An optimized path planning for wheeled robot in obstacle environments

Abstract— **In this paper, we have proposed an obstacle avoidance algorithm for a path planning in unknown environment for a mobile robot based on the fuzzy logic control. Therefore, the wheeled mobile robot is equipped with 3 wheels, one steering wheel and two fixed wheels and mounted on the same axis. Its task is to move from a starting position to a target position. For this, our proposed algorithm creates one or more imaginary target and applies a fuzzy logic control system, which is adopted by a rule table that is induced from two inputs data (the distance and the angle between the robot and the target) and two outputs data (the angle orientation and velocity of the steer wheel). Experimental results show the effectiveness of the proposed algorithm.**

Keywords—Wheeled robot, Fuzzy logic, velocity, orientation, Path planning.

I. Introduction

Many research results about path tracking of a mobile robot were implemented. Where we can consider the fuzzy logic system [1] one of the effective means in unknown environments. This fuzzy logic system has usually implemented for planification of the trajectory from a strat position to a target position with obstacle avoidance of mobile robot in unknown environments.

In [2] He proposed a new approach to design a fuzzy controller for increasing the ability of mobile robot to react to dynamic environment. A simple structured fuzzy logic system was implemented in [3]. Its main concept was introduced in [4].

In this paper we propose a fuzzy logic based control system for path planning of a tricycle mobile robot. Here the steer wheels' velocitie and orientation are controlled by a fuzzy logic system. The methods for fuzzification and reasoning are Mamdani's method. The number of control rules is fiveteen for the steer wheel.

The organization of this paper is as follows: In next section we present the Kinematic Model of Mobile Robot. We describe the path planning algorithm and the fuzzy logic system for the wheeled mobile robot in Section 3 and Section 4. In Section 5 we show that good performance could be obtained at several simulation results. Finally, we present some concluding remarks.

II. Kinematic Model of Mobile Robot

The mobile robot is a wheeled robot, to have its stability, it is equipped with 3 wheels, one steering wheel and two fixed wheels and mounted on the same axis, this model is named tricycle robot.

A kinematics model of a mobile robot used in this paper is shown in Fig. 1.

We assume that the contact between the wheels and the ground is pure rolling and non-slipping [5].

The steering wheel is set to an angle α(t) from the straight-line direction, the tricycle will rotate with angular velocity w(t) about a point lying a distance R along the line perpendicular to and passing through the rear wheels. The {Xb, Yb} represents the base frame. robot posture in base frame is represented by :

$$q = \begin{matrix} x \\ y \\ \theta \end{matrix} \quad (1)$$

The linear velocity of steering wheel is represnted by :

$$V_s(t) = W_s(t)\, r \quad (2)$$

$$where\ r\ is\ steering\ wheel\ radius$$

The angular velocity of the moving frame relative to the base frame is represented by :

$$W_s(t) = \frac{V_s(t)}{d} \sin \alpha(t) \quad (3)$$

The kinematic model in the world frame is represented by:

$$V(t) = V_s(t) \cos \alpha(t) \quad (4)$$

$$W(t) = \frac{V_s(t)}{d} \sin \alpha(t)$$

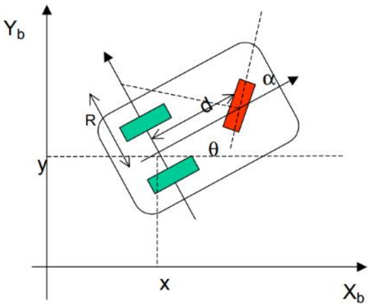

Fig.1

We assume that the wheeled robot mobile takes a circular form as shown in Fig.2.

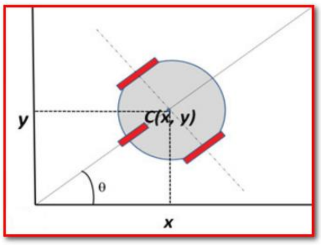

Fig.2

III. PATH PLANNING ALGORITHM

The wheeled robot mobile navigates in the environment by planning a path between a start and a target position with avoiding one or more of obstacle.

