

DESIGN OF AUTOMATIC COLLISION AVOIDANCE SYSTEM BY USING ULTRASONIC FOR FISHING VESSEL

K. Norfadhlina¹, Muhamad Iruwan Mat Daud² and W.M. Dahalan²,

¹Maritime Engineering Technology Section, Universiti Kuala Lumpur, Malaysian Institute of Marine Engineering Technology, 32200 Lumut Perak, Malaysia

²Marine Electrical & Electronic Engineering Technology Section, Universiti Kuala Lumpur, Malaysian Institute of Marine Engineering Technology, 32200 Lumut Perak, Malaysia

Corresponding author: norfadhlina@unikl.edu.my

ABSTRACT

An obstacle detection is the most useful and inspiring task in actual time scenario. Improvement of evolving embedded technologies in automotive field, the life of people becomes more comfortable and provides safety against accidents. Nowadays, most vessel are equipped with safety system to warns the pilot or driver to be more alert in avoiding accidents from occur. In this proposed work, a collision avoidance system for marine vessel is introduced which detects the presence or incoming obstacle from three directions, bow, port, and starboard and alert the driver accordingly. This prototype of the system uses an ultrasonic sensor for the detection of the range of incoming obstacle.

Keywords: *Microcontroller, Ultrasonic sensor, Collision avoidance system.*

1 INTRODUCTION

Like land vessel such as car, bus or motorcycle tend to get into accident, a sea or marine vessel also have a high chance to have an accident. This accident can leave a great impact to the ship or marine vessel itself while also people live can be threaten. This is because most of ship doesn't have a sensor to detect incoming vessel at a blind spot. According to study that have been done by [1] fishing vessel are likely to have more risk to involve in collision because of highest density traffic at Port Klang which is full with carrier, cargo, container, tanker, tug, vehicles and passenger carrier. From the statistic that have been published by Japan Transport Safety Board, fishing vessel have most cases involved in marine accidents.

**Number of Vessels Involved in Marine Accidents in 2020
as of September 30, 2020**

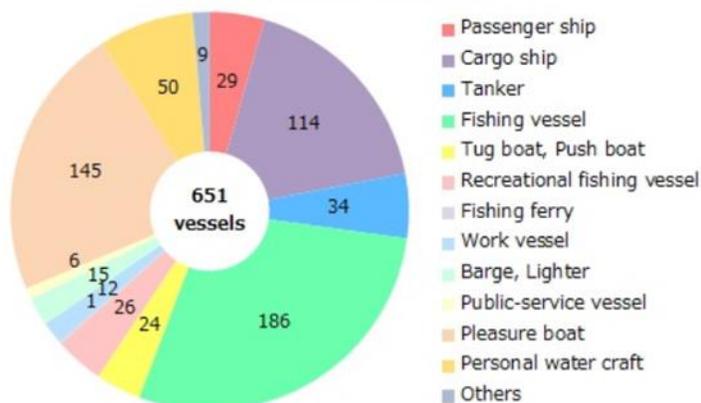


Figure 1: Chart of Number of Vessels Involved in Marine Accidents in 2020

A collision avoidance system is a system used for safety of moving vessel and usually used by land vessel. Using a sensor to detect distance of incoming object/vessel and give a visual warning through a monitoring system. This system is designed for marine vessel as it also can contribute to accident on the sea and also around the port. In this proposed prototype of system, the system is equipped with an ultrasonic sensor hc-sr04 with max detection of 4 meter. The ultrasonic sensor is used to detect the obstacle. According to [2] ultrasonic sensor detection based on the principle of measuring the propagation time of ultrasonic waves. This principle ensures reliable detection is independent of the color rendering of the object or to the design and the type of its surface. It is possible to reliably detect even such materials as liquids, bulk materials, transparent objects, glass etc. If there is any obstacle in the path, the ultrasonic sensor senses and give the signal to system feedback. The led indicator will light up to indicate the obstacle in closes range, which is the unsafe range for the ship. The data can be monitor by Arduino display window. The existing systems available only for automobiles, so this system is proposed for the application of sea vessel. This could be implemented in ship for avoiding the collision in sea.

