple way, namely using your hands to spread fish feed directly into the pond. This simple method has several drawbacks, including unpunctually feeding time and inaccurate dosing at each feeding. This inaccurate traditional method usually affects the water quality of aquaculture ponds and creates poor water quality that subsequently can cause nonoptimal fish growth, fish infection, growing fish diseases and have a negative impact on fish growth [3]. One of the main challenges faced by cultivation development is the management life and maintenance. The essential elements for growth and production are food and feeding. This affects the economic aspects, especially in aquaculture projects [4]. In addition, the commercial feed contains high protein that can cause the accumulation of ammonia levels in the water and can accelerate decrease in water quality [5].

An automatic fish feeder [6,7] can be an alternative solution. It is a robot boat / unmanned ship that moves automatically according to the specified point using a global positioning system (GPS) and reaches all points that is going to be sprinkled with fish feed. The unmanned ship can be controlled manually using a remote or automatically using a waypoint on mission planner.

Unmanned Surface Vehicle (USV) are typically used in different application areas, one of which is used for coastal surveillance [8]. USV is for maritime surveillance and marine safety. In a few years the last patrol boat system has been created using the concept of maritime surveillance, namely the smart concept of using marine patrol boats without crew [9]. In this study, USV is used to provide effective fish feeder.

Previously, there have been many studies on automatic fish feeding. Most studies make the tool static. Several domestic companies have made products for automatic fish feeding large-scale ponds. In large ponds, static feeding has limitations regarding the distribution of feeding. This will affect the consistency of fish dimensions at harvest. The USV Fish Feeder minimizes this problem because the USV can move mobile in the pond and can provide feed at the point where it is needed. The advantage of the USV Fish Feeder is that it can help evenly distribute feed, especially in large-scale ponds.

The objective of this study is designing the buoyancy needed for the hull of the USV Fish Feeder that can move automatically to the way point and feed the needs in ponds with different pool shapes and sizes according to GPS navigation.

2. USV Fish Feeder Design

2.1 Design Making and Work Principle

USV Fish Feeder have an initial design to describe the layout of components.

Fig 1 Explain the 3D design of USV Fish Feeder, USV has total length 94 cm, total width 67 cm and total height 76 cm. The system is designed to create an Unmanned Surface Vehicle (USV) Fish Feeder. The system created by the USV can move using the remote control or moves automatically according to the way point This automatic feed system will sprinkle feed when the USV has reached the waypoint. The USV will move automatically using software mission planner, with data communication using telemetry connected to the tool and to the laptop. The USV fish feeder will move according to the waypoint that has been set with GPS to get the coordinate point and position when moving, GPS is attached to the USV fish feeder, the movement of the USV fish feeder can be seen from the coordinate point with the help of GPS. The GPS used on this USV fish feeder is Ublox Neo 7m, after testing the position accuracy between the data from the GPS and the actual position in the pool. Based on time, coordinate, speed, and relay data when the USV fish feeder is operating in auto mode. All these components are controlled with Pixhawk, on Pixhawk there are also several sensors, namely gyroscope, accelerometer, magnetometer where this sensor also helps the USV fish feeder to be in line properly. In the feeding system, there is one fish feed tank to hold feed with a volume of 7.5 kilograms and a small bucket with a Load cell sensor to measure the weight of fish feed before being stocked in a pond so that the feed sown at each point is in accordance with the needs of the fish. There are 2 servo motors, servo motor A has the function of opening the bottom lid of the tank so that it can distribute feed to a small bucket until the feed weight is as needed. While the servo motor B functions to flip the feed on a small bucket to be sprinkled directly on the pond.