This planning is generated by an algorithm which that proposes an optimal path from the start position to the target position. This path is composed from many positions that takes the robot during its displacement. The final path planning can be straight from initial position to the final target but if an obstacle is appeared, the robot will change the trajectory to avoid the obstacles, in this case the algorithm system will create an other target named imaginary target near to the detected obstacles where the robot changes its orientation to this imaginary target after that when the robot reaches this imaginary target, it will plan an other trajectory to the final target and if it detected an other obstacles the algorithm system will create an other imaginary target. This process is still repeated until it achieved the final target.

The displacement of the robot mobile between a position to the imaginary or final target is controlled by two parameters as the orientation angle and the velocity of the steer wheel.

IV. FUZZY LOGIC SYSTEM

A. Inputs variables and Outputs variables

In our proposed system, there are two inputs and two outputs system as shown in Fig.3. The inputs are the angle between the robot orientation and the imaginary or final target orientation, and the distance measured between the robot position and the imaginary or final target position. The outputs are the angular velocity and the rotation angle of the steer wheel of the mobile robot.

B. Fuzzification

Input and out membership functions were defined as Table Fig.3.a.b and Fig.3.c.d, respectively.

The linguistic variables are taken for the distance from the robot position to the target that are VN: Very Near, N:Near, Z: Zero, F:Far, VF: Very Far.

The linguistic variables are taken for the angle between the robot orientation and the imaginary or the final target orientation that are L: Left, F:Front, R: Right. Here “Left” means that the goal is located at the left side of the robot.

The linguistic variables are taken for velocity of the robot that are VL: Very Low, L:Low, N: Null, H:High, VH: Very High.

The linguistic variables are taken for the angle orientation of the robot that are L: Left, S:Straight, R: Right.

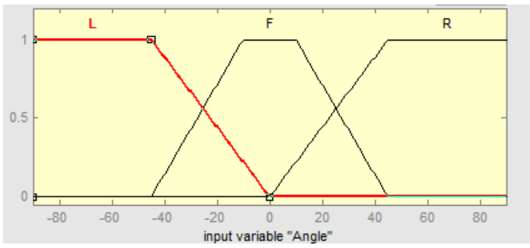

Fig.3.a

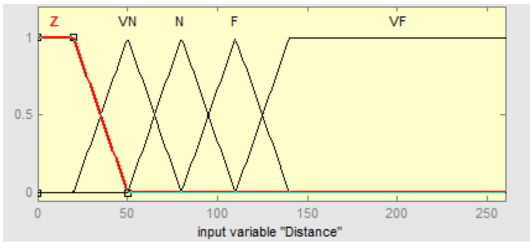

Fig.3.b

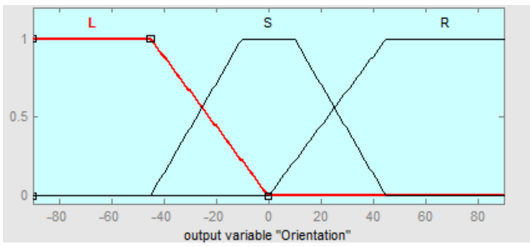

Fig.3.c

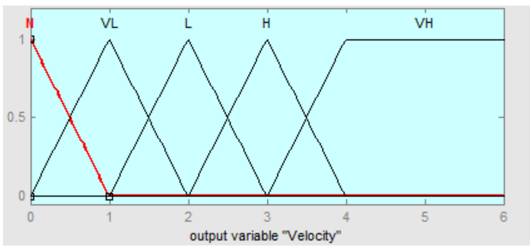

Fig.3.d

C. Rule of the Fuzzy Inference System

The Fuzzy rules are based on human experience and the conditions of the system to be controlled.

They are shown in TABLE I .For the angle orientation of the robot and the velocity of the steer wheel. The actual number of fuzzy rules should be taken depends on many factors. The general principle is on the completeness of the premise.

