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Fuzzy Controller Technique in Navigation of a Mobile Robot

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***Abstract*— The field of mobile robotics is often partitioned into systems designed for either indoor or outdoor environments. The autonomous navigation of mobile robot in a physical environment, many mobile robots are able to move in structured environments. Mobile robots are machines which navigate around their environment extracting sensory information concerning that environment and performing actions dependent on this sensory information. The fuzzy logic controller developed is simples and efficient. Fuzzy logic control is characterized by the use of linguistic rules to manipulate and implement human knowledge in control systems so as to handle the uncertainty present in the environment.A hierarchical behavior based control strategy has been devised in which four different reactive behaviors are combined by means of a fuzzy supervisor.**

***Index Terms*— Obstacles, Mobile robot, Fuzzy logic.**

I. INTRODUCTION

The application of mixed soft computing techniques like neural network, fuzzy logic and genetic algorithm are apply in various researchers that are commonly present in real-world problems. The membership functions and rule set of fuzzy logic controller (FLC) which a robot uses to navigate among moving obstacle.The objective of this paper is to navigate an autonomous mobile robot using a fuzzy logic controller.In the area of robotics, one of the main areas of research is to construct autonomous intelligent mobile robots, which can plan own motion during navigation through two-dimensional or three dimensional terrains [1].Mobile robot navigation in an unknown environment has two main problems: localization and path planning. The other problem is the path planning in which the mobile robot needs to find a collision free path from its starting point to its destination point. In order to be able to find that path, the robot needs to run a suitable path planning algorithm, to calculate the path between any two points [2].A navigation method in an unknown environment based on the combination of generic behaviors has been developed. Most of these behaviors are obtained by means of fuzzy inference systems. In the case of partially known environment, we used the advantages of global and local navigation strategies [3].Navigation is a major requirement for an autonomous mobile robot trying to fulfill its mission. The sensors used for localization determine the types of localization method that can be applied to mobile robot navigation problems [4].To perform complex navigation tasks and to coordinate its movement with other agents in indoor environments, autonomous mobile robot needs knowledge about the world in which it is moving.A lot of successful works on self-localization in indoor or bounded environments with laser range finders are very accurate, sharp and robust [5].An autonomous mobile robot moves in unknown environments to reach a specified target without collisions with obstacles, sensors must be used to obtain information about the real world problems. Artificial intelligence techniques are widely used to solve the problem of robot navigation in unstructured environments [6].Achieving robust and reliable autonomous operation even in complex unstructured environments is a central goal of field robotics [7]. Motlagh et al. described a control technique for reactive navigation of mobile robots. The problems of large number of rules, and inefficient definition of contributing factors, e.g., robot wheel slippage, are resolved. Causal inference mechanism of the fuzzy cognitive map (FCM) is hired for deriving the required control values from the FCM's motion concepts and their causal interactions. The results and comparisons with the related works are given using Active Media simulation and a developed FCM simulation tool. [8]. Muthu et al. present the performance of a low cost, fuzzy logic based controller for autonomous navigation in which the controller makes the system move through obstacles without human intervention in an efficient manner. Further, in this correspondence, we present the way we developed the fuzzy logic controller along with liquid crystal display(LCD) controller, universal asynchronous receiver transmitter(UART) [10]. Foudil et al. defined Autonomous mobile robotics is providing robots with some level of intelligence and ability to perform desired tasks without continuous human guidance. Fuzzy logic has become a mean of receiving human knowledge and experience and dealing with uncertainties in the control process difficulties. Now, fuzzy logic is becoming a very popular topic in control engineering fields [12].

