AUTOMATIC SHIP CONTROLLER USING FUZZY LOGIC

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Abstract
An autonomous navigation algorithm for marine vehicles is proposed in this paper using fuzzy logic. Therefore we use a multi variable fuzzy logic control system for safer automatic navigation. Although alternative approaches such as genetic algorithms and neural networks can perform just as well as fuzzy logic in many cases, fuzzy logic has the advantage that the solution to the problem can be cast in terms of that human operators can understand, so that their experience can be used in the design of the controller. An automatic ship controller using fuzzy logic is proposed here which controls the path of the ship with collision avoidance system, keeping track of the movement of ship. Fuzzy logic based controller is shown to be better than PID Controller.
Keywords: Collision avoidance, marine vehicles, fuzzy logic, moving obstacles.

I. INTRODUCTION

To design an autopilot for a ship is always a challenging problem. A ship dynamics is influenced by unpredictable environmental disturbances such as waves, winds, currents, change of depth under keel, etc. as well as ship sailing conditions such as speed, loading condition, trim, etc. To design an autopilot capable of taking into account all these factors is nowadays possible by proven adaptive or robust control design methods. The proposed adaptive fuzzy autopilot emerges as a viable practical alternative for coastal sailing where the track keeping is of vital importance in all circumstances.

There are several technique used for ship tracking, namely PID, adaptive and predictive controllers .For ship navigation task, the PID controller coefficients need to be changed due to several reasons like environmental changes (wind, waves, and currents), random disturbances, internal errors etc. To accommodate these changes PID controller coefficients Kp, Ki, Kd, must be tuned accordingly, which demands the support of other controllers (fuzzy, genetic etc.), which in turn increases the complexity of the system. Hence PID controllers are not suitable for Navigation applications.

II. RELATED WORK

At present, ship modeling and control is an issue of high interest in research areas. For the ship modeling, there many ships mathematical models namely nomoto's, bech, and norbin and yang model [1]. The control problems are challenging due to the fact that the motion of ships possess six degrees of freedom to be controlled. Usually, the ship has: large time lag, large inertia, nonlinearity and under actuated characteristics; and its motion is strongly influenced by the model parameter perturbations (wind, wave and current flow).So the design of the motion controllers with high performance is always difficult [5].

These ship models are developed such that they can be controlled by any controller by giving command signal. We used Bech's nonlinear model, which supports 6 degree of freedom and larger rudder angle turns of ship, is used to simulate ship dynamics.

There are some wave mathematical models namely Bretschnieder spectrum, Pierson-Markowitz(P-M) spectrum, Modified Pierson-Markowitz, and JONSWAP spectrum. Inorder to consider Sea disturbances, modified Pierson-Markowitz Spectrum (P-M) is used which will take into account of both high and low tides.

In such situation, the researchers call the intelligent control theories and try to achieve better results of control. In this paper, we attempt to use the fuzzy control approach for navigating the ship automatically by considering the sea parameters.

Fuzzy Logic control is a practical alternative for a variety of challenging control applications since it provides a convenient method for constructing nonlinear controllers via the use of appropriate information [8]. So, optimal control laws can be implemented based on ship path following. Fuzzy controllers have been successfully used in many fields and shown extraordinary advantages over traditional control technology, such as nonlinearities, and robustness [9].

Collision avoidance approach: The primary control command in marine vehicle navigation is the heading angle, which is affected via the rudder as shown in Fig. 3. In the figure, {*X*0 ,*Y*0} and {*X* ,*Y*} are the global and the body-fixed coordinate systems, respectively; (*x*, *y*) is the location of the
center of gravity of the marine vehicle with respect to the global coordinate system; *u* , *v* , and *r* are the longitudinal, transverse, and angular velocities, respectively;δ is the rudder angle and ψ *d* is the desired heading angle.Control of marine vehicles is usually carried out via a combination of inner and outer loops as illustrated in Fig. 4. The inner, course-keeping controller attempts to follow the heading angle command while the outer, track-keeping controller determines the desired heading in relation to the desired track. The approach proposed here, however, is inspired by the VFF method whose direct application is depicted in Fig. 5. As shown in the figure, the vehicle is assumed to beunder the influence of two forces at any given point in time: *Fa* which acts to pull the vehicle towards the next waypoint, and *Fr*, a force directed away from the given obstacle. Evidently, a simple application of VFF does not provide track-keeping in its true sense. Moreover, in the case of a moving obstacle, a single forcing function *Fr* is insufficient to address the situation adequately, particularly when the vehicle is within the proximity of multiple obstacles.

