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Maneuver Control System for Collision Avoidance Based on Experimental Study

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Abstract

Autopilot mode in the ship navigation system is intended to assist the work of the captain in controlling the ship, but the autopilot mode still has some disadvantages such as in the case of maneuvers to avoid collisions. Many studies on design of anti-collision design. But almost all use a numerical approach. In this paper will be discussed the design of maneuver controls that will be used on the ship model to avoid the ship from the collision. Where within the control system there are several sensors, including ultrasonic sensors, gyro sensors and Qualysis cameras. From ship model testing conducted, the design of maneuver control proved able to avoid the ship from the occurrence of collisions. Minimum distance of ship and obstacle at 250 m distance is 34.17 m, at a distance of 200 m is 13.46 m while at a distance of 150 m is 13.36 m.

Keywords: Collision avoidance; fast patrol boat; microcontroller; model test; system control

1. Introduction

The mode of autopilot in the cruise world becomes an important discussion as it helps the seafarers in making it easier to sail the ship. But in autopilot mode itself still has weakness among others in use to avoid collision.

Avoiding collisions is an important issue in transportation systems. The purpose of collision avoidance maneuvers is that ships avoid the risk of collisions and determine actions to avoid or reduce collisions [1].

Much research on the design of controls maneuver to avoid collisions on ships with various methods. Methods ever used among others is manual calculation method, fuzzy logic method and image processing method. Each method has different advantages and disadventages. Some studies releted to avoid ship collisions include reference [2]. The object used in this study is USV (unmanned surface vehicle) in the form of unmanned ships that work automatically according to the program designed. To support the working system USV required several types of sensors such as cameras. The camera works to record the image in front of the ship for further processing by the computer by using the image processing method of HSV Filter, to identify the object and use Fuzzy Logic to determine the angle of the turning of the ship while avoiding the object. From this research, it can be concluded that the ship succeeded in avoiding obstruction objects in all scenarios, to identify the object distance using image processing, the optimal angle of object readings is 750 to 1050 with the average of object coordinate readout error of 0.868 px and the mean error the object's reading angle is 7.450 °/cm [3].

Based on research that has done, the conclusion as follows has been done a design of fuzzy logic controller to control the bow and the speed for this type of MT Brotojoyo Tanker which capable of keeping the trajectory in the Port of Tanjung Perak, Surabaya. In the test without disturbance occurs the maximum error of 35.09 meters and a minimum error of 0.9 meters, while in testing with disturbance macimum error value of 35.59 meters and a a minimum errror of 0.84 meters. Fuzzy logic system has been designed can increase the efficiency of time sailing 38 minutes [4].

The fuzzy logic control system used is the Sugeno method with nine fuzzy rules. The value of fuzzy output using the weight average method. The control system is designed using a GPS module to determine the position and compass sensor to determine the direction. The conclusion of this research is the design of control system using fuzzy logic controller can control the ship to track the path well. The ship can move at a speed of 0.28 m/s and the rudder

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speed is 5.639 m/s. The compass sensor used has an error of 0.089 %. While the GPS module has an average error error of 6.449 meters. The average time it takes is 3.625 seconds.

From several literatures, it is done by using ship model scale test method in the basin of maneuver testing. For the purposes of testing it is necessary to design the proper maneuver control so that the ship can avoid the collision. The use of microcontroller and some sensors such as ultrasonic sensors to detect the distance of the ship with obstacles, gyro sensors to know the movement of ship yaw, servo rudder to know the movement of ship rudder and Qualysis camera to know the trajectory between the ship and obstacles

2. Experiment Method

The research methodology was developed to produce a technically good maneuver control design, in which the steps in the methodology can be described as follows:

2.1. Main dimension

First determine the main dimension of the ship which is an important factor in ship designing. The ship model used follows Fast Patrol Boat, where the main dimension between real scale and model scale to be used in research can be seen in Table 1.

2.2. Collision avoidance control system equipment

2.2.1. Arduino Mega 2560

Arduino Mega 2560 is a microcontroller board based on Atmega 328. This board has 54 digital input/output pins (14 pins can be used as PWM output), 16 analog inputs. 16 MKz crystal oscillator, USB connection, power jack, ICSP header and reset button, as shown in Fig. 1.