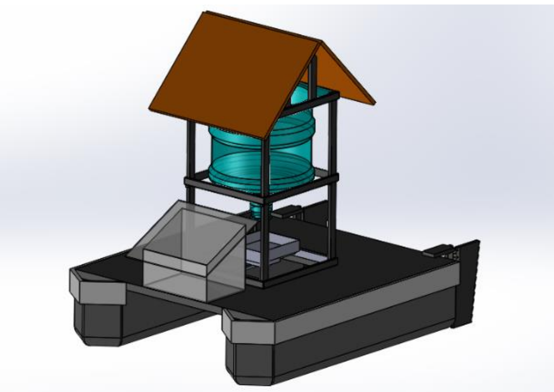

Fig 1. 3D Design USV Fish Feeder

2.2 Hull of USV

To make the hull of USV, we considered the Archimedes Law. The law applies where an object is immersed completely or partially in a liquid substance, the liquid will exert an upward force (buoyancy force) on the object, where the magnitude of the upward force (buoyancy force) is equal to the weight of the liquid being displaced [10].

Dimensions of USV Hull presented in Fig.2. The part of the ship's body that provides buoyancy to prevent the ship from sinking is the hull [11]. The USV Fish Feeder has a five-sided hull. The thickness of the hull

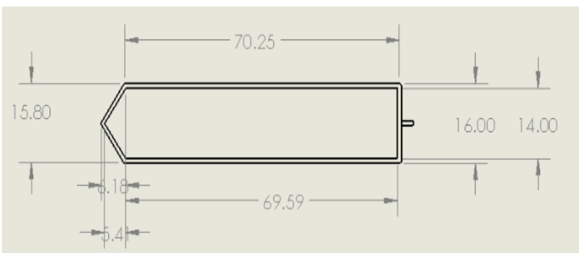

Fig 2. Dimensions of USV Hull (in cm)

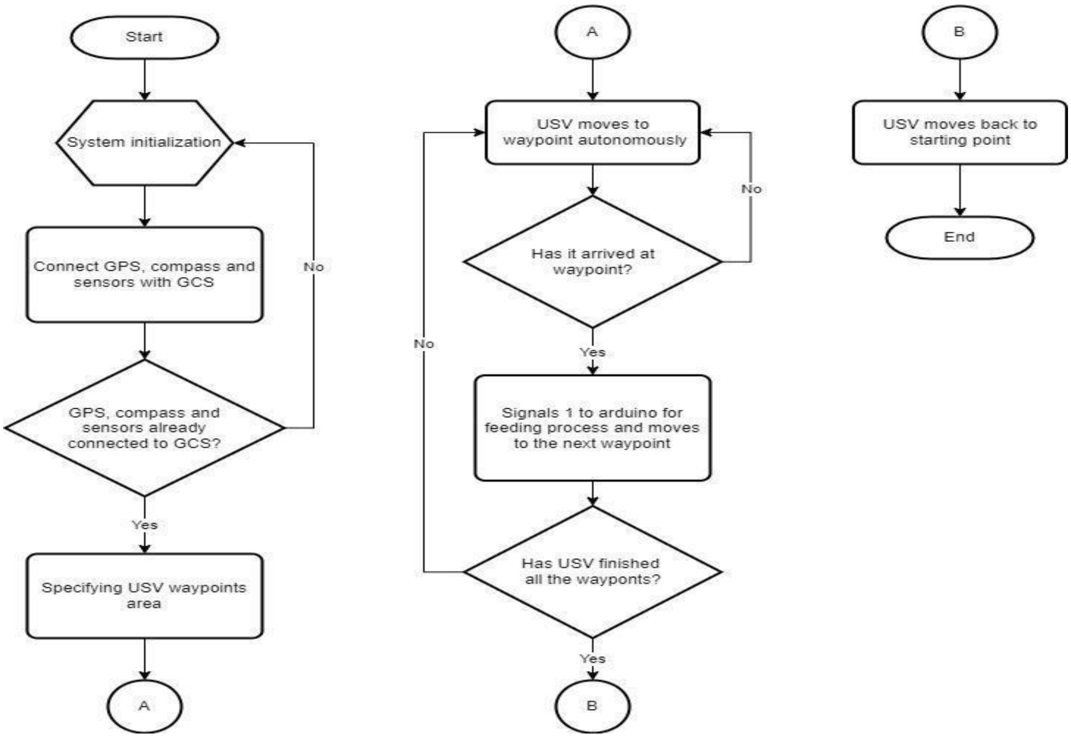

Fig 3. Block Diagram Autonomous System

of this ship is 1 cm. The volume calculation is divided into two parts, namely a rectangle and a triangle. On the rectangular part it has an outer length of 70.25 cm, an inner length of 69.59 cm, an outer width of 16 cm and a depth of 14 cm. The front of the ship is triangular with an outer base of 15.80 cm and an inner base of 14 cm, an outer height of 6.18 cm and an inner height of 5.41 cm.