II. USING FUZZY LOGIC METHOD

The mobile robot turns around obstacle our projected navigation method supplies the robot with the turning point for avoiding the obstacle and moving on the collision free path. The inputs of the fuzzy approach consist of obstacles which stand on the front, right and left of a robot as shown in Fig. 1, and each input variables has three triangular membership function (MF) close, medium and away as shown in Fig. 2. The fuzzy controller as shown in Fig. 3 uses various sensors based information such as front obstacle distance (F_O_D), right obstacle distance (R_O_D), and left obstacle distance (L_O_D), and heading angle (H_A) for select the path while moving near to goal. The fuzzy position function commands the robot moves to particular position for defending obstacles. The fuzzy logic rules for obstacle avoidance as follows.

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If (L_O_D is close and R_O_D is close and F_O_D is close), Then (heading angle is negative).
If (L_O_D is close and R_O_D is close and F_O_D is medium), Then (heading angle is negative).
If (L_O_D is away and R_O_D is medium and F_O_D is away), Then (heading angle is positive).
If (L_O_D is medium and R_O_D is away and F_O_D is medium), Then (heading angle is positive).
If (L_O_D is away and R_O_D is away and F_O_D is away), Then (heading angle is zero).

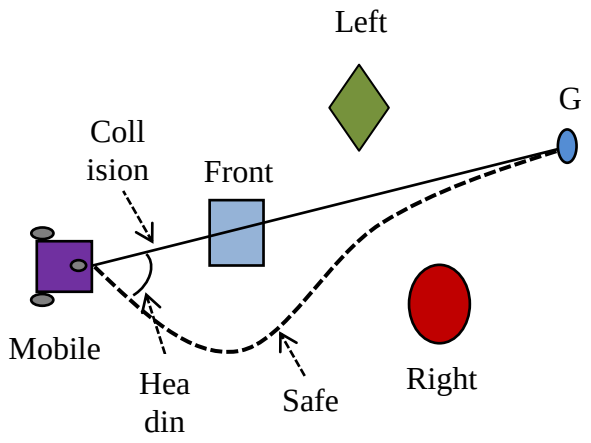

Fig. 1 Mobile robot avoiding obstacle using fuzzy logic controller

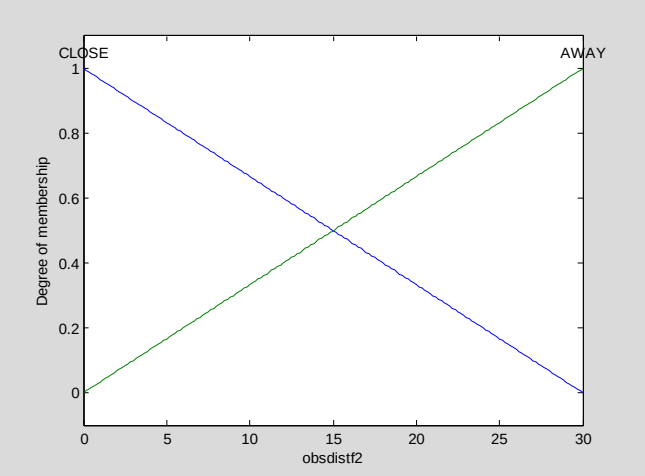

Fig. 2 Fuzzy membership function for obstacle distance

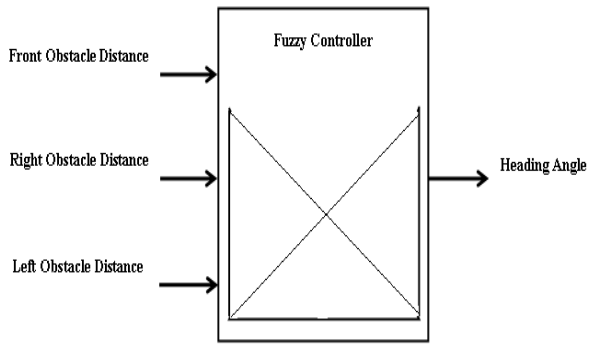

Fig. 3 Fuzzy logic controller

A mobile robot navigation path planning system based on fuzzy logic. Fuzzy rules are adopted in the controller of a mobile robot enable it to avoid obstacles in a cluttered environment. When computing the configuration sequence, we allow the mobile robot to move from one position to another. When the environment of the mobile robot is obstacle free, the problem occur less complex to handle. But as far as the environment becomes complex, motion planning needs much more computations to allow the mobile robot to move between its current and final configuration without any collision with the surrounding environment [8].Sensor based mobile robot navigation systems typically relied on ultrasonic sensors or laser scanners providing one dimensional distance outlines. The major advantage of this type of sensors results from their ability to directly provide the distance information required for collision avoidance.Ultrasonic sensors or one dimensional laser rangefinders, which have been widely, used for transportation and navigation tasks of an autonomous mobile robot [9].The fuzzy logic control system scheme consist of a heading angle between a robot and the specified target and the distance between the mobile robot and the obstacles to left, front and right locations.The set of fuzzy rules will allow us to control and to select different behaviors of an autonomous mobile robot in different circumstances. The problem of driving a mobile robot to a goal in an unknown environment is formulated as a fuzzy logic control problem in which local information is used to make eight logic rules by using two membership functions as shown in Table 1.

Table 1 Fuzzy control rules for obstacle avoidance using two membership Function

