Autonomous Surface Vehicle (ASV) Prototype to Determining Ship Routes with PID Using Pixycam

Sapta Nugraha[1], Risandi Dwirama Putra[2*], Eko Prayetno[3], Hendra Permana[4], Muhammad Farid Al-Baqir[4], Hollanda Arief Kusuma[5]

{saptanugraha@umrah.ac.id[1], risandi@umrah.ac.id[2], ekoprayetno@umrah.ac.id[3]}

Universitas Maritim Raja Ali Haji, Tanjungpinang[1], Universitas Maritim Raja Ali Haji, Tanjungpinang[2], Universitas Maritim Raja Ali Haji, Tanjungpinang[3], Universitas Maritim Raja Ali Haji, Tanjungpinang[4], Universitas Maritim Raja Ali Haji, Tanjungpinang[5],

Abstract. This research aims to develop an Autonomous Surface Vehicle (ASV) Prototype to determine Ship Routes by using PID and Pixycam. ASV is created by constructing GPS and video systems as well as employing PID as operational control system algorithms. This PID tends to evaluate the distance to generate steering-wheel-like servo motor movement. The results showed that ASV can move without colliding with impediments. In this research, the collected data which are converted into the distance, PID, and servo values include coordinates, a date, and an x-y image. The acquired PID value is compared with the distance and servo by studying the data movement along a straight or curved path. Furthermore, the Autonomous Surface Vehicle (ASV) that uses the PID algorithm to determine the ship's course is created successfully and functions efficiently. This device tends to travel using the PID by avoiding recorded obstacles and following the object's path. Meanwhile, the ship's movement is affected based on the engine's constant rotation. This makes the achievement of a constant straight movement to become difficult. The camera's image capture rate is capped at 5 fps to improve Arduino performance. The Arduino retains normal functionality when the frame rate increase. However, a substantial quantity of recorded data becomes lost and the Arduino tends to stop working.

Keywords: Boat, catamaran, ecotourism, renewable, solar.

1 Introduction

The Autonomous Surface Vehicle (ASV) is a ship that automatically moves on the water's surface [1]. ASV rapidly expands because it can be used in waters inaccessible to crewed vessels. Several studies in the aspects of autonomous motion, form, and control systems make efforts to assist in developing this ship. A previous study [2] created autonomous ASV based on waypoints and apply it to the car moving in a straight, zigzag, parallel, and S-shaped trajectory. The stable hull form of the USV was designed in [3] to allow bathymetric studies in calm waters. A method called the Fuzzy Self-Adaptive PID algorithm was used to simulate ASV

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control [4]. Furthermore, the Global Positioning System (GPS), a camera, and a compass are required for automatic movement. The use of GPS on an ASV necessitates navigation to automatically drive the vehicle based on the selected location points. Therefore, the ASV tends to automatically move to the designated site.

Several reconnaissance ships are equipped with cameras to observe the area. Additionally, common applications for the cameras help in assisting robot movement and serving as sensors. This PixyCam produces photographs in real-time and runs a device based on the image processing results and colors [5]. Essentially, ships with automatic control require an algorithm such as the Proportional Integral Derivative (PID). The presence of PID helps to minimize the incidence of mistakes in the desired movement [6]. Therefore, this research is one of the first steps in employing ASV with a PixyCAM to provide an alternate option based on the use of PID. It also aims to develop an ASV Prototype to determine Ship Routes with PID using Pixycam.

2 Research Methodology

2.1 Research Instrument and Material

Table 1. the device/component/ material and research equipment

No	device/component/material	Amount used	
1	Arduino Nano	Three pieces	Device/component
2	PixyCam CMUCAM 5	One piece	Device/component
3	Servo	Two pieces	Device/component
4	ESC	Two pieces	Device/component
5	Brushless Motor	Two pieces	Device/component
6	Baterai Lipo 6S 5200 Mah	One piece	Device/component
7	Receiver + Transmitter	One piece	Device/component
8	GPS Neo 6M	One piece	Device/component
9	SD Card Module	One piece	Device/component
10	Laptop	One piece	Research equipment
11	Solder Kit	One piece	Research equipment
12	Multimeter	One piece	Research equipment
13	Grinder	One piece	Research equipment
14	Sandpaper	One piece	Research equipment
15	Ruler	One piece	Research equipment

2.2 System Design

This system employs several components including PixyCam, Arduino, ESC, and Brushless Motor. PixyCam is a color sensor-based camera module that tends to operate independently or globally. Also, serial communications include USB, SPI, I2C, and UART. This device instructs the NXP LPC4330 or PixyCam CPU to process the image after capturing. The next step is that PixyCam sends Arduino the acquired image. Figure 1 shows that the Arduino finally processes the data to acquire distance info.