Nowadays, latest development in navigation systems causing the most maritime accidents at the sea. Moreover, these accidents would affect the financial losses through human resources. As the result, the safety level of ships will be taken more seriously from the different aspect of damage conditions. The current system used for safety of sea vessel and its crew might be the efficient one of the sea transportation eras. "As the movement of the vessel being navigate by Communication Technologies and Navigation Aids

(ship's Radar, AIS, GMDSS, Satellite Navigation, ECDIS, etc.) make it possible to arrange Common Maritime Information Environment for all the ships encountered in Close Quarters situation" [3].

A. Ultrasonic Sensor

Ultrasonic sensors are often used in automation tasks to measure distance, position changes, level measurement, such as presence detectors or in special applications, for example, when measuring the purity of transparent material. They are based on the principle of measuring the propagation time of ultrasonic waves. This principle ensures reliable detection is independent of the color rendering of the object or to the design and the type of its surface. It is possible to reliably detect even such materials as liquids, bulk materials, transparent objects, glass etc. According to [2] the use of ultrasound can be divided into two group; Active ultrasound, when applied exhibit physical or chemical effects. The generated output reaches higher values. The ultrasound is used for cleaning, welding, drilling and the like; Passive ultrasound output is contrast generated at much lower values. its main area of application is then measuring distance, detecting defects in materials and gases.

Table 1 : Ultrasound dispense for three state condition

Gases		Solids		Liquids	
(m/s)		(m/s)		(m/s)	
Air (0°C)	331	Al	5100	Water (20°C)	1481
Air (20°)	343	Steel	5000	Water (25°C)	1497
He (25°C)	965	Concrete	1700	Gasoline (20°C)	1170
H (25°C)	1284	Cu	3500	Hg (25°C)	1450
He – Helium H – Hydrogen Al – Aluminium			Cu – Cuprum Hg - Quicksilver		

Ultrasonic sensor operates on the principle of measuring the time between sending usually a few very short pulses and receiving the reflection of the transmitted signal. The basic building blocks are the transmitter and receiver. Transmitter block may be composed of two types of transducer; Magnetostrictive transducers – are working at low frequencies and their principle is based on a mechanical change in the

length of magnetic material; Piezoelectric transducer – operate at high frequencies and the principle is based on the inverse piezoelectric effect. Ultrasonic receiver is based on the principle of the transfer of mechanical waves reflected back to an electrical signal.

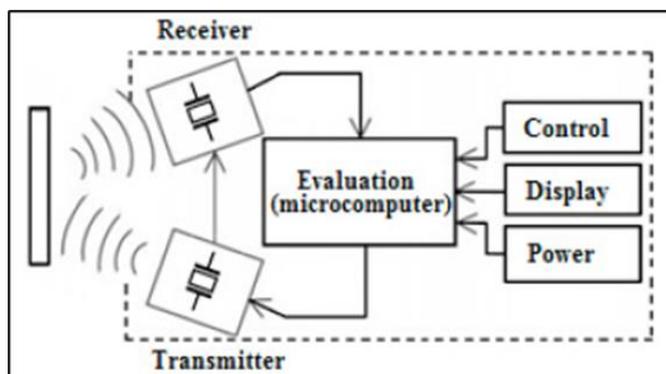


Figure 2 : Ultrasonic sensor diagram basic of operation

Ultrasonic sensor SRF08 - this ultrasonic sensor is recommended to be implemented in this system as it able to measure distance up to 11 meters. This range suitable for use on fishing vessel because detection distance must be wide as moving vessel has acceleration. The principle of measurement of the sensor is the ultrasonic signal on the eight periods and a frequency of 40 kHz. Sonar measures the time between sending the test signal and the receiving of its reflection. Ultrasound rangefinder HC-SR04 - According to [4] the principle of the ultrasonic rangefinders is to measure the time during which that signal propagates at the distance from the transmitter to the receiver. The propagation speed of the signal is known. The sensor consists of a transmitter that generates ultrasonic waves, a receiver that perceives the echo, and auxiliary nodes for normal operation of the module. The rangefinder generates sound waves at a frequency of 40 kHz. The sound waves reflect from the object and returns to the receiver, the sensor gives the information about the time, which was demanded to sound waves for propagation from the sensor to the object and back. As per state on study research by [4] the ultrasonic signal is propagated by a wave directed at an angle of 30°. The direction of propagation of the ultrasonic signal from the transmitter. The most effective measuring angle is 15°. External objects falling under this measurement angle interfere with the determination of the distance to the desired object.

