Autonomous Ship Navigation System

Vishwas Suman S Dsouza, Yoganand H R, Siddesh G K

Abstract: ***The current navigation system used in ships are still manual for various operations like data acquisition and processing. An autonomous navigator must be installed on the ship when the requirement is to maneuver the ship without any assistance. Such navigators accepts the data from different sensors to gauge the locations of obstacles present in water. Our work aims at developing a prototype model of the ship that is capable of autonomously sailing and navigating its own way through the obstacles present around it. The operation of the ship involves data acquisition and decision making in real time. The operation of the ship is also simulated in MATLAB using Fuzzy Logic. The electronic system designed for the ship has excellent scalability and can be used for the larger ships as well with modifications. The final system consists of both hardware and software making the ship completely autonomous.***

Index Terms: Autonomous Navigator, Data Acquisition, Fuzzy Logic, MATLAB, Prototype, Scalability.

I. INTRODUCTION

In the current day-to-day life, we see automation happening in every domain of engineering and technology. Human tendency is to enjoy the luxury which the computer (the brain) provides using different sensors to help navigate and interact with the real world. The navigational decisions can be high level such as travel from point A to point B or low level decisions such as just pass through a doorway.

We see land robots serving their purpose without human interventions. Similarly drones which are programmed in such a way as to complete the expected task. Automation in ships is a new technology that is growing up and is gaining a lot of importance.

Autonomous Guidance and Navigation (AGN) systems and their applications has been the dream of many marine engineers since a long time. Several works have already been done in this field and lot of testing is being carried out in order to ensure its proper functionality. There are four main problems encountered related to navigation. They are:-

1. Apperceiving: The autonomous system must be capable of obtaining and processing the information from the sensors.

2. Positioning: The autonomous system must always have the knowledge of its current position and its orientation in its surrounding environment.

3. Cognizing: The system must be capable of determining the multiple ways in which it can reach its Goal.

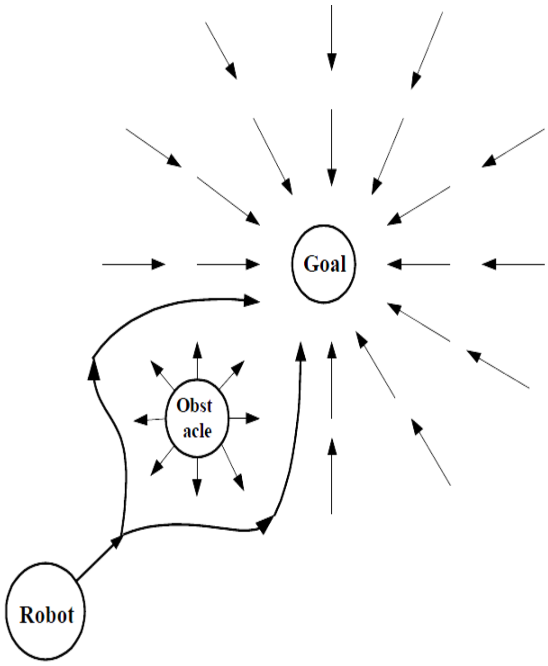

Fig. 1: Navigation Principle

4. Re-Correction: Once the Autonomous ship has deviated itself away from the obstacle, it should have the knowledge of correcting itself to the most accurate path to reach the destination.

There have been many researches focusing on navigational algorithms, and visual navigation is regarded as the highest-level algorithm designed for navigation.

This paper discusses about a navigational algorithm that is capable of detecting an obstacle in the vicinity of the ship and in turn causing the ship to deviate away from it. The object that the ship encounters is stable and not moving. The re-correction path for the ship is also designed to an intermediate level. The working of the ship is also simulated using fuzzy logic in MATLAB by defining four membership functions which represent the basic factors for the autonomous navigation of the ship.

The main objective of the algorithm designed in this paper is to control the ship from its origin avoiding different kind of obstacles. The information about the hardware and software used is dealt separately in methodology and implementation. Finally the information about the fuzzy behavior is discussed.

II. METHODOLOGY AND IMPLEMENTATION

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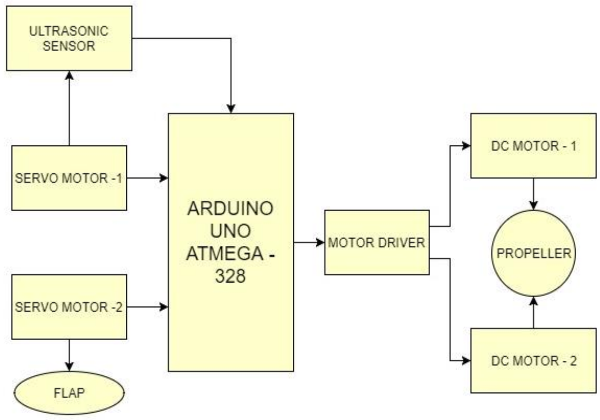

Fig. 2: Functional Block Diagram

The above figure shows the functional block diagram consisting of the micro – controller that receives the input from the ultrasonic sensor and provides the output to the motor drivers controlling the motors. It also send output information to servomotor, which connects to a flap that determines the direction of movement of the ship. Detailed description of the working and components used is given in the further sections of the paper.