Fuzzy rule no.	Obstacle distance 1	Obstacle distance 2	Obstacle distance 3	thetaf
1	away	close	close	Positive
2	away	close	away	Negative
3	away	away	close	Positive
4	away	away	away	Positive
5	close	close	close	Positive
6	close	close	away	Negative
7	close	away	close	Positive
8	close	away	away	Positive

Finding the angle ‘θ’ at each point of a given path and then calculating the updated robot positions are specified formula below:

$$\theta = \tan^{-1}\left(\frac{tary - y}{tarx - x}\right)$$

Design of Fuzzy Behaviors

There is not however an established way of designing the rule bases of these behaviors. A lot of approaches use expert knowledge to decide on the response of the behavior according to its objective but without defining that objective explicitly. On the other hand, we think that the robot must use several abstraction levels on the information that it has collected from the environment which it can use to control its own motion.

- The situation to achieve or to maintain one behavior will be defined explicitly by means of certain values of the input variables.
- The regulatory control is used to build the rule base of the behavior, defining a set-point or objective of the behavior.
- The structure of the behaviors becomes very homogeneous and makes the definition of the evaluation measures.

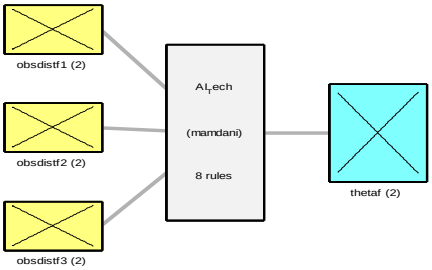

Fig 4.9 Fuzzy Interface System (FIS) Mamdani Type

The main objective is to design a controller to guide the mobile robot safely in an unknown environment from an initial state to a final state step by step. The mobile robot will have to take actions such as to speed up or down, turn left, turn right, etc. These actions are taken by determining or controlling the values of variables such as velocity, steering angle, obstacle angle, etc. To be able to navigate, the mobile robot has to obtain information about its surroundings. The accomplished of a fuzzy logic inference process based on rules (IF-THEN statements) taken from a knowledge base. An approach for designing fuzzy logic controllers for performing the simplest form of reactive navigation of an autonomous mobile robot, the rule bases that represents the action or behavior of the controllers were designed to model an expert human driver. An interesting feature of fuzzy control system is that it is easy to deal with uncertain situations by representing the input and output relation in the "IF-THEN" manner and constructing knowledge base.MATLAB contains many inbuilt toolboxes. FIS (fuzzy inference system) editor in the Fuzzy toolbox is used for simulation. Fuzzy inference is the process of formulating the mapping from a given input to an output using fuzzy logic. The process of fuzzy inference system involves membership functions, fuzzy logic operators, and based on IF-THEN rules. There are two types of fuzzy inference system (FIS) which can be implemented in the Fuzzy Logic Toolbox are Mamdani-type and Sugeno-type. These two types of fuzzy inference systems vary in the way outputs are determined.Fuzzy logic, which is the logic is based on fuzzy control, is much closer in spirit to human thinking and natural language than the traditional logical systems.The objective is to design a fuzzy logic based navigation algorithm that will enable the mobile robot to move parallel to obstacles.