TABLE I. TFUZZY RULES OF THE STEER WHEEL

Distance	Angle		
	Left	***Front***	***Right***
VN	L	S	R
	VL	VL	VL
N	L	S	R
	VL	L	VL
Z	L	S	R
	N	N	N
F	L	S	R
	H	H	H
VF	L	S	R
	H	VH	H

The essential rules are formulated for the proposed controller given in Fig. 4

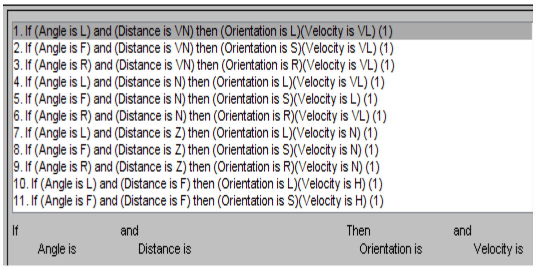

Fig.4

D. *Defuzzification*

Many defuzzification algorithms have been reported which are Centroid, Bisector, Middle of Maximum (MOM), Smallest of Maximum (SOM), Largest of Maximum (LOM), etc. In our paper, we are using the centroid method which is usually know as center of gravity (COG).

$$u = (\int u.C(u)\,.\;du)/(\int C(u).du) \qquad (5)$$

V. SIMULATION AND EXPERIMENTAL RESULT

Simulations are done in C# with different environments to verify the proposed system. We have discussed the comparison with the conventional fuzzy logic control system of [6] and the proposed system in two scenarios which is shown in Fig.5 and Fig.6. Firstly, the starting point and the target point are (10, 40) and (260,440) respectively in the simulation program and designed with a few obstacles. From the simulation we had seen that robot reached the target safely and less time from the other existing methods. Secondly, the simulation program and designed became complicated with more obstacles. In this case, From the simulation we had seen that robot reached the target safely and less time from the other existing methods where we observe the robot that moved by our proposed fuzzy logic system used the imaginary target system until it reached the final target. The path length and the time travelled in different environments are shown in Table 2.

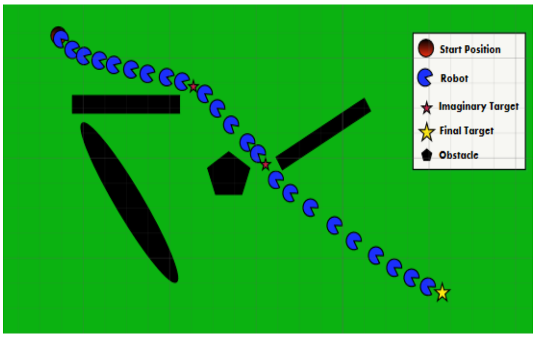

Fig.5.a

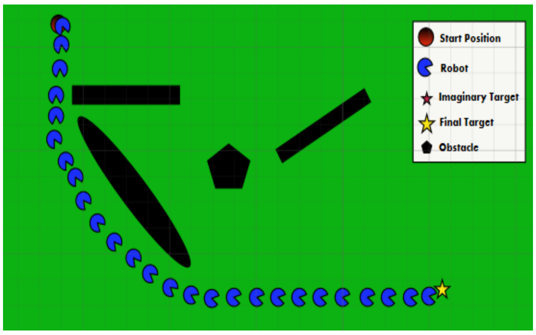

Fig.5.b

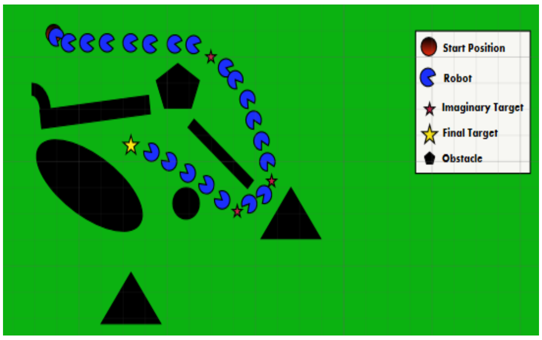

Fig.6.a

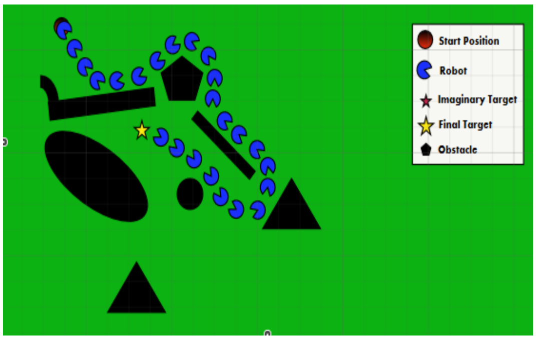

Fig.6.b

The velocities of the steer wheel when the distances are given in the Fuzzy inference system are shown in Fig 7.a