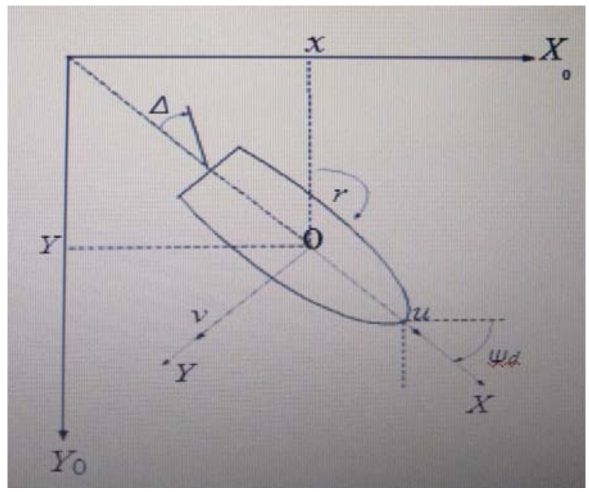

Fig. 1 The concept of track keeping mode

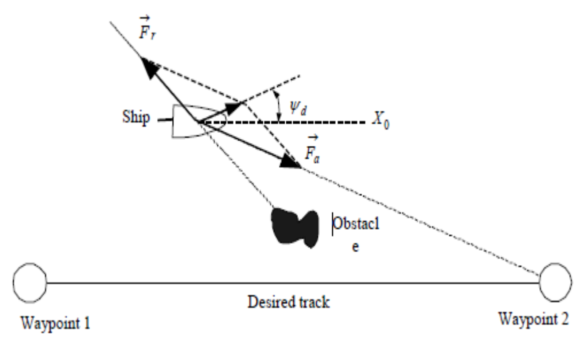

Fig. 2 Track keeping

By considering above models in this paper an attempt is made to implement the simulations obtained for the path following and for the collision avoidance in a hardware model for the marine parameters.

III. PROPOSED METHOD

There are several technique used for ship tracking, namely PID, adaptive and predictive controllers .For ship navigation task, the PID controller coefficients need to be changed due to several reasons like environmental changes (wind, waves, and currents), random disturbances, internal errors etc. To accommodate these changes PID controller coefficients Kp, Ki, Kd, must be tuned accordingly, which demands the support of other controllers (fuzzy, genetic etc.), which in turn increases the complexity of the system.
Fuzzy Controller is nothing but a fuzzy code designed to control something, usually mechanical. They can be in software or hardware and can be used in anything from small circuits to large mainframes.

To analyze PID Controller performance, the dc motor control is attained for the considered parameters and compared with the simulations obtained for the fuzzy logic.

Controller using fuzzy logic is developed for the ship as it is more robust. The algorithm for the proposed ship controller is embedded in Aurdino board.

Algorithm steps for simulation are given below:

1. Ship parameter declaration i.e. length, speed and non linear parameters of the ship.
2. Ship transfer function declaration.
3. Latitude Longitude array initialization.
4. Conversion of coordinates to angles.
5. Reference angles are given to fuzzy controller.
6. Based on the error the fuzzy controller generates the rudder angle for ship based on fuzzy rules.
7. Then rudder angle is fed to ship in presence of wave disturbance.
8. The process is continued for continuous monitoring