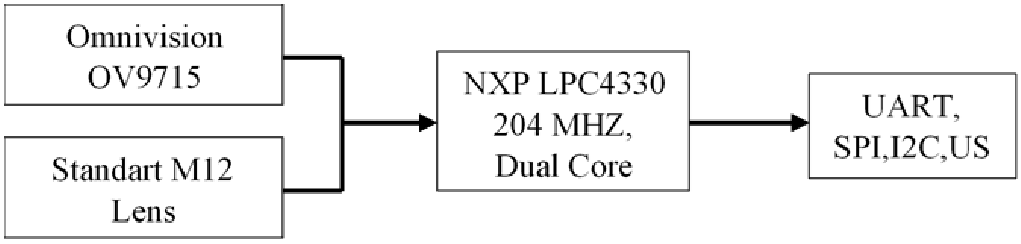


Figure 1. The image processing

Arduino 1 as one of the system components obtains information from the Remote-Control Receiver and this indicates whether the ASV is operated manually or automatically. PixyCam tends to fail and transmit data to this component when the camera is manually and automatically moved respectively. Arduino processes the color and distance data from the object to the ASV using the PID method. This algorithm ASV's objective help to smooth the movement when conducting maneuvers. Figure 2 shows that Arduino 1 delivers data to Arduino 2 through a serial connection during this operation.

Figure 2. PID Algorithm Processing

The ESC will wait for a PWM (Pulse Width Modulation) signal from Arduino 1 with a constant value between 0 (halt) and 25 (full speed) (move). In this operation, the ESC does not obtain the PID value (Figure 3).

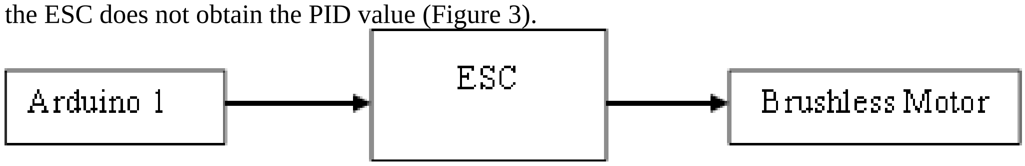


Figure 3. Workflow ESC

Arduino 1 transmits PID data to Arduino 2 via serial communication, and the data is separated utilizing data parsing syntax. Arduino 2 will now acquire GPS data. In the form of time, date, and coordinates. The tiny SD card module will store all information. Figure 17 illustrates the Arduino 2 process flow (Figure 4).

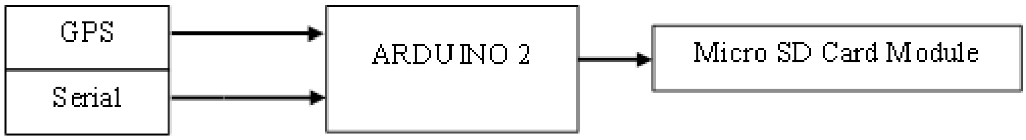


Figure 4. Workflow ESC with Micro SD Card Module

2.3 Mechanical Design

In this study, AutoCAD was utilized for mechanical design. The design of this ASV comprises two hulls and one component bay. The ship's propulsion system is placed behind the ship. Each side of the steering wheel and motor is connected via a shaft. The catamaran hull has two primary keels supporting the ship's whole body. The height of the ship's center, measured from the bottom of the ship's hull, is 15 centimeters to hold between the two hulls and mount various components on top.

2.4 Electronic Design

The wiring schematic for the electronic design employed in the ASV system is discussed. The primary components of this electronic design are PixyCam, Arduino, ESC, and a brushless motor. PixyCam functions as an input and is directly linked to Arduino 1's SPI pin. (Nano / Uno R3) The SPI pin is situated on pins 13 (SCK), 12 (MISO), 11 (MOSI), and 10 (SS). Arduino 1 will process the transmitted data using the PID method. The 5V and GND pins are connected to the ESC data connection, through which the D6 and D5 pins provide information to the ESC. The utilized resource is a LiPo battery. Because the ESC data wire may be utilized as voltage input, the Arduino and PixyCam will switch on once the battery provides power to the ESC. 5V is the voltage generated by the ESC. The motor will move in response to a signal from the ESC. If the signal sent to operate the motor is incorrect, the motor will merely create noise without moving. The SS pin allows Arduino and GPS to communicate in both directions. The GPS connections are connected to the digital pins 4 and 5 on the Arduino 2. On the Arduino 2, the micro-SD card module can store PID, distance, Servo, and GPS data.