The velocities of the steer wheel when the angles are given in the Fuzzy inference system are shown in Fig 7.c

The orientations of the steer wheel when the angles are given in the Fuzzy inference system are shown in Fig 7.b

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The velocities of the steer wheel when the inputs are given in the Fuzzy inference system are shown in Fig. 8.

The proposed system has smaller control rules, then the computational time is also more fast.

However the conventional fuzzy logic system of [6] used 49 control rules and the proposed system used only 15 rules.

TABLE II. COMPRISON OF TWO METHODS

	Parameters	
	Trajectory length(m)	***Trajectory time(s)***
Proposed method	38.6	40
Method in [6]	42.3	44

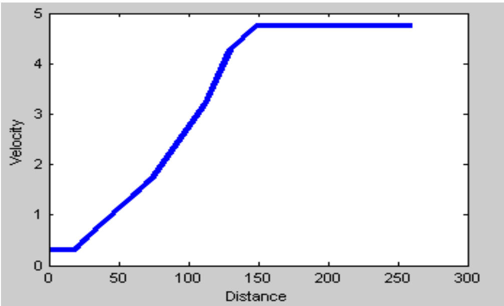

Fig.7.a

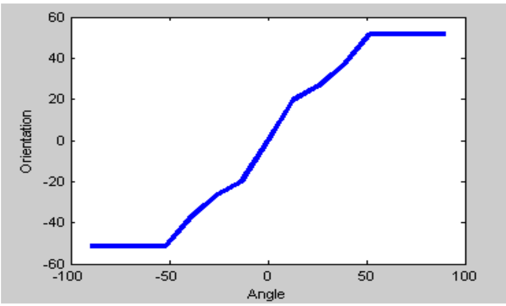

Fig.7.b

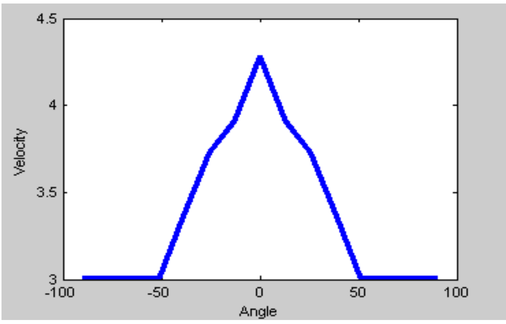

Fig.7.c

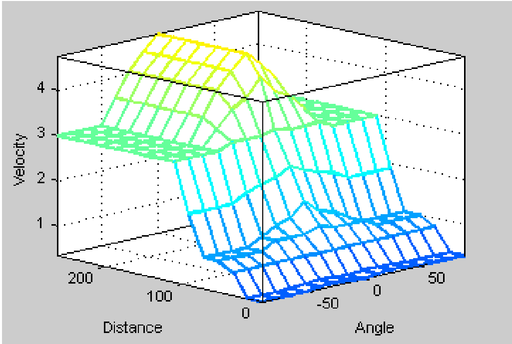

Fig.8

VI. CONCLUSION

We here presented the fuzzy logic system control based obstacle avoidance algorithm with multi imaginary target for a wheeled mobile robot

Their outputs for the fuzzy control system were the velocitie and the orientation of the steer wheel. And their input variables were the angle orientation and the distance between the robot and the target position. The angle of input variable was divided by three part of front, left, and right. Therefore, the number of total control rules was only 15 compared to the case of 49 in [6] the robot. The simulation results demonstrated the effectiveness of the obstacle avoidance capability with fast time in an unknown environment.

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