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Research Article

A Fuzzy Logic Behavior Architecture Controller for a Mobile Robot Path Planning in Multi-obstacles Environment

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Abstract: The path planning and obstacle avoidance are the most important tasks for an autonomous mobile robot moving in an unknown environment. This paper presents a simple fuzzy logic controller which involves searching target and path planning with obstacle avoidance. In this contest, fuzzy logic controllers are constructed for target searching behavior and obstacle avoidance behavior based on the distance and angle between the robot and the target as inputs for the first behavior and the distance between the robot and the nearest obstacle for the second behavior; then a third fusion behavior is developed to combine the outputs of the two behaviors to compute the speed of the mobile robot in order to fulfill its task properly. Simulation results show that the proposed approach is efficient and can be applied to the mobile robots moving in unknown environments.

Keywords: Behavior architecture, fuzzy controller, mobile robot, obstacle avoidance, path planning

INTRODUCTION

Mobile robots have been the object of many researchers over the last few years in order to improve their operational capabilities of navigation in an unknown environment which consist of the ability of the mobile robot to plan and execute a collision-free motion within its environment. However, this environment may be imprecise, complex and either partially or non-structured (Janglova, 2004). The path planning problem of a mobile robot can be stated as: given the starting position of the robot, the target location and a description of its surrounding environment, plan a collision-free path between the specified points under satisfying an optimization criterion (Sugihara and Smith, 1997).

The path planning in an unknown environment depends on the different sensory systems (cameras, sonar, etc.) which provide a global description of the surrounding environment of the mobile robot; therefore, this description might be associated with imprecision and uncertainty. Thus, to have a suitable path planning scheme, the controller must be robust to the imprecision of sensory measurements. Hence, the need for an approach such as fuzzy logic (Beom and Cho, 1995; Ehsan *et al*., 2011) which can deal with uncertainties is more suitable for this kind of situations.

Because of the complexity of the surrounding environment to be characterized or modeled accurately, behavior architecture control applications become important for the mobile robots navigation. It decomposes the navigation system into specific behavior modules which are connected directly to sensors and actuators and operate in parallel. Simple behaviors are then combined in order to produce a complex strategy able to pursue the strategic goals while effectively reacting to any contingencies. Therefore, this architecture can act in real-time and has good robustness. Brooks (1986) proposed an architecture that has been applied successfully in mobile robot navigation (Fig. 1), but its main drawback is the arbitration technique which allows only the activation of one behavior at one time. In many situations, the activation of two behaviors is required, for example, when the robot is moving toward the target and avoids obstacles at the same time, two behaviors should be combined to fulfill this task (Yung and Ye, 1999).

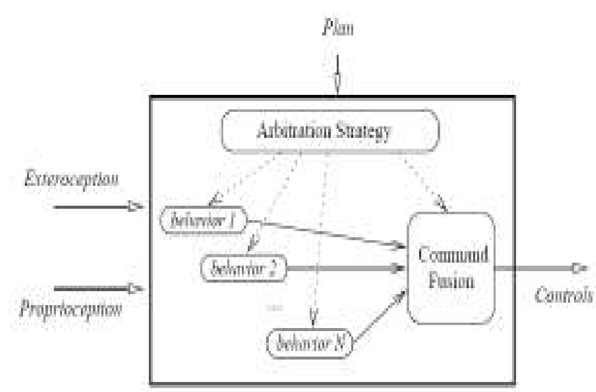

Fig.1: Behavior architecture

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Fuzzy logic was used in many works to design robust controllers for the navigation of mobile robots in a cluttered environments and it can solve such complex real world problems within a reasonable accuracy and a low computational complexity, due to their heuristic nature. In addition, genetic algorithms (Seng *et al*., 1999), neural networks (Kian *et al*., 2002) and their combinations were developed to construct the fuzzy logic controller automatically. However, the fusion of different behaviors remains to be difficult when they attempt to control the same actuator simultaneously. Many efforts have been devoted to solve the problem of fusion behavior methods.

PROBLEM FORMULATION

The fundamental idea for the mobile robot navigation methods is inspired from wild animals while follow their preys. This control approach is highly efficient for reaching a static or moving target. The mobile robot attempts to change its velocity in order to decrease its distance and angle with the target at each decision point. In this work, we consider a two wheels mobile robot with kinematic model shown in Fig. 2.
The kinematic model is given by:

$$\begin{cases} \dfrac{dx}{dt} = V\cos\theta \\ \dfrac{dy}{dt} = V\sin\theta \\ \dfrac{d\theta}{dt} = w \end{cases} \tag{1}$$

where, V and w are the robot's linear and angular velocities respectively. θ is the angle between the robot's direction and X axis.

