Arduino-Based Ship Steering Simulation by Comparing Incremental Rotary Encoder Sensor With Infrared Sensor

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ABSTRACT

In vocational institution, practicum activities can be done by using a bridge simulator, such as in the nautical study program, which has a steering component in the simulator. In our engineering study program, we tried to design a ship steering simulation by comparing an incremental rotary encoder sensor with an infrared sensor to determine the direction and degree of rotation. The steering gear is a very important tool of a ship because it determines the safety of the ship. Therefore, the rudder must meet the requirements set by SOLAS 74 rule 29 Chapter II regarding steering gear. When the ship is traveling at maximum economic speed, the main steering gear must be able to steer 35 degrees to the left/right within 28 seconds. In connection with this, we wanted to design, build, and manufacture a tool that can simulate ship steering. This simulation tool that we have designed generally has several capabilities such as being able to steer the ship from 35 degrees port to 35 degrees starboard, or vice versa, during maximum engine speed and load in a maximum period of 28 seconds. [1] Arduino is used to process data from incremental rotary encoder sensors and infrared sensors which will be sent via serial USB to the computer. Rotary encoders and infrared are used to determine how many degrees the ship will turn right or left, both are compared in terms of time and accuracy. To display a ship’s steering simulation, a visual basic application is used to display a ship’s movement simulation, ship’s steering and ship’s rudder.

KEYWORDS

Arduino, Infrared, Rotary Encoder

1. Introduction

The use of simulators in vocational maritime education helps to increase the knowledge and skills of cadets [1]. After graduating from education, it is expected that cadets will have the knowledge and skills that are suitable for the world of work [1], [2]. In accordance with SOLAS 1978, a ship steering system must be capable of steering the ship from 35 degrees port to 35 degrees starboard, or vice versa, during maximum engine speed and maximum load within a maximum period of 28 seconds. Simulator is a tool that is used as a learning medium that has the same shape and function as the original tool or unit. The
use of simulator as a learning tool is an excellent method to find out if the components are functioning as they are intended to be [3], [4], [5].

The ship steering simulation made using the CX Programer application is used to control the ship’s rudder movement which can be observed in a simulation using the HMI (Human Machine Interface) [6]. The sensor used is a limit switch to adjust the ship’s steering gear. The testing is carried out by comparing the volume of the steering gear to alter the direction of the ship starting from 1 rotation, counted 60 degrees, then a simulation will show a sign that the rotation will stop at 60 degrees per minute. A rotary encoder system made using an optocoupler sensor is used to calculate the speed of ocean currents using an Arduino device to process output data in real time [7]. This prototype is divided into 2 parts: the master section and the slave section. The master part is responsible for receiving data on the direction and speed of ocean currents and storing the data in memory. This section also functions to set the reading time and display direction and speed data on the LCD display. Meanwhile, the slave section is responsible for reading direction and speed using an electromagnetic sensor and a rotary encoder [8].

In measuring vehicle by using an infrared sensor and a photodiode sensor, it will count the timer on the programmed Arduino when the sensor is blocked by a vehicle. The speed data is displayed on the LCD and Microsoft excel. Data is also sent to a laptop and processed using Paralax / PLX-DAQ software. To be able to monitor speed data on Android devices, Team Viewer is also used [9]. The Rotary encoder system uses a disc to calculate the rotational speed of the motor using infrared as a light source that will hit the optocoupler as a light receiver [10], the time it takes for this disc to rotate to hit this light is what we will use in the calculations to determine the rotational speed.

The maneuver movement testing on the bridge simulator is done using Ro Ro ship with the objective of knowing the extent the ship’s steering angle has when maneuvering on the bridge simulator and knowing the characteristics of the ship which shows the maneuver time for Surging, Swaying and Yawing movements.