2.3 Autonomous Navigation and Design of Feeding Dispensing System Implementation

Autonomous navigation and design of feeding dispensing system implementation use a mission planner as a software. The block diagram autonomous system is presented in Fig.3. Mission planner is an opensource application that functions as a ground control station usually for the control of UAVs/drones, planes, rovers and USVs/unmanned ships.Mission planner has many features in it that can provide missions in the movement and work of tools, monitoring tools, configuration, and calibration. Calibrations that can be done in this mission planner are the calibration of the controller and its sensors, ESC calibration, and compass calibration. PID control methods can also be carried out on this software provider so that the movement of USV is better.

UAVs in general carry a payload of cameras, sensors, and devices telemetry for communication between the vehicle to the Ground Control Station (GCS). The figure below is how the USV fish feeder system works which is combined with GCS using 433MHz telemetry so that it can be monitored and run automatically [12,13].

Fig 4. describe about flowchart feeding dispensing, the system starts by waiting for command data from Pixhawk PX4 to Arduino UNO. When the data has been received, Servo Motor A will move to pour feed from the tank on the container which will be measured in weight by the load cell sensor to reach the required weight and when the weight is appropriate, the servo motor A will again move to close the tank. When the container has accommodated the feed according to needs, servo motor B will move to rotate the container to pour feed on the pond and when all the feed has been poured, Servo Motor B will move the container back to its original place. After that, Arduino UNO again waits for the command signal from Pixhawk PX4 [14,15].

3. Result and Discussion

Measurement of Unmanned surface vehicle fish feeder is used for ship stability. The USV Fish Feeder is presented in Fig. 5. In picture (a) shows the feeder mechanic and picture (b) show the overall view of the ship. It has total length 94 cm, total width 67 cm and total height 76 cm. The hull buoyancy test was carried out to see balance of the ship. The thickness of the hull of this ship is 1 cm. The volume calculation is divided into two parts, namely rectangles and triangles.

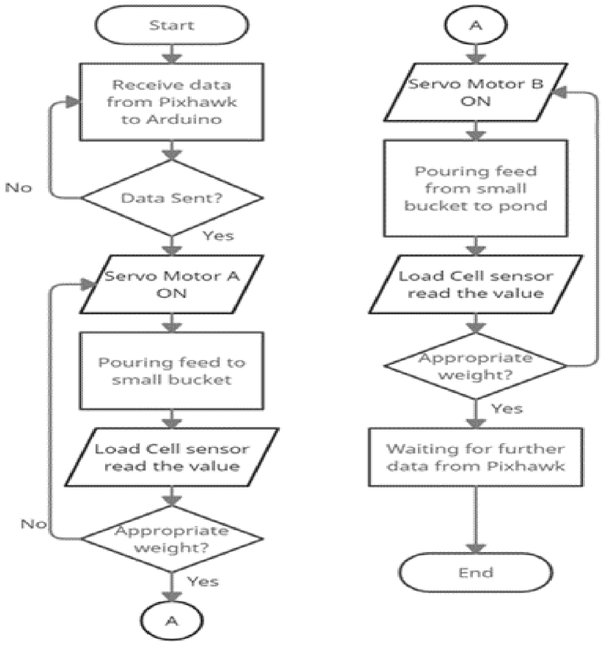

Fig 4. Flowchart Feeding Dispensing

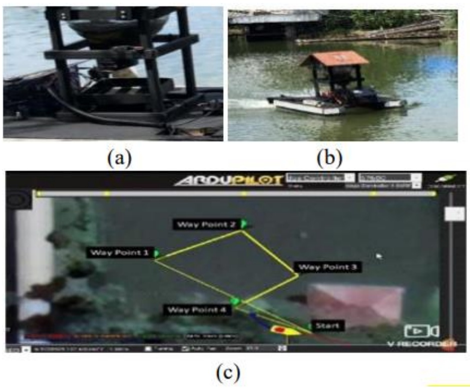

Fig 5. Unmanned Surface Vehicle Fish Feeder.