A. Hardware

The components that were used in the prototype ship is as follows:

Table 1: Hardware Components Used in the Prototype Ship

Micro – Controller	Arduino Uno Atmega – 328
Motors	1. DC motors 2. Servo Motors (SG 90)
Driver	LM 293D
Sensors	Ultrasonic Sensor (HC – SR04)
Regulators	Voltage regulator (IC-7805)
Actuators	1. Flap 2. Propeller
Batteries	9V DC

The most essential and fundamental unit of the autonomous system is the Arduino Uno Atmega – 328 Micro – controller. It is responsible for receiving the data from the ultrasonic sensor and then actuating the operation as designed. The flow in which the operation of the ship takes place is depicted in Fig – 2 and is as described below:

Initially when the autonomous system is turned ON, the ultrasonic sensor continuously senses for obstacles in the direction of movement of the ship. The detection range of the sensor is divided into three categories.

1. Obstacle is very near (<20 cms).
2. Obstacle is at a moderate distance (20 – 80 cms).
3. Obstacle is far away (>80 cms).

(The distances shown below is with respect to the prototype ship only).

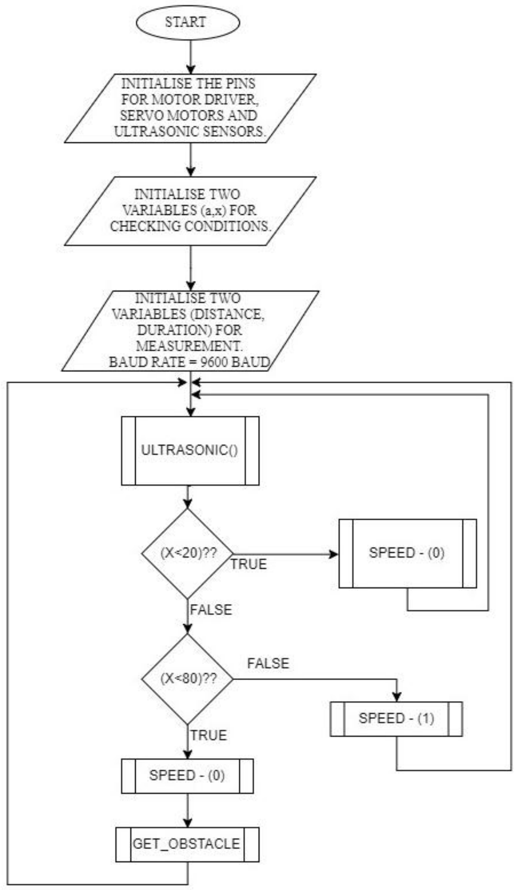

Fig. 3: Operational Flow of the System

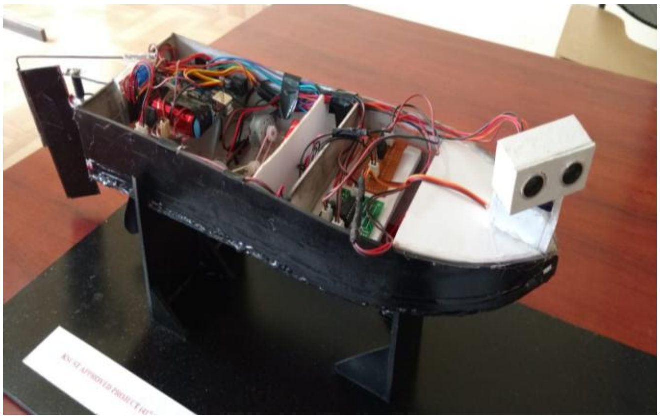

Fig. 4: Prototype of the Ship

As in case 1, when the obstacle is very near, the controller sends a message to the motor driver to turn off the motors which in turn controls the propeller attached to it. This case is considered as an emergency case. When the sensor does not detect any obstacle in the vicinity of the ship, the ship starts to move again.

Case 2 describes the most important functioning of the ship, thus making it autonomous. When the obstacle is detected at a moderate distance, first the instruction is sent to motor driver to reduce the speed of the motors. The ultrasonic sensor that is mounted on a servo motor (as shown in fig – 3) is made to rotate left first by rotating the servo motor's shaft. Ultrasonic sensor again detects the presence or absence of an obstacle.