2.5 Firmware Design and Data Analysis

The libraries are wire—h, SPI.h, and Servo. h, pixy, SoftwareSerial.h, and TinyGPS++.h. The design seeks to simplify the creation of firmware to reduce the frequency of firmware faults. The obtained data consists of coordinates, a date, and an x-y picture. All acquired data will be transformed into the distance, PID, and servo values. The acquired PID value will be compared with the distance and servo values by analyzing the data's movement along a straight or curved path.

3 Result and Discussion

3.1 Ship Performance Test

In the manual control, input is provided to the system through a transmitter attached to the Arduino's receiver. Figure 5 shows the complete movement of the ship is controlled by the transmitter during manual control. The input values are transformed into either input or output PWM. This manual control uses only two and one transmitter channel for motion and switching respectively.

Figure 5. Transmitter remote (left) and Manual Control Test (right)

Table 2. Equipment List for determining payload on Solar panel Boat

Transmitter	Value	Response	Rudder and ESC		Active Component
			Land Condition	Lake Condition	
Ch. 1 mid	128	Good	Straight rudder	Straight	Servos 1 & 2
Ch. 1 left	0	Good	Left rudder	Turn left	Servos 1 & 2
Ch. 1 right	255	Good	Right rudder	Turn right	Servoss 1 & 2
Ch. 3 below	0	Good	ESC is not moving	Stop	Brushless 1,2.
Ch. 3 above	255	Good	ESC is not moving	Moving	Brushless 1,2.
Ch. 5 on	255	Good	Manual	Manual	Servo, Brushless
Ch.5 off	0	Good	Auto PID	Auto PID	Servo Brushless

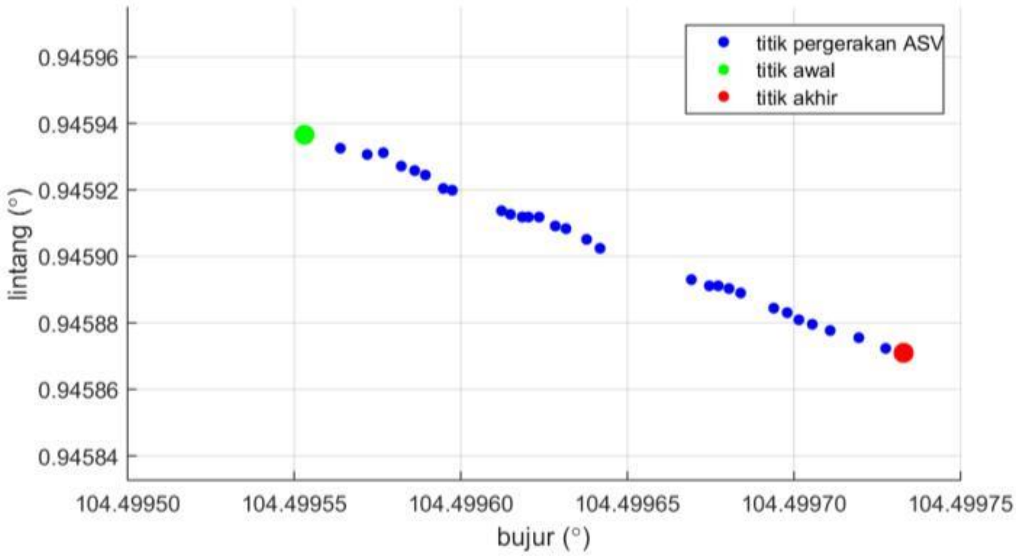
The automatic control test is carried out using the PixyCam as input and collecting data, including the object's distance and PID. Pixy receives (x,y) data, which is processed through PID for servo output. The path is created by placing the red and green balls on the left and right sides. Each ball has a 1-meter distance by constructing a straight path and turning. The track's overall length is 20 meters and each PID control uses the same constant of Kp = 1.15, Ki = 3.4, and Kd = 7.6. Meanwhile, the setpoint is 90 degrees for all tests because it is one of the factors used to determine Servo's center point. Appendix 1 includes all PID constant experiments.