rectangles and triangles. The rectangle has an outer length of 70.25 cm, an inner length of 69.59 cm, an outer width of 16 cm and an inner width of 14 cm. The front of the ship is triangular with an outer base of 15.80 cm and an inner base of 14 cm, an outer height of 6.18 cm and an inner height of 5.41 cm. Picture (c) showing course of the ship from start to waypoint 4.

3.1 Hull Calculation

To determine the volume of the hull we used Eq. (1) and (2) with F_a is water lift force, ρ_f is the density of the water, g is gravity, W_l is the weight of the hull and W_{bf} is the hull weight in water.

Known,

$$F_a = \rho_f \times V_b \times g \qquad (1)$$

$$W_{bf} = W_l - F_a \qquad (2)$$

Based on equations (1) and (2), in this study, we get F_a is 36.69 Newton and W_{bf} is -78.89 Newton, because our system consists of two hull them total W_{bf} is -157.78 Newton. Hence, to keep the USV floating on the surface of the water value $W_{bf} = 0.$ It can be concluded that the maximum load that can be USV Fish Feeding accommodated is 157,78 Newton or 16.09 Kg.

3.2 Buoyancy Test Result

Buoyancy Test Result includes load on fees tank, feed weight, right hull (RH), left hull (LH), line value different (LVD), and average between right hull and left hull and ship stability.

The result of buoyancy test has presented in Table 1. RH Table of Buoyancy test result show the right hull, LH for left hull, PNG for Line Value Different, B for buoyancy and S for Stable Seen by the test data with a feed load of 0 kg the hull sink line averaged 7.5 cm. This initial value was obtained because the lower hull design of the ship's lower and smaller volumes made the hull buoyancy very small at the end of the hull.

Seen by the data taken from the feed load of 0–7 kg, it can be concluded that the buoyancy on the stomach is worth 0.414286 cm per kilogram. In the second and third first tests, there was a difference in lines between the hull and the left where the average difference in values was 2%.

Table 1. Buoyancy Test Result

No	Load on feed tank (kg)	Feed Weight+ other (kg)	Sinking Line				B
			RH (cm)	LH (cm)	LVD	Average (cm)	
1	0	6	7.6	7.4	3%	7.5	S
2	1	7	8	7.8	3%	7.9	S
3	2	8	8.4	8.1	4%	8.25	S
4	3	9	8.9	8.6	3%	8.75	S
5	4	10	9.3	9	3%	9.15	S
6	5	11	9.6	9.4	2%	9.5	S
7	6	12	10	9.8	2%	9.9	S
8	7	13	10.4	10.4	0%	10.4	S

There are several factors that influence the difference in values such as there is an error in making the stomach, center of gravity, wind, waterlogging and the author's inaccuracy in taking the data. However, with the difference in value still below 5%, the hull that the author has designed can be said to be stable. Based on the Archimedes USV Fish Feeder law, which the author designed, it can withstand loads with a total of 16 kg, but in the hull buoyancy test table, there is only a maximum of up to 13 kg of data because the volume of the fish feed tank made by the author can only accommodate a maximum feed load of 7.5 kg.

After the buoyancy test, the next step is checking the autonomous system by testing the Rudder Angle Ship Movement and Motor Speed. The results are presented in Fig. 6.

3.3 The Rudder Angle Ship Movement and Motor Speed Test.

The rudder angle ship movement test includes diameter (m) and rudder angle (ϴ).