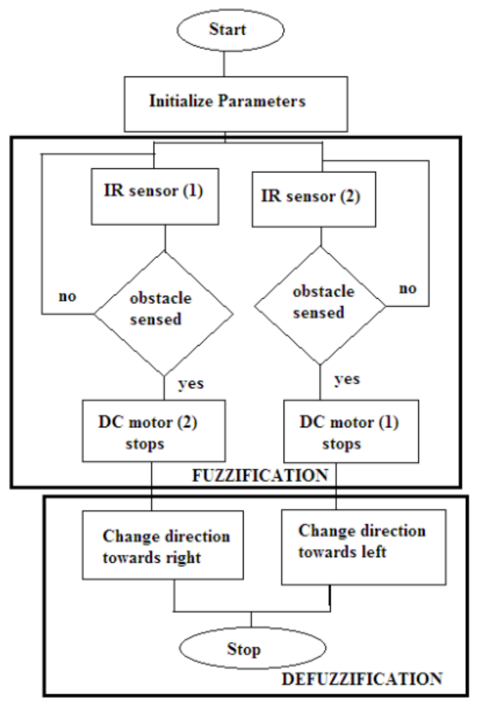

Fig. 3: Flowchart

Based on the above simulations the embedded code was formulated in fuzzy logic using the two processes of fuzzification and defuzzification and implemented on a aurdino board.

Components Used:

- Arduino nano pro board
- LCD display(16X2)
- GPS tracker
- GSM
- IR sensor
- DC Motors

In this implementation the initial parameters are loaded into the controller like obstacle distance to be sensed and the speed with which the motor should run initially. Based on the distance of the object sensed the direction to be taken is updated in the controller where actually fuzzification is done .Later the defuzzification part is carried out.
Fuzzification: For each input and output variable selected, we define two or more membership functions (MF). Qualitative category for each one of them need to be defined for example: low, normal or high.
Rule base (decision matrix) definition: Once the input and output variables and MF are defined, we have to design the rule-base (or decision matrix of the fuzzy knowledge-base) composed of expert IF <antecedents> THEN

<conclusions> rules. These rules transform the input variables to an output that will tell us the risk of operational problems (this output variable, risk of a problem, also have to be defined with MF, usually low, normal and high risk). Depending on the number of MF for the input and output variables, we will be able to define more or less potential rules. The easier case is a rule base concerning only one input and one output variable.

Example: or a given variable x involved in the development of a problem, we could have this kind of "theoretical" rule: IF x is normal THEN risk of problem is normal. The more variables we have, the more rules we have to define in order to make the inference reliable.

IF x is low THEN risk of problem is low.

IF x is normal THEN risk of problem is normal.

IF x is high THEN risk of problem is high.

		Input Y			
		LOW	NORMAL	HIGH	VERY HIGH
Input X	LOW	Low	High	High	High
	NORMAL	Low	Low	Medium	Medium
	HIGH	Low	Low	Low	Low
	VERY HIGH	Low	Low	Low	Low

Fig. 4: Rule table

Defuzzyfication: The MFs of the output have always the same shape and configuration in our risk model: the risk

of any problem has the same ranks for the MFs of the output: low, normal and high, and always without overlapping. Figure 6 shows the shape of each MF of the output variable (risk on any problem considered in the risk model).

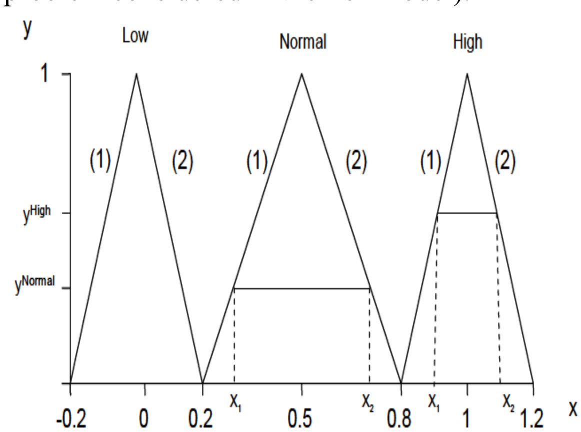

Fig. 5 Shape of MF

IV. DISCUSSION OF RESULTS

The DC motor controlling using PID in MATLAB was attained for the considered parameters and compared with the simulations obtained for the fuzzy logic. MATLAB simulation results of both PID and Fuzzy are compared and the plots of the same are as shown

Red color indicates the Reference trajectory, black color indicates the obtained PID trajectory, and blue color indicate the obtained Fuzzy Logic trajectory. From the plot it is clear that, Fuzzy Logic controller results are closer to reference trajectory (91-96%), and PID based controller has more deviation from reference trajectory (75-85%). So performance of the Adaptive (Fuzzy Logic) controller is better than PID controllers.