Low budget is a significance of this design, the selected sensor family was the ultrasonic, based on prices and the reasonable accuracy that can be achieved. They can work outdoors and indoors with a quite large detection angle to perceive obstacles from different directions. According from research that have

been done by [5] HC-SR04 has reasonable accuracy, but the measurements tend to underestimate the actual distance, and the dispersion is larger. However, it is the sensor with the lowest price (USD 2). The worst results come from SRF08, with greater measurement dispersion than others and a price of USD 25. For this project, and keeping low budget in mind, HC-SR04 has demonstrated enough accuracy and a great value–price relationship. Ultrasonic sensor is selected for this project because the reasonable price its offer rather than SRF08. In addition, the HC-SR04 model is widely used, the consumption power is also low, and it can detect at 15-degree angle while the range of four meters.



Figure 3 : Ultrasound sensor SRF08



Figure 4 : Ultrasonic sensor HC-SR04

B. Collision Avoidance System (CAS)

Collision avoidance System (CAS) is a system designed to help prevent rear-end collisions with vehicles which are stationary or travelling in the same direction. [6] state that, several studies have shown that driver distraction or inattentiveness is a factor in the great majority of rear end accidents. The system is aimed at alerting the driver to an imminent rear end collision both at low speeds, typical of city driving, and at higher speeds typical of rural roads and highways. This also include sea and marine vessel as collision might also happen on the sea.

Study by [7], The integration of fuzzy collision-avoidance and H_{∞} autopilot systems are proposed in this paper. Collision avoidance is one of the urgent topics on ship voyage at sea. Experts' experience is

still essential when a ship is in the danger of colliding with the others nowadays although a lot of electronic voyage supported apparatuses have been equipped on ships. To include these experts' experiences to resolve the problems of collision, they designed a fuzzy collision-avoidance expert system that includes a knowledge base to store facts and rules, an inference engine to simulate experts' decision and a fuzzy interface device.

The Collision Avoiding System CAS system determines the likelihood of a collision based on driving conditions, distance to the vessel ahead, and relative speeds, and uses visual and audio warnings to prompt the captain to take preventative action. It can also initiate automatic turn to avoid a collision from happen within the range.

2. METHODOLOGY

A. Proposed System

The block diagram of proposed system is shown in Figure 5. This gives a clear description of the working of the collision avoiding system. All the components of the system are connected with the control unit. The power supply supplies the power to the control unit. The control unit used here is microcontroller ATmega328P, Arduino Nano V3.0. In this project, the design of an automatic collision system preventing accident for ship. The ultrasonic sensors are used to detect the obstacles in the ship path. Ultrasonic sensors work on a principle similar to sonar which evaluates distance of a target by interpreting the echoes from ultrasonic sound waves. This ultrasonic module measures the distance accurately which provides 0cm - 400cm with a gross error of 3cm. Its compact size, higher range and easy usability make it a handy sensor for distance measurement and mapping.

The module can easily be interfaced to microcontrollers where the triggering and measurement can be done using two pins. The sensor transmits an ultrasonic wave and produces an output pulse that corresponds to the time required for the burst echo to return to the sensor. By measuring the echo pulse width, the distance to target can easily be calculated and also detects the obstacles in the path. If any obstacles are found in the path of the ship the message will be conveyed to the monitoring unit of the ship.