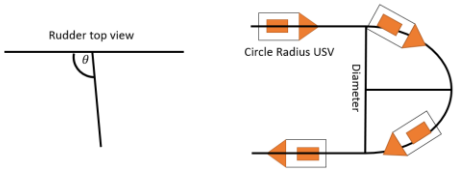

Fig 6. Circle Radius USV Test Illustration

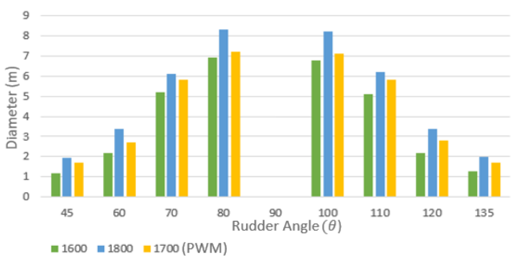

Fig 7. Chart of diameter to angle of rudder and PWM motor

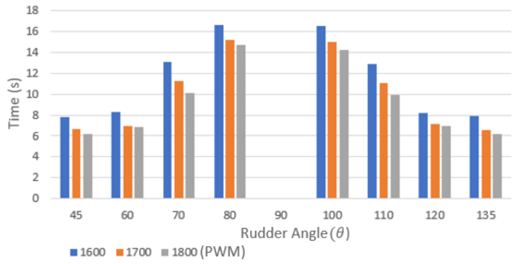

Fig 8. Chart of time to angle of rudder and PWM motor

Fig 6 is an illustration of USV turning right and left with parameters of rudder angle, time, PWM and diameter. The USV moves to the right when the rudder angle is 45°-88° and to the left when 92°-135°. From Fig 7 shows the test results between the diameter (m) and the steering angle (°) are different with the PWM motors of 1600, 1700 and 1800. Fig 8 shows a graph of the time (s) it takes to move from the starting point to the end point as illustrated in Fig 6, with different steering angles (°) with the PWM motors of the 1600, 1700 and 1800. The motor and rudder will move with the PWM signal issued by the Pixhawk signal pin. For the PWM throttle to advance ranges from 1501-1800, at the time of testing the USV will carry a full load of 7.5 kg and the turning diameter distance will be measured using a Kennedy measuring wheel. The condition of the rudder when running straight is when the PWM servo is 1545, which is the initial setting of 1500 but during the trials the USV moves slightly obliquely to the left, after being changed to 1545 the ship is already running straight and to turn left PWM servo 1145-1543 and to the right PWM servo 1547-1945.

From the plot of the diagram above the optimal speed in manual mode for movement when the full load is 7.5 kg is on the PWM of the motor a maximum of 1700, where the USV can move optimally with a

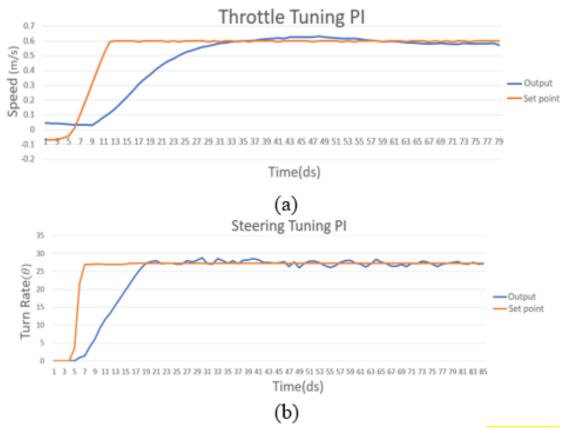

Fig 9. P.I. Result Chart on Mission Planner.

circle radius that is not too far away with a fast travel time.

3.4 Tuning PI

The balance of the ship being seen from the buoyancy test and rudder angle ship movement and motor speed, moreover PI Tuning also needs to be done

The result chart on mission planner is present in Fig 9. In this tuning process, many experiments were carried out and P and I values were obtained for throttle and steering. For steering (a) the values P = 0.28, I = 0.13 and FF = 1.2 and throttle (b) P = 0.23 and I = 0.12 with cruise speed 1 and cruise throttle 40. After considering the balance of the ship, the next test is knowing waypoint movement of the USV, feed dispensing system test, and waypoint feeding.

3.5 Waypoint Movement of The USV

USV has movement for several waypoint according the illustration below with Wp G is waypoint on Ground Control Station (GCS) and Wp R is real condition of USV.