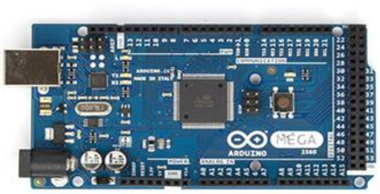

Figure 1. Microcontroller Arduino Mega 2560

Table 1. Main dimension.

No	Symbol	Rate Scale	Model Scale
1	LOA	90 m	1.27 m
2	LWL	86.45 m	1.22 m
3	Breadth	13 m	0.185 m
4	Draught	3.6 m	0.051 m
5	Displacement	1700 ton	4.66 kg
6	LCB	0.54% LPP	
7	Service Speed	18 knot	1.1 m/s
8	Top Speed	28 knot	1.71 m/s
9	Propeller	3.3 m	0.047 m

2.2.2. Ultrasonic sensor

The ultrasonic sensor used is a non-contact distance measuring module shown in Fig. 2. To trigger and read the measurement data requires only 1 pin microcontroller. In addition provided 12C communication interface.

Figure 2. Ultrasonic sensor

2.2.3. IMU sensor

The inertial measurements unit (IMU) is shown in Fig. 3 as an inertial component used to guide a system commonly used in ground vehicles, marine vehicles, and control rockets. The IMU sensor works by sensing a movement, and the directional displacement using a combination of accelerometer sensor is used to determine the acceleration of gravity, gyroscopes are used to determine angular acceleration and the magnetometer sensor is used for heading or determining the direction of the wind and is used as a reference to the yaw axis.

Figure 3. IMU sensor GY-521

2.2.4. Radio Telemetry

Radio telemetry shown in. Fig. 4 is a hardware that serves to transmit data using wirelesscommunication system.

Figure 4. Radio Telemetry 433 Mhz

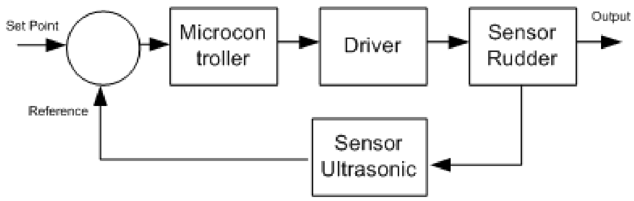

Figure 5. Ultrasonic sensor block diagram [5]

2.3. Design of control system

2.3.1. Ultrasonic sensor design model test

In the ultrasonic sensor book manual of Elecfreaks [5], the design of ultrasonic sensors serves to know and measure the distance of the model with a obstacle.

In the design of ultrasonic sensors, block diagram in Fig. 5 and wire communication in Fig. 6 are used by connecting Vcc, Gnd, Echo and trigger pins.

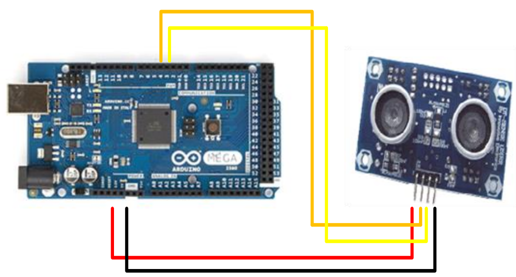

Figure 6. Design of ultrasonic sensor

To avoid the ship from collision, the ultrasonic sensor is set as listed in Table 2.

Table 2. Ultrasonic sensor setting

No	Distance of the Collision (m)	Sensor Setting (m)
1	250	285
2	200	235
3	150	185

2.3.2. IMU sensor design model test

According to the manual book of IMU Sensor [6], the design of gyro sensor serves to know and measure changes in heading angle yaw model of the ship.

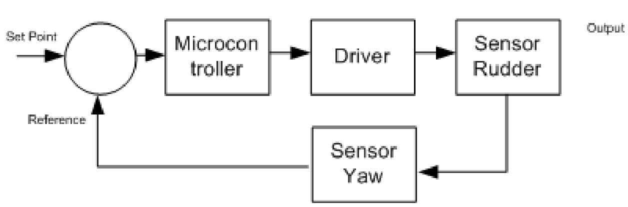

Figure 7. IMU sensor block diagram

The design of the gyro sensor uses block diagram in Fig. 7 and i2c serial data communication by connecting Vcc, Gnd, SDA, SCl and INT, as illustrated in Fig. 8.