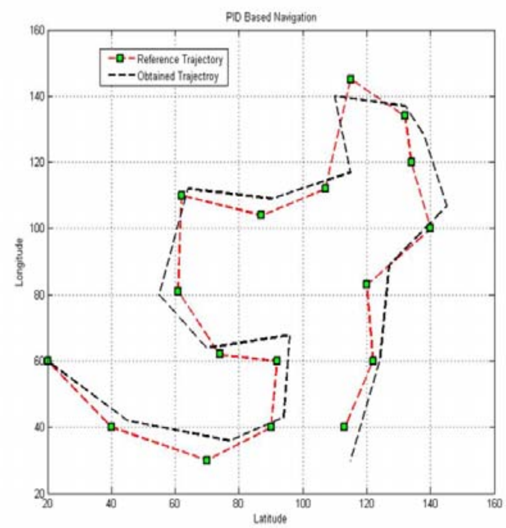

Fig. 6: Comparison of Fuzzy

Logic-PID based navigation

Hardware implementation

The aurdino board is used to interface with various sensors o receive the input for the logic and for dumping the source code into it. Here only two parameters are considered for input so as to reduce the system complexity the number of inputs can be increased in future. The IR sensor value is taken as one input and other inputs are from the temperature or wind sensor to the network. The fuzzification is done to these values which produce certain defuzzified output which is again used to control the DC motor's direction for monitoring the ship navigation. The block diagram is shown in Fig. 7.

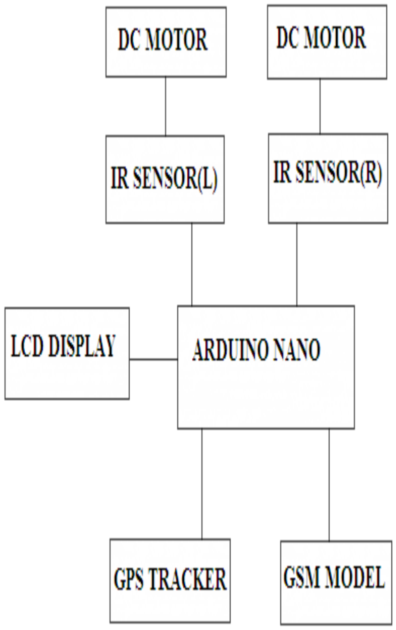

Fig. 7: Block Diagram

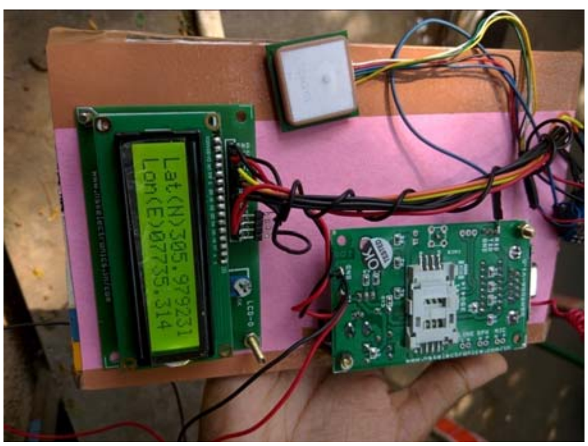

Fig. 8: Hardware implementation of Location using GPS

GPS, GSM, LCD Display, IR Sensor module are shown in Fig, 8, 9, 10, 11 respectively. The latitude and longitude position of the ship was displayed on the LCD using GPRS. GSM module was used to send the information as a message to the user. IR sensors were used for controlling the direction of DC motor based on the obstacle sensed. This model senses any obstacle in its path and changes direction accordingly and sends a message to the user when any obstacle is sensed by it. The complete hardware set-up of the controller for automatic navigation of the ship is shown in Fig. 12.