Fig 10. is an illustration at the time of the depiction of the waypoint for the ship to run automatically without the problem of hitting the edge of the pond so that the feeding process runs well. The value of Wp G is set on the GCS in Mission Planner which is compared with Wp R that we can determine the accuracy of the waypoint on our system.

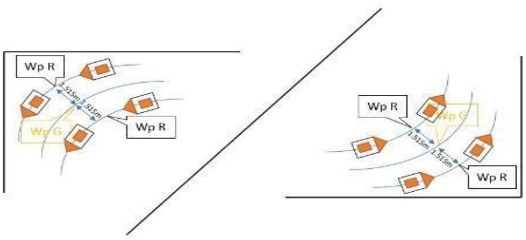

Fig 10. Illustration set Waypoint

Fig 11. Mission Planner Interface Waypoint

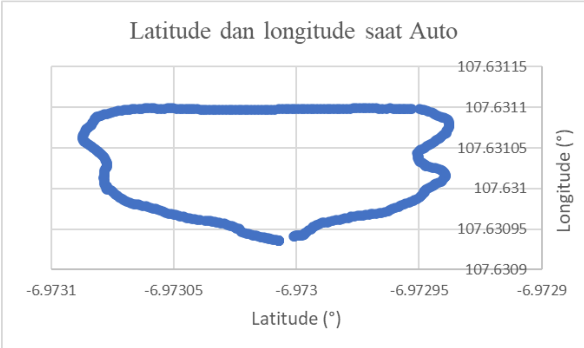

Fig 12. USV Coordinate Chart when it is controlled automatically.

Fig. 11 describe the USV will move towards 4 waypoints and return to the home or place where the USV started to move, which at each waypoint USV will provide fish feed to the pond. The data retrieved when the USV is carrying out the mission is time, latitude, longitude, and speed data. Here is the data generated by the USV fish feeder when carrying out the mission from the beginning of the move until it returns to its original place in auto mode.

The USV mileage during the mission from start to return to the starting place measured by the Kennedy measuring wheel was about 55.5m. In taking data on the USV mileage in the pool using the Kennedy measuring wheel, there can be measurement errors because measurements are not directly carried out in the pool but follow the movement of the USV from the edge of the pond.

Fig. 12 shows the position of the USV coordinates during the mission x-axis as latitude and y-axis as longitude. The graph depicts the USV motion during the move there was a slight error in waypoint 3 to 4, the factor that influenced it was the situation around the pool at that time was windy and quite fast, but even though there was a slight error in the position, the USV still tried to get to waypoint 4 correctly

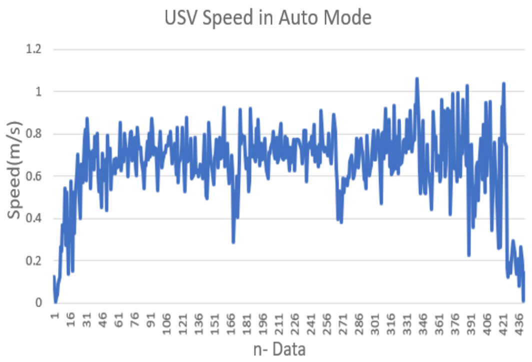

Fig 13. USV Speed Data Plot in Auto Mode.

Fig. 13 explain about USV Speed Data Plot in Automatic mode. The graph on fig.11 shows x-axis as n-data and y-axis as speed data (m/s). The average speed value obtained during auto mode is 0.65456 m/s and the time it takes USV to complete the mission from start to the original point is 1 minute 28 seconds and the time from start all the waypoint 4 is 1 minute 14 seconds. Then the time comparison can be done by multiplying the average speed by the travel time of 88 seconds is 57.6 meters while the distance measured by the Kennedy measuring wheel is 55.5 meters and this result is quite close to the existing data value with the actual distance.

3.6 Feed System Test

Feed system test consisted of several set point and carried out with 3 trials each set point.

Table 2 show the result of feed system test, when the initial feed is removed from the tank there is an instability in the process of the feed dispensing mechanism that makes the initial process of feed production longer. Based on the test data above, it can be concluded that the higher the set point value, the faster the speed of the feed removal system on the USV Fish Feeder.