Figure 6. Automatic Control Test (right)

Testing is satisfactorily carried out by integrating all components into a single system. This is to achieve research results and ensure that the system functions as intended. Table 6 shows the test retrieves data in the form of latitude, longitude, date, time, distance, Servo, and PID from the micro-SD card. In conclusion, all trailers are in a straight line and three times in a circle.

3.2 Observation of Vessels Based on Position

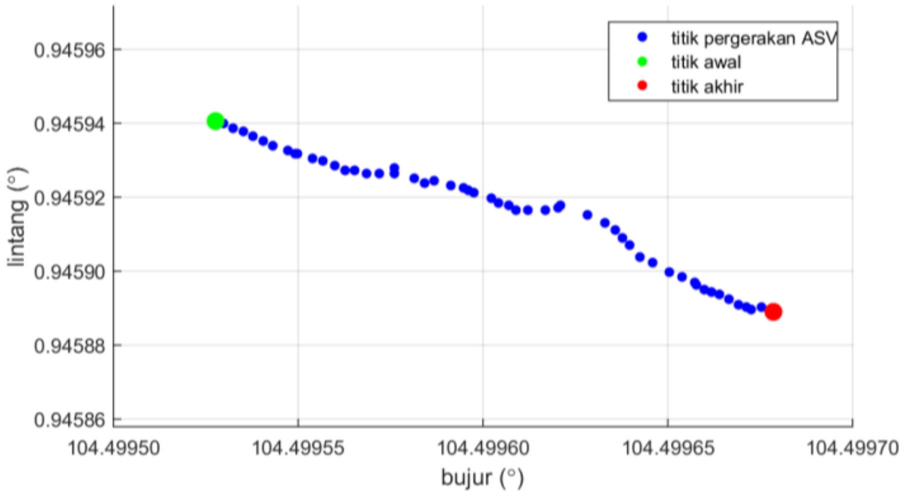
The Changes in ASV position can be caused by wind and waves. The whole positional movement of the ASV during this experiment was recorded on a micro-SD card using a GPS Ublox Neo 6M as a data retrieval device. GPS is located on Arduino 2; if PID data has been collected from Arduino 1, GPS will retrieve data. When the data is obtained, the coordinates are depicted in Figure 7. The pattern appears crooked because the ASV is not moving in a straight line ahead. ASV movement is often curved. The computed coordinates appear insufficient since the camera does not capture the object's color. This can occur if a green object is detected or the entire thing is out of range, causing the spacecraft to halt moving.



note: movement point of ASV (blue mark); starting point (green mark); endpoint (red mark); lintang (latitude), bujur (longitude)

Figure 7. Movement pattern on the straight track.

Because it is easier for the camera to catch the object's color throughout the turning path, the movement pattern on the turning track (Figure 8) seems dense. Figure 44 depicts the track's turning movement through a curve. At the turn time, the wave disrupts the movement, resulting in a zigzag appearance. When moving along a straight and twisting path, ASV does not touch the item.



note: movement point of ASV (blue mark); starting point (green mark); endpoint (red mark); lintang (latitude), bujur (longitude)

Figure 8. Movement pattern on the turn track.

3.3 Observation of Vessels Based on PID Data

In this experiment, the ASV travels to the end of the track, all motions are handled automatically, and time, distance, PID, and servo data are collected. Figure 9 demonstrates that as the distance collected by the camera increases, the PID value decreases. This is because the error value will decrease as the distance approaches the setpoint.