In the absence of obstacle, a command is sent to another servomotor that is controlling a flap that determines the direction of movement of the ship. The flap is rotated in a direction that causes the ship to move towards left and the speed of the motor is increased thus making the ship to deviate away from the obstacle.

In the presence of an obstacle on the left, the ultrasonic sensor is made to rotate towards right. If the obstacle is not detected, then the same above operation takes places causing the ship to move towards right, thus deviating away from the obstacle.

As shown in case 3, when the obstacle is very far, the ship continues to move in its usual speed until an obstacle is detected. If any obstacles are detected then the operations described in case 1 & 2 takes place.

The correction path is based upon which direction the ship is deviated to avoid the obstacle and the size of the obstacle. If the ship deviates towards left to avoid the obstacle, then correction direction is towards right and vice versa.

The architecture of the prototype ship is designed in such a way as to provide the appropriate aerodynamics. The design also focuses on providing the ship with the best stability on water. The material used for the construction of the prototype ship is PVC foam board. It provides appropriate flexibility for designing the ship with the desired shape. Hot glue gun is used to fix the edges of the prototype ship.

B. Software

The softwares used for implementing the autonomous navigation system are as follows:

1. Arduino IDE: This software is used to program the micro- controller to perform all the operations as described in the three cases.
2. MATLAB: This software is used to perform the simulation of operation of the ship using the fuzzy logic toolbox. More details about fuzzy logic and the simulation is described in the next section.

III. MATLAB SIMULATION

The simulation of the working of the autonomous ship is done on MATLAB (version R2017a) using the Fuzzy Logic toolbox present within the software.

The inputs and the outputs are to be defined as per the desired output. In this context four parameters have been defined (as shown in Fig – 4), two each for input and output and they are as follows:-

1. Direction of the obstacle.
2. Distance of the obstacle from the ship.
3. Speed of the ship.
4. Direction of deviation from the obstacle.

Parameters 1, 2 are defined as inputs and parameters 3, 4 are defined as outputs. The way in which the outputs must vary with respect to the inputs are to be defined in what is called as membership functions. A separate membership function is to be defined for each parameter under consideration. The membership functions chosen for all the four parameters are triangular membership functions. The range of membership functions defined for each parameter is as follows:

Table 2: Membership Definitions

Function Name	Range	Comments
Direction of Obstacle	0 – 200	Range between 0 - 100 is considered left, >100 is considered right and 100 is straight.
Distance of obstacle	0 -200	200 is the maximum distance considered.
Speed	0 – 250	250 is the maximum speed.
Direction of deviation	0 – 180	Range between 0 - 90 is considered left, >90 is considered right and 90 is straight.

The rules as to what operation has to be performed in accordance with the given inputs is as shown in the below table.

Table 3: Rules Definitions

Inputs						Outputs					
Distance of obstacle			Direction of Obstacle			Speed of the ship			Direction of deviation		
N	Mo	F	L	St	R	S	M	Ft	L	St	R
✓				✓		✓			-	-	-
	✓			✓			✓			✓	
		✓		✓				✓		✓	
✓			✓			✓			-	-	-
	✓		✓				✓				✓
		✓	✓					✓			✓
✓					✓	✓			-	-	-
	✓				✓		✓		✓		
		✓			✓			✓	✓		

Where, N = Near; Mo = Moderate; F = Far; L = left; R = right; St = Straight; S = Slow; M = Medium; Ft = Fast.

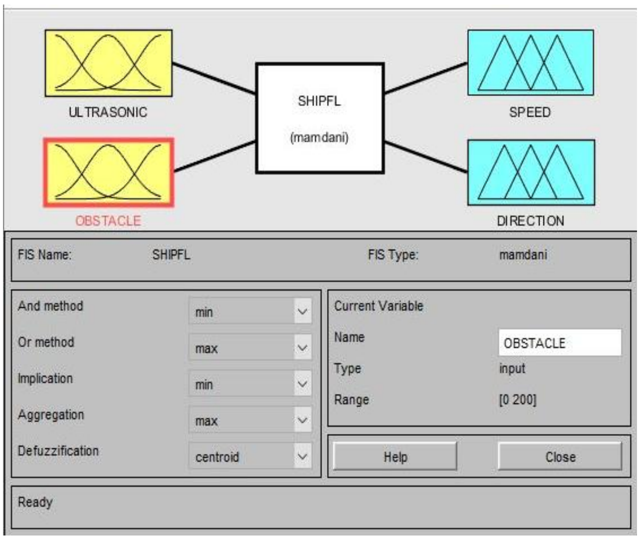

Fig. 5: Membership Functions

IV. RESULTS

The Prototype ship designed successfully detected the obstacles in its vicinity and got deviated away from it. The correction of route towards the destination was also done autonomously. The simulation of the working was successfully designed and tested for all possible cases. The following images shows the real time working of the prototype ship and some simulation results.