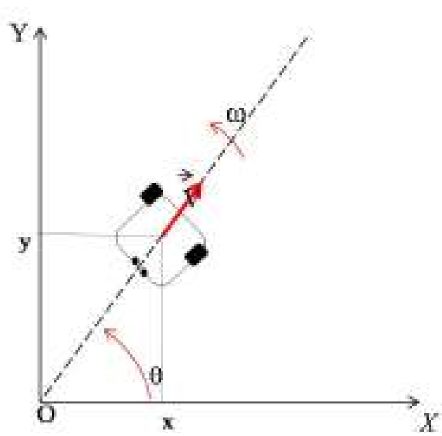


Fig. 2: Schematic model of a wheeled mobile robot

The aim of this paper is to design a simple fuzzy logic controller based on behavior architecture that compute the robot's linear and angular velocities and ensures obstacle avoidance with goal attainability.

DESIGN OF THE FUZZY LOGIC CONTROLLER

A typical architecture of a Fuzzy Logic Controller (FLC) is depicted in Fig. 3. It comprises a fuzzifier, membership functions, control rule base, an inference engine and defuzzifier. First, physical inputs are normalized by multiplying the corresponding scaling.

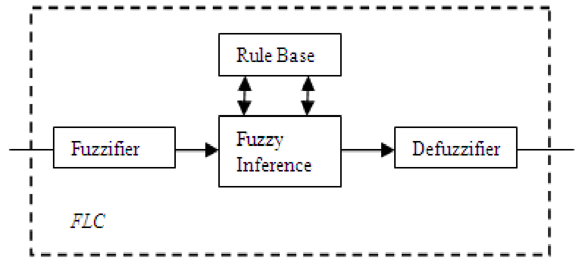


Fig. 3: FLC architecture

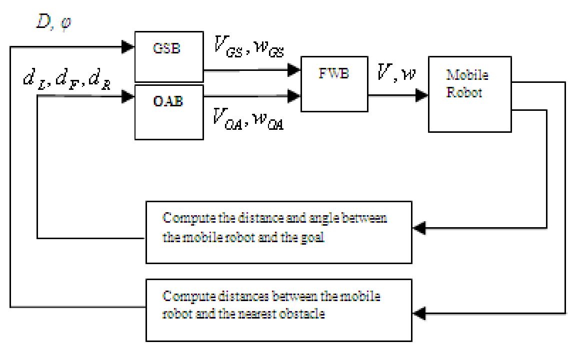


Fig. 4: FLC block diagram

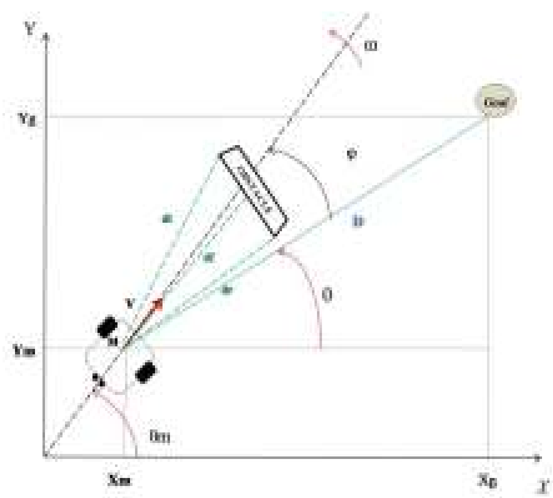
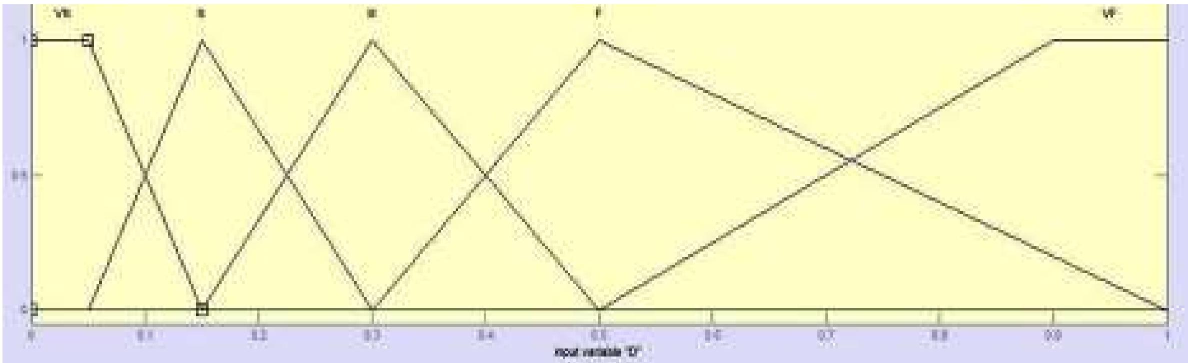
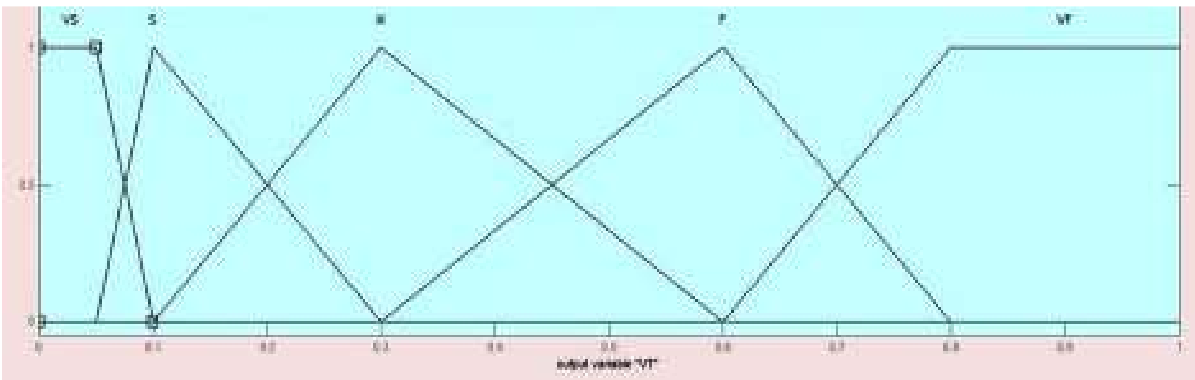