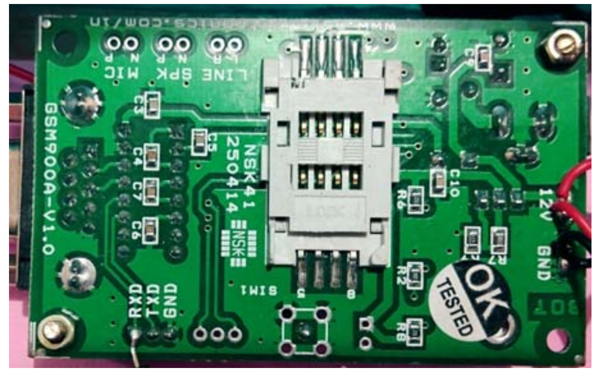

Fig 9: GSM Model

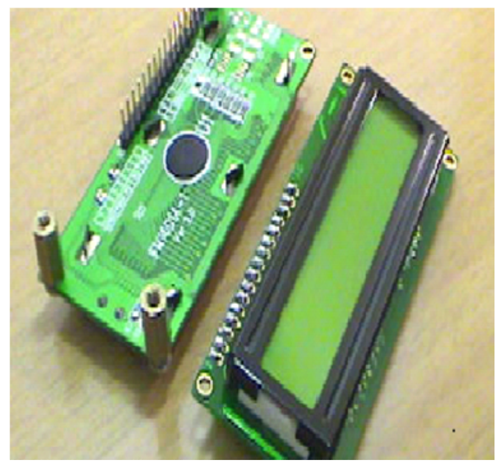

Fig. 10: LCD Display module

Fig. 11: IR Sensor module

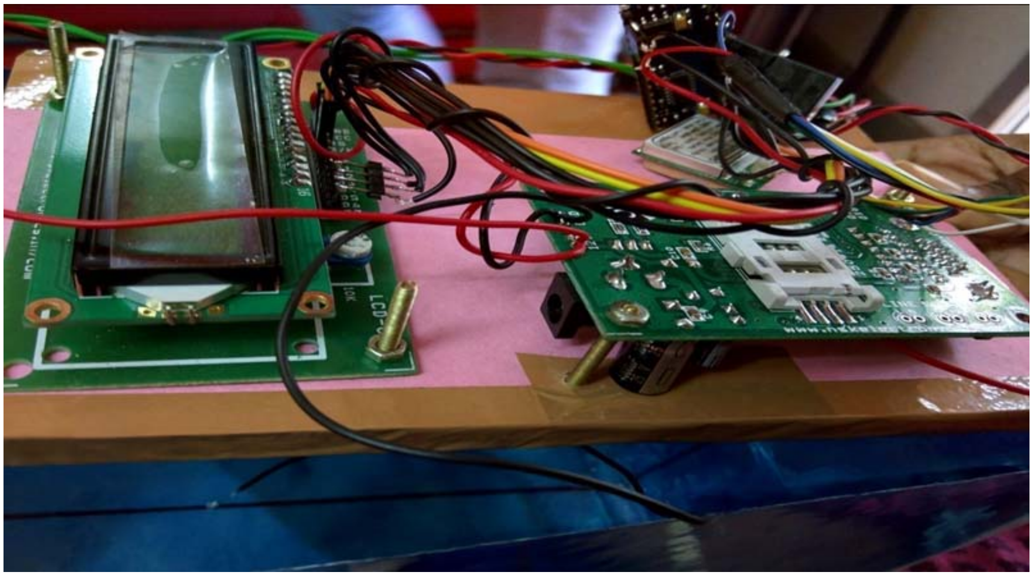

Fig. 12: Complete hardware set-up

V. CONCLUSION

The main objective of the proposed work is to overcome the limitations of traditional Navigation system, to design a efficient control system for the automatic navigation system using fuzzy logic and to inform the port offices about its location in case of missing.

Initially the simulation was carried out to develop the model for collision avoidance using PID and FUZZY. As Fuzzy was proved to be better, the further simulations were developed using fuzzy logic. Hardware implementation for fuzzy logic controller is done for the ship navigation system. The latitude and longitude position of the ship was displayed on the LCD using GPRS. GSM module was used to send the information as a message to the user. A DC motor was programmed using fuzzy logic to control its speed and direction. IR sensors were used for controlling the direction of DC motor based on the obstacle sensed.

Now this model senses any obstacle in its path and changes direction accordingly and sends a message to the user when any obstacle is sensed by it. By this an automatic navigation of the ship has been achieved.

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