Fig 6: Prototype Ship Deviating Away from the Obstacle

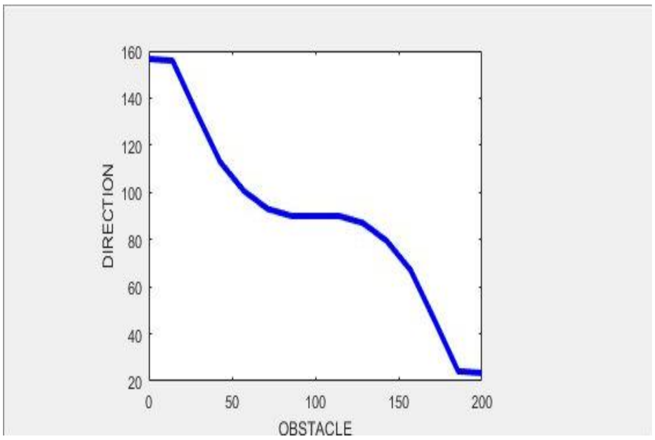

Fig. 7: The Variation of the Distance of the Object from the Ship and the Corresponding Speed of the Motor.

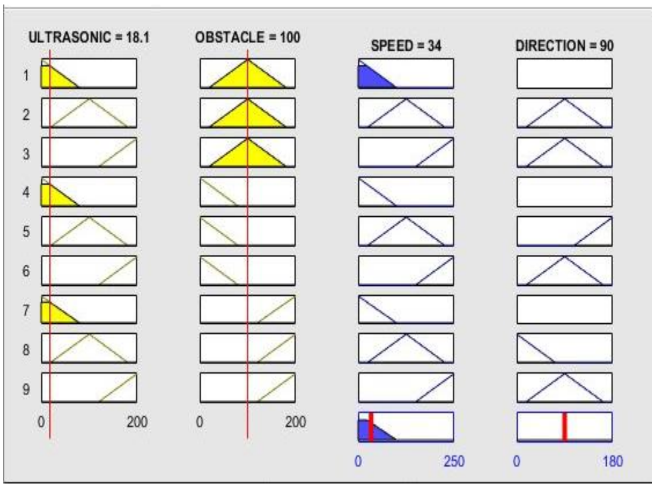

Fig. 8: Simulation Result When the Obstacle is Very Near (i.e.,18.1 as shown), Irrespective of the Direction of the Object, the Speed of the Motor is slow i.e.,34/250.

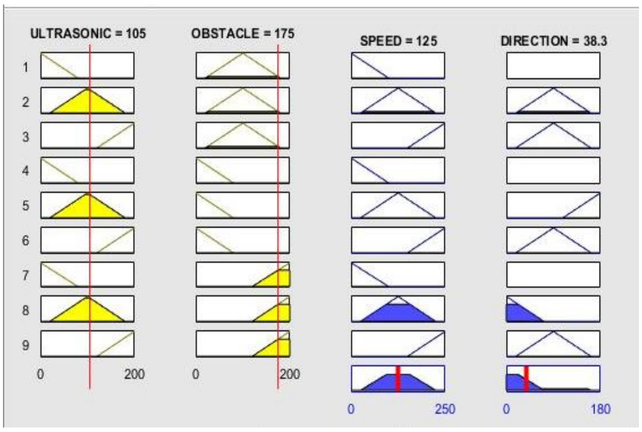

Fig. 9: Simulation result when the object is at a moderate distance from the ship (105) and the obstacle is towards left(>90), then the speed is also moderate(125) and the direction of ship movement is towards right(<90).

V. CONCLUSION

This work serves as foundation to the new emerging technology of autonomous navigation on water. The main goal of this work was to build a complete system that consists of both software and hardware designed in a cost effective way making the overall system autonomous.

The prototype ship was designed to provide great stability on the surface of water. The working of the ship was tested in the presence of static obstacles. The deviation and correction of path took place successfully while avoiding the obstacle. The simulation results obtained through fuzzy behavior simulated the same real time operation.

Autonomous Ship navigation technology can be used in various real time applications like, navigating the ship through dangerous places where there is a probability of loss of human life. Various military applications where there is threat to the navy personnel, autonomous ships can be used. With few modifications as mentioned in the future scope, this technology can have more applications.

FUTURE SCOPE

The project focuses only upon autonomously navigating through static obstacles. More research work can be done to improvise and develop the system to work faithfully in the presence of dynamic obstacles as well.

The destination where the ship has to reach can be defined in the micro controller. Continuous tracking of the location of the ship can be done by installing a GPS module in the autonomous system.

Also, to detect the obstacles present under the surface of water, an underwater ultrasonic sensor or sonar can be used. The accuracy of the correction path can also be improved.

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