In the simulation using the Matlab- Simulink software, it is used in turning circle and zig-zag maneuvering simulations [11]. The simulation program has been developed with the concept of time domain simulation based on the equations of the mathematical model of ship movement at 3-DOF (Degress of Freedom) which includes the equations of the hull, propeller, and rudder components along with the hydrodynamic coefficients therein. The results of the research showed that as the steering angle increases, the ship’s turning circle ability increases, but vice versa in zig-zag maneuvering. Furthermore, increasing the distance between the rudders can improve the ability of both turning circles and zig-zag maneuvering, but with a relatively large rudder moment this can endanger the ship [12], [13], [14].
2. Method

In designing this steering simulation tool, the researchers implemented three stages: the tool design preparation stage, the tool manufacturing stage and the data analysis stage [15], [16]. The design preparation activities included conducting a literature research, collecting data from various references (journals, etc). These journals revealed several problems and researchers began to look for these problems as the main topic of research. The tool manufacturing stage was carried out in the Polimarin computer laboratory with the help of Visual Basic Software to present a ship steering simulation. While the last stage, the data analysis, was done by testing the ship's steering simulation in comparing the performance of infrared sensor and incremental rotary encoder sensor in the simulation [17]. The research data was taken by monitoring the Arduino serial [18]. To provide an accuracy level of the incremental rotary encoder, the researcher also monitored the Arduino serial by rotating 35 degrees to the right and 35 degrees to the left. Furthermore, according to SOLAS rudder regulations, it is required to collect data when testing 35 degrees port and 35 degrees starboard for no more than 28 seconds at maximum speed. In accordance with SOLAS 1978, a ship’s steering system must be capable of steering the ship from a position of 35 degrees port to 35 degrees starboard, or vice versa, during maximum engine speed and maximum load within a maximum period of 28 seconds. Simulator is a tool that is used as a learning medium that has the same shape and function as the original tool or unit. The use of simulator tools as a learning tool is an excellent learning method to find out the components, functions, and workings of the tool or unit [19], [20].

The equipment used in this research consisted of an Arduino microcontroller, incremental rotary encoder, infrared, and visual basic software. The Arduino platform provides an easy and inexpensive microcontroller for making control devices that interact using sensors and actuators [21], [22]. In this research, the microcontroller used was the Arduino Uno type. An optical rotary encoder is an electromechanical device that can monitor motion, speed, and position by using an optical sensor to generate pulses that can be converted to motion, position and direction. The rotary encoder was used to determine how many degrees the ship will turn right or left. The output of the rotary optical encoder in the form of pulses determined how many degrees the ship would turn right or left. The pulse data were processed by Arduino and then sent serially via the USB port. In principle, an Optocoupler with an LED-Phototransistor combination is an Optocoupler consisting of an LED (Light Emitting Diode) component that emits infrared light (IR LED) and a light-sensitive semiconductor component (Phototransistor) as a part used to detect infrared light emitted by the IR LEDs. The software used in making this learning media used the visual basic programming language used to create Windows applications. The advantages of Visual Basic are that the programming language is short and simple, there are many sources that can be used to learn it, and the compiler is faster than other programming languages such as Delphi, Java, and C languages [23], [24], [25].

3. Results and Discussion

The simulation design for ship steering is as shown in Figure 2, starting from the steering gear which functions as an interface between the ship’s captain and the rudder to navigate the ship to the left (port side) and to the right (starboard side). To connect the rudder with the infrared sensor and the rotary encoder sensor, a shaft is used which is assembled using a couple and is designed so that the sensor can be connected to the rudder as shown in Figures 3 and 5. The steering design used a rotary encoder sensor, as shown in Figure 5, which was connected to the steering shaft and Arduino to read how many degrees the steering wheel was rotated and to read the steering direction to the right or left. The value of the rotary
encoder reading can be read using the serial monitor contained in the Arduino IDE software with a baud rate setting of 9600.

Figure 2. The Scheme for Simulation

Figure 3. The Scheme for Simulation Tool Using Rotary Encoder
The output of the rotary encoder signal was in the form of a digital pulse or square wave consisting of two signals: signal A and signal B. The output of the two signals were different in phase by 90 degrees so that it could be used to distinguish the direction of rotation of the rudder to the right or left using software programmed arduino.