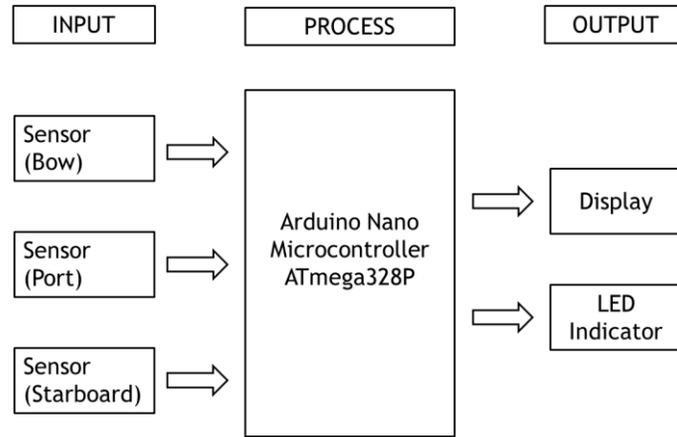


Figure 5: Block Diagram of Collision Avoidance System

B. Construction & Operation

The microcontroller relates to all three ultrasonic sensors and connected three led indicators that represent three part of sensor which is port sensor, bow sensor, and starboard sensor. The power is supply by using mini-USB jack and used to make the microcontroller on and makes the program to run. Through the microcontroller all the components are activated. The ultrasonic sensor is used to detect the obstacles in the path of the ship if any obstacle is detected in the path the display will show distance between the ship and incoming obstacle; the led indicator will light up to alert the user. The operation has been summarized in the flowchart below.

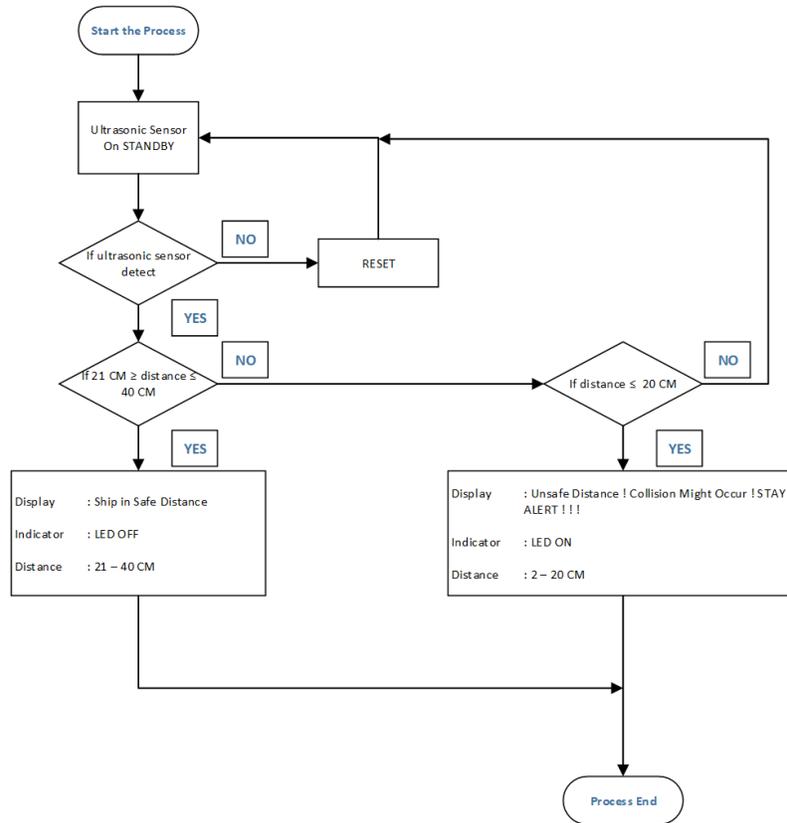


Figure 6: Flow chart operation function of the project

C. Hardware (Prototype)

The above figures 6 and 7 show the flow chart operation function of operation collision avoidance system and prototype of the system. The circuit of the system consist of Arduino Nano V3.0, three Ultrasonic Sensor HC-SR04 and led indicator and place accordingly at port, bow and starboard of the system. The system power by using USB cable, mini-USB jack.



Figure 7: Finish prototype

3. RESULT AND DISCUSSION

This system basically detecting range of obstacle or incoming object and the data will be display by Arduino software display that known as Serial Monitor. The serial monitor can be generated by command “*serial.print*” by using the coding for the collision avoidance system. The range of incoming obstacle is show by command “*Serial.print ("Sensor1 = ")*”, it will display accordingly by the detection of obstacle moving towards the ship. Table 3 below show the summarized data that can be conclude from the system detection.