III. SIMULATION RESULTS AND DISCUSSION

The simulation experiment shows that the proposed fuzzy controller, using MATLAB, can perform robot navigation in known or partially known environments. The trajectory of mobile robot navigation in unknown environment with three obstacle(s) as shown in Fig.5.1, Fig.5.2 Fig.5.3 and Fig.5.4 respectively, the bedside table on this figures are show that the starting point, obstacle(s), heading angle, and goal point of a robot. The simulation program offers an excellent alternative based on navigation methods with a fraction of the processing requirements result a fast responding reliable application. In this thesis conclude that present a new mobile robot navigation strategy based on the fuzzy logic approach avoiding the obstacle drives robot ultimately target at the required distance with the given initial position. We have developed simulation to test robot trajectory under the unknown environment according to fuzzy logic rules. The simulated robot collision free path developed and set the number of obstacle(s) at different location of the environment. When the robot is near to obstacle, it must change its heading angle to avoid obstacle(s).

- In the Fig. 5.1, a robot is controlled by fuzzy controller to moves from its start (0, 0) to the goal (250, 250) avoid three obstacles placed in (50, 50),(100, 100) and(180, 180)respectively. In this simulations show, the robot finds goal in environments with number of obstacles without hitting the obstacle(s).

When the acquired information from the sensors shows that there are no obstacles around robot, its main reactive behaviour is target. Intelligent controller mainly adjusts robots motion direction and quickly moves it towards the target if there are obstacles around the robot as shown in Figure 5.1 In the proposed control strategy, reactive behaviours are formulated by fuzzy sets and fuzzy rules, and these fuzzy rules are integrated in one rule base.

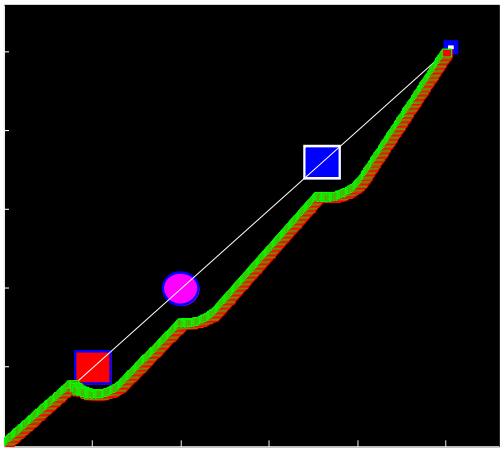

Fig 5.1 Simulation of Three Obstacles along Path using Fuzzy controller

IV. CONCLUSION

In this paper, we use fuzzy logic to realize the reactive behaviors for mobile robot navigation. Mobile robots are the subject of large scientific interest since a long time. A theoretical development of a complete navigation procedure of a mobile robot in an obstacle free environment has been described.Many applications require the ability to navigate a mobile robot platform through environments containing obstacles, some known, and some unknown. The goal of the

fuzzy logic controller is to drive the mobile robot without colliding with the obstacles. The use of fuzzy controller is not limited to common static environments such as rooms and warehouses, but can also be used dynamic environments, where unknown moving objects are part of surroundings. This simulation results behind that implementing obstacle avoidance uses a fuzzy logic approach and is conducted an autonomous mobile robot platform which can modify to include sensors. The current research work is to be extended for multiple mobile robots instead of single mobile robot.

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