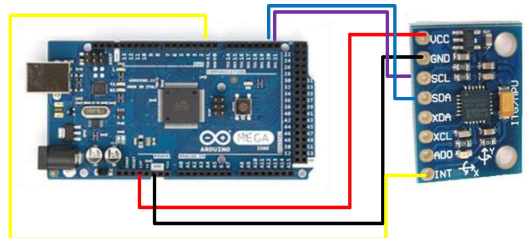

Figure 8. Design of IMU sensor

2.3.3. Servo rudder design model test

The design of servo rudder in Fig. 9 serves to know and measure the angle change rudder model ship. The design of servo rudder using PWM (Pulse Width Modulation) method. With PWM method can be generated servo movement is quite accurate with the desired resolution.

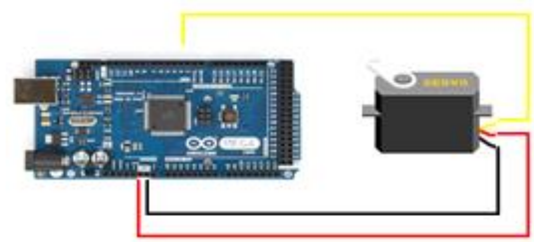

Figure 9. Design of servo rudder

2.3.4. Radio telemetry design model test

In the Advanced Telemetry System manual book [7], telemetry radio design on the test model in Fig. 10 serves to transmit raw data information changes yaw model ship to the system ground station with realtime.

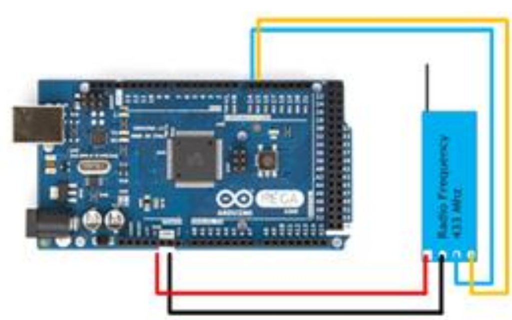

Figure 10. Design of radio telemetry

2.4. Trajectory model measurement system

Measurement of trajectory model movement during the test was performed using QTM (Qualisty Track Manager) equipment. QTM is a software designed using Qualisys camera model, the camera is used as a medium of fast and precise data collection. This system allows users to record data in real time both in 2D, 3D and 6DOF with fast

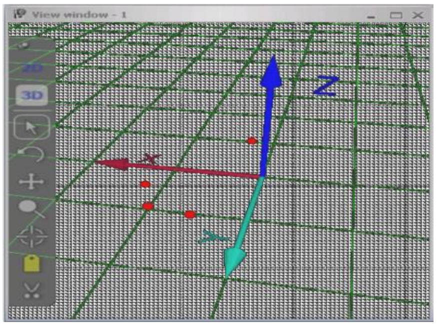

Figure 11. QTM

response time [8]. QTM can also identify marker automatically either passive or active marker, easy in addition of camera if necessary expansion of area object that is recorded. Figure 11 shows the coordinate system on the display.

At the time of capture measurement implemented software will immediately record marker movement (if no setting delay) and can be displayed preview of measurement with preview button. For the sampling rate of the measurement itself can be adjusted from the capture period. The results of the QTM calibration can be seen in Fig. 12. Where the red dot is the marker of the ship that has been installed the Qualisys marker, whereas the x, y and z axis each represent the axis present in the test basin.

2.5. Scenario testing

The test scenario in this study follows the pattern of COLREG 72. COLREG 72 has arranged scenarios to avoid collisions in accordance with the position of the ship, including head-on position, crossing position and overtaking (the ship behind will precede the ship in front). Of the three scenarios according to COLREG 72 which will be used in this research is the head-on scenario (ship facing). Where the two ships will do the steering wheel (rudder) to the starboard (right). So the ship can avoid the collision.

In this study the speed of the ship is made constant at 10 knots. While the speed of the ship obstacle at 2 knots. Model test conducted at Manauvering Ocean Basin (MOB) where basin test fasilities belongs Indonesian Hydrodynamics Laboratory - BPPT Surabaya, in calm water condition (non disturbance).