![Figure 4. The Rotary Encoder Signal](image)

The steering design used an infrared sensor as shown in the figure consisting of two infrared modules to calculate the degree of rotation of the steering wheel and the direction of rotation of the steering wheel to the right or left.

![Figure 5. The Scheme for Simulation Tool Using Infrared](image)

Infrared signal reading for right turn and left turn is as shown in figure 6. The workings of the reading from the infrared sensor of this module used reflections from dark colors and light colors which were placed in a circle.
Just like the output of the incremental rotary encoder signal, the output of the infrared sensor signal module consisted of two signals: signal A and signal B, with different phases to determine the direction of the steering wheel turning to the right or to the left. The output was in the form of high and low pulses, obtained from the readings of two infrared modules on the dark side and the bright side as input from the Arduino to send the reading data via USB serial to the computer.

Data from the arduino was sent to the computer via the USB port with the visual basic software being used, as shown in figure 8. The steering gear control functioned as a monitoring of how many degrees the steering wheel was when it was rotated and the rudder control functions as monitoring how many degrees the position of the steering wheel was when the steering wheel was turned. There were digital readings on both. In serial data transmission, a baud rate of 9600 bits per second (bps) was used which indicated how many bits were sent in each second.
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The 35 degrees port testing was done by turning the steering gear to the left by 35 degrees by observing the rudder movement and getting 4 seconds until the rudder reached 35 degrees plus turning the steering gear back to midship or 0 degree by observing the rudder movement and getting 4 seconds until the rudder reached 0 degree. The 35 degrees starboard testing was done by rotating the steering gear to the right by 35 degrees by observing the rudder movement and getting 4 seconds until the rudder reached 35 degrees plus by turning the steering gear back to midship or 0 degree by observing the rudder movement and getting 4 seconds until the rudder reached 0 degree.
Serial monitor when the incremental rotary encoder was in the midship position obtained 0 and when the starboard position was positive and when the port position was negative. The incremental rotary encoder signal reading for the starboard side used the Arduino serial monitor as shown in Figure 9 and the results of the incremental rotary encoder sensor test when turning left or 0 degree port to 35 degrees port are shown in Figure 10. The test obtained data numbers 0 for 0 degree to 160 for 35 degrees starboard. When the steer was turned towards the starboard, the rudder moved to the left and the ship slowly turned to the right. The response of the incremental rotary encoder sensor when the rudder was rotated was very good, meaning that there was almost no difference in time when the rudder was rotated with the steering gear control reading then given a slow delay, the rudder control adjusted the steering gear control position. The accuracy level of the incremental rotary encoder sensor was 4.571, obtained from 160 divided by 35.

Figure 12. The Serial Monitor of Arduino IDE

For infrared sensors, the same test was performed by reading the numbers displayed on the Arduino IDE serial monitor as shown in Figure 12. After that, the results were obtained and presented in figure 13. For the accuracy level of this infrared sensor, it was set at 1 degree to get the level of accuracy as in an incremental rotary encoder it required a plate that was four times larger. In accordance with SOLAS 1978, a ship steering system must be capable of steering the ship from a position of 35 degrees port to 35 degrees starboard, or vice versa, when the engine speed is maximum and maximum load is in a maximum period of 28 seconds and from the test results it is obtained in 16 seconds using both infrared and rotary encoders.

Figure 13. The 35 Degrees Port Testing
4. Conclusion

From the discussion results, it can be concluded that the incremental rotary encoder and infrared can be used for sensors to read degrees and determine the rudder direction to the right or starboard and to the left or port in a ship's steering simulation. In accordance with SOLAS 1978, a ship's steering system is capable of steering the ship from a position of 35 degrees port to 35 degrees starboard, or vice versa, during maximum engine speed and maximum load in a maximum period of 28 seconds and from the test results obtained 16 seconds. The 16 second time was obtained by adding a delay using a timer in the visual basic application. The use of an incremental rotary encoder sensor is indeed more effective in terms of shape due to the limited reading distance from the infrared sensor which results in the shape of the tool being too large.

References