The load cell sensor gave commands to both servo motors when their values correspond to the specified set point. The accuracy test of the load cell sensor is carried out to determine the accuracy of the sensor in signaling the output to the servo motor signal input. The result is presented in Table. 2. The test results show that the average accuracy value of the load cell by signaling the output is 98.99%. The feed released in the feeding system at the USV Fish Feeder was weighted by the FS 400 scale to find out the accuracy of the feed that comes out whether it is in accordance with the predetermined set point. The test resulted in an average feed output error value in the USV Fish Feeder feeding system of 4.93%. It can be concluded that the fish feeding system at the USV Fish Feeder is quite good with a sensor accuracy of 98.16% and a feed output error value that is still below 5%.

The calculation of the feed conversion ratio required 3.25 kg feed per autonomous mission, therefore for four waypoints, the feed expenditure is 812.5 g per waypoint. The error value in the feed output is 3.17%. When the set point load cell is 800 meaning that the feed comes out at 800-825 g. There are mechanical limitations in the USV Fish Feeder feed system, so the author used a 1: 2 scale in the test. In this study, the set point load cell is 400 g per waypoint, or the feed comes out at 400-412 g per waypoint. Hence, the total feed in this test is around 1650.72 g per autonomous mission.

Table 2. Result of Feed System Test

Set Point	Test	Serial Monitor Load Cell (g)	Feed weight out (g)	Required Time (s)	Speed of feed system (g/s)	Load Cell Accuracy Value (%)	Feed Output Error (%)
100	1	102	108	3.66	27.87	98.00	8.00
	2	100	107	3.72	26.88	100.00	7.00
	3	101	105	3.69	27.37	99.00	5.00
200	1	202	212	4.65	43.44	99.00	6.00
	2	204	213	4.6	44.35	98.00	6.50
	3	200	211	4.63	43.20	100.00	5.50
300	1	301	311	5.82	51.72	99.67	3.67
	2	301	310	5.82	51.72	99.67	3.33
	3	305	314	5.83	52.32	98.33	4.67
400	1	404	414	6.93	58.30	99.00	3.50
	2	406	411	6.99	58.08	98.50	2.75
	3	405	413	6.99	57.94	98.75	3.25

Table 3. Waypoint Feeding Test

Waypoint	Feed production (g)	Space (m)	Time (s)	Notes
Start – 1	400-412	20	20.34	Feed Sown
1 – 2	400-413	10	11.67	Feed Sown
2 – 3	400-414	10	11.21	Feed Sown
3 – 4	400-415	10	11.4	Feed Sown

Waypoint Feeding Test is present in Table 3. The results of this test show the success of each USV Fish Feeder waypoint in issuing feed according to the set point, which is 400 g. Judging from table 4.3, the average error value at the set point with a feed expenditure weight of 400 g is 3.17%. In this test, it was also explained about fish feed sprinkled on each waypoint worth a range of 400-412 grams. In this test, the total travel time for automatic fish feeding for 4 waypoints with a total distance of ± 50 meters, which was 54.62 seconds. The results show that at each waypoint the feed system will automatically issue feed, so it can be concluded that the feeding system can be carried out automatically. In conclusion, the test carried out with 4 waypoints and a total distance of ± 50 meters was successfully carried out with a period of 54.62 seconds.

4. Conclusions

In this study, we have built a USV with buoyancy of 0.41 cm/kg. During the movement, the left and the right hull has an average difference 2%. The maximum feed load is 7.5 kg. The GPS is working properly in determining the distance with an error radius of 1. 51 meters. In the automatic mode, the USV fish feeder can move towards the specified four waypoints at an average speed of 0.65 m/s and the USV travel time of 88 seconds. USV Fish Feeder can feed 400-412 grams per waypoint or 1600-1650 grams per one autonomous mission in a period of 54.62 seconds. Even though the average value of feed output accuracy in load sensor is 99.16%, however there is an error of feed output of 4.93% due to mechanical problems which require further study.

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