Variations that are done is the distance of the ship with the obstacle (the distance of the collision) that is 250 meters, 200 meters and 150 meters. Tests on each variation of the distance of the ship against the obstruction are done as much as 3x in order to be taken on average.

3. Results Analysis and Discussion

3.1. Ship and obstacle trajectory

From the test results by using Qualysis camera, the ship trajectory graphic (*x* axis, *y*-axis) at 250 m, 200 m and 150 m.

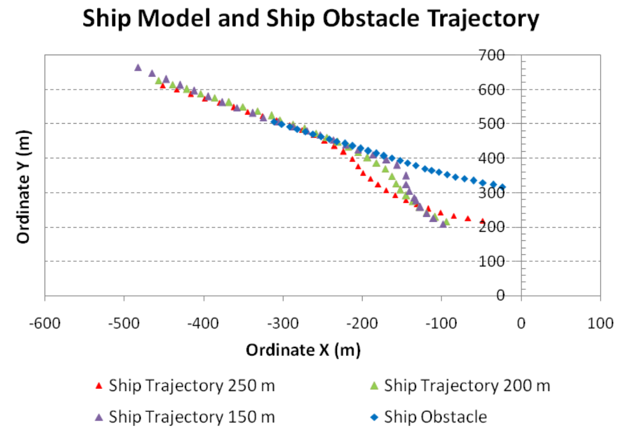

Figure 12. Ship and obstacle at distance of collision 250 m, 200 m and 150 m

3.2. Distance from ship to obstacle

From the trajectory of the ship and the obstacle in Fig. 12, we can find the distance between the two points of the ship's trajectory point (*x*-axis, *y*-axis) and the point of the obstacle (*x*-axis, *y*-axis). The *z*-axis on the ship and the obstacle is not counted because during the test the ship moves on the axis of the 2D axis is the X and Y axis. The formula for finding two points is as follows:

$$\text{Distance} = \sqrt{difference\ x^2 + difference\ y^2} \quad (1)$$

$$= \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \quad (2)$$

Where:

x_1 = Value X Obstacle
x_2 = Value X Ship
y_1 = Value Y Obstacle
y_2 = Value Y Ship

From Eq. 2, we can calculate the distance between the two points that is *x*-axis, *y*-axis of the ship's trajectory and *x*-axis, *y*-axis obstacle at 250 m, 200 m and 150 m. The results shown in Fig. 13.

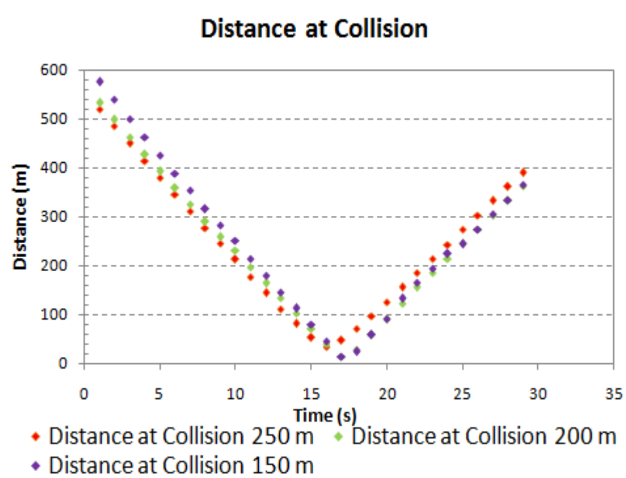

Figure 13. Distance from ship and obstacle at distance of collision 250 m, 200 m and 150 m

4. Conclusion

From the results of measurement and analysis of test results it can be taken a conclusion. Based on the experimental results it is found that the design of maneuver controls installed in the model of fast patrol boats during the test, may prevent the ship from occurring collisions.

Ships at 10 knots can avoid collisions at 250 m, 200 m and 150 m in non-disturbance conditions. The closest distance between the ship and the obstac le at a distance of 250 m is 34.17 m at T = 16 seconds, at a distance of 200 m is 13.46 m at T = 17 seconds and at a distance of 150 m is 13.36 m at time T = 17. This distance is obtained when the ship is adjacent or side by side with obstacles.

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