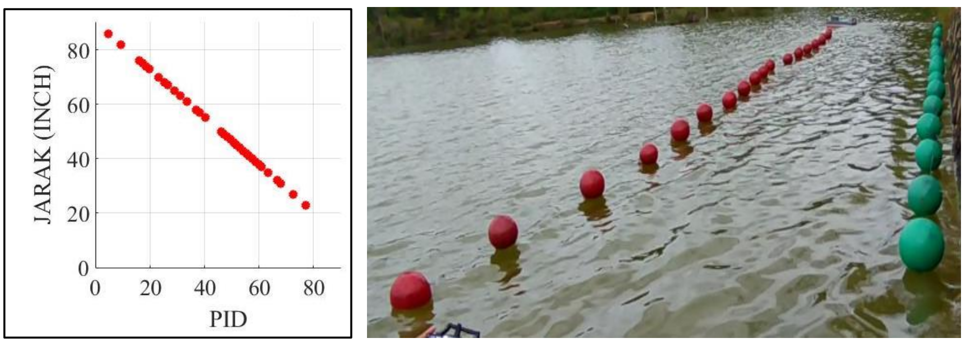


Figure 9. the PID graph in a straight track

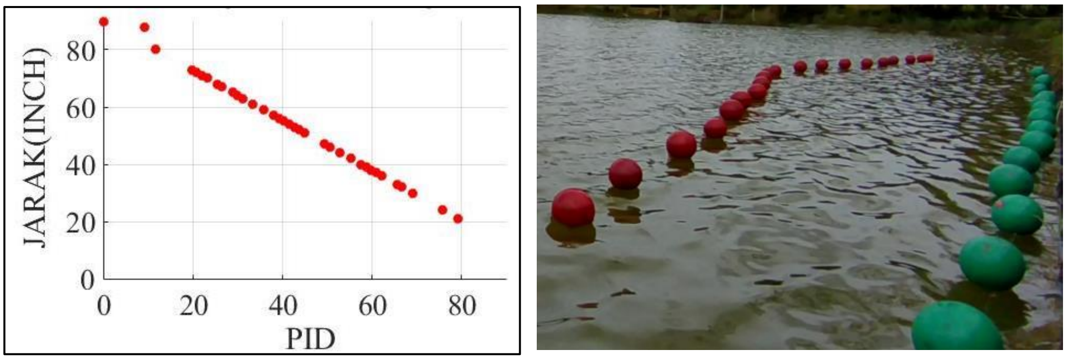


Figure 10. the PID graph in turn treck

The first experiment's results consist of a straight line and a 20-meter-long track. The servo value is derived from the results of the syntactic map redefinition of the PID algorithm. If the distance is less than 35 inches, the PID value map is calculated by subtracting 30. If the distance is greater than 40 inches, the PID value map is multiplied by 30; if it is less than 40 inches but greater than 35 inches, the Servo will be at 90 degrees. The movement of the servo results in a value of 90 to 120 degrees and as many as 30 data points, as shown in Figure 9. However, the movement from 90 to 75 degrees has 21 data, whereas the movement from 60 to 48 degrees contains only 5 data. If the servo angle is 90 degrees, the ASV will move in a straight line. However, if the servo value is below 90, the ASV will shift to the left. If the servo value exceeds 90, the ASV will slide to the right. Figure 9 displays a zigzag pattern for the servo movement angle because when the camera reads the object's color, the ship rolls with the wave movement. This affects servo movement instability.

3.4 Discussion

The results of our study indicate that the design of the Autonomous Surface Vehicle (ASV) Prototype to Determine Ship Routes with PID Using Pixycam has been operating with high precision, as evidenced by the ASV's movement (Figure 7). This is supported by images captured with a Pixy camera. The Prior research (Normalasari et al., 2018) also employed Pixy Camera-Based Visual Perception on the Wall Follower Robot, with a Pixy CMUcam 5 sensor employing a color-based algorithm to detect objects. Our research methodology (Normalasari et al., 2018) utilizing Pixy will calculate the color and saturation of each RGB pixel from the image sensor and use it as a color filtering parameter. The study results (Normalasari et al., 2018) indicate that the PixyCam on the Wall Follower robot can navigate a labyrinth whose walls are covered with square-shaped colored paper.

In this study, using a wooden ship body provides stability for testing the Autonomous Surface Vehicle (ASV) Prototype with PID and Pixycam. Previous research (Zaky et al., 2018) demonstrated that wood-based autonomous robots could move stably. During testing, our research further demonstrates (Figures 9, 10) that the ship sails along a 30-meter waypoint consisting of specified latitude and longitude coordinates from waypoint 1 to waypoint 2. The operation concept is that APM reads the data received by GPS. Once the data has been read, APM sends commands to drive devices such as servos and motors to move the ship to a specified place through coordinate points determined by the Waypoint technique.

4 Conclusion

Based on the study, the Autonomous Surface Vehicle (ASV) that uses the PID algorithm to decide the ship's course is successfully constructed and operates effectively. This device move by avoiding recorded items and following the object path. However, the ship's movement is affected not only by the steady spinning of the engine but also by the wind and waves. This makes the achievement of steady straight movement to become difficult. Furthermore, the camera's image capture rate is limited to 5 fps to improve Arduino performance. The Arduino continues to function normally but the amount of collected data becomes lost when the fps increase.

5 Acknowledgment

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6 References

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