Table 2: Summarized result from the testing

INPUT		OUTPUT		
		Range	Indicator	Display
Sensor 1/ Port Sensor	If obstacle not detected	Distance > 40cm	LED OFF	None
	If obstacle detected	21cm > Distance < 40cm	LED OFF	Ship in Safe Distance
		Distance < 20cm	LED ON	Unsafe Distance ! Collision Might Occur ! STAY ALERT !!!
Sensor 2/ Bow Sensor	If obstacle not detected	Distance > 40cm	LED OFF	None
	If obstacle detected	21cm > Distance < 40cm	LED OFF	Ship in Safe Distance
		Distance < 20cm	LED ON	Unsafe Distance ! Collision Might Occur ! STAY ALERT !!!
Sensor 3/ Starboard Sensor	If obstacle not detected	Distance > 40cm	LED OFF	None
	If obstacle detected	21cm > Distance < 40cm	LED OFF	Ship in Safe Distance
		Distance < 20cm	LED ON	Unsafe Distance ! Collision Might Occur ! STAY ALERT !!!

All the sensors are set the same criteria of detection where the sensor only detected object within range of 2 centimeter (minimum range for the sensor) until 40 centimeters for the prototype of the collision avoidance system. The range are divided by two phase which is the safe distance and the unsafe distance. The safe distance will be declared by the system when obstacle is detected within 21 centimeters until 40 centimeters. The display will tell the ship in safe distance while the led indicator is off. The system will alert by led indicator is on or light up when the system detected object within range of 20 centimeters and below. For real life application, when the system tell that the ship is not in safe range, the pilot or driver need to immediately prepared to change the course from the incoming obstacle. If the ship equips with automatic maneuver, it can automatically change course when a collision detection is detected.

4. CONCLUSION

The obstacle detection is most versatile in real life scenario. A new control system based automatic obstacle detection for ship is introduced which is controlled electronically. It has been developed by integrating features of all the hardware components used. Presence of every module has been reasoned out and placed carefully thus contributing to the best working of the unit. Secondly, using highly advanced IC's and with the help of growing technology the prototype has been implemented successfully. The obstacle detection system can be used in many fields like automobile, shipping and industrial applications too. However, this system needs to be considered that the sea vessel is moving on the water surface that the movement of the ship can be affected by buoyancy of the water. The ultrasonic sensor can detect with certain diameter of range. So, a device that stabilize the sensor need to be build together for this system work properly. The ultrasonic sensor HC-SR04 also have a limited range of 4-meter detection max, that is also not going to work with a ship like fishing vessel as the ship quite big and the speed also play important role and making this system can be fully implement with real sea vessel.

REFERENCES

- [1] M. Mustafa *et al.*, "Data mining analysis on ships collision risk and marine traffic characteristic of Port Klang Malaysia waterways from automatic identification system (AIS) data," *Lect. Notes Eng. Comput. Sci.*, vol. 2239, pp. 242–246, 2019.
- [2] L. Koval, J. Vaňuš, and P. Bilík, "Distance Measuring by Ultrasonic Sensor," *IFAC-PapersOnLine*, vol. 49, no. 25, pp. 153–158, 2016, doi: 10.1016/j.ifacol.2016.12.026.

- [3] P. V. Alekseevich, “Collision {Avoidance} {System} using {Common} {Maritime} {Information} {Environment}.” no. October, p. 6, 2015.
- [4] V. A. Zhmud, N. O. Kondratiev, K. A. Kuznetsov, V. G. Trubin, and L. V. Dimitrov, “Application of ultrasonic sensor for measuring distances in robotics,” *J. Phys. Conf. Ser.*, vol. 1015, no. 3, 2018, doi: 10.1088/1742-6596/1015/3/032189.
- [5] D. Abreu, J. Toledo, and B. Codina, “Low-Cost Ultrasonic Range Improvements for an Assistive Device,” pp. 1–24, 2021.
- [6] M. Momani, “Collision Avoiding System (CAS),” *Contemp. Eng. Sci.*, vol. 5, no. 7, pp. 341–354, 2012.
- [7] C. M. Su, K. Y. Chang, and C. Y. Cheng, “Fuzzy decision on optimal collision avoidance measures for ships in vessel traffic service,” *J. Mar. Sci. Technol.*, vol. 20, no. 1, pp. 38–48, 2012.