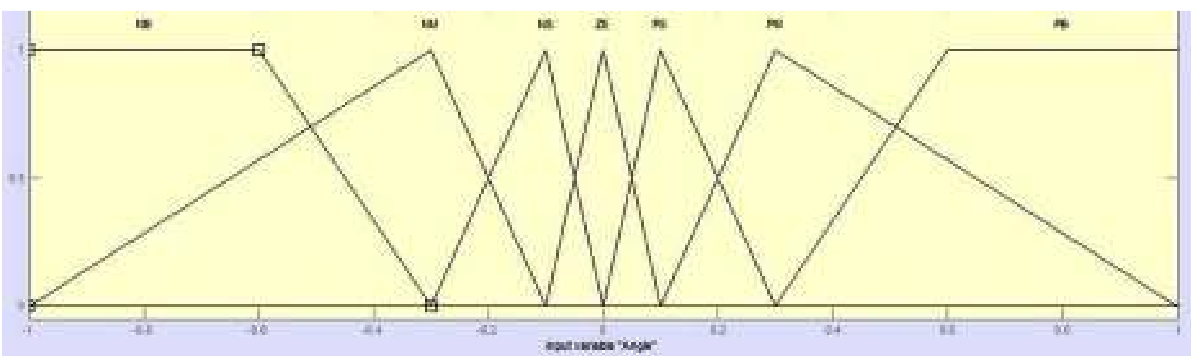
Fig. 5: Robot path planning configuration



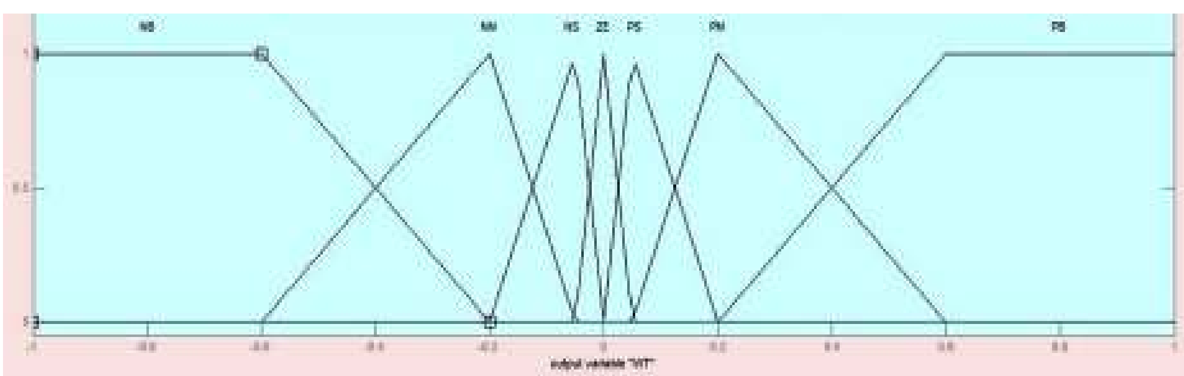
(a) Distance D



(b) Linear speed V_{GS}



(c) Angle φ



(d) Angular speed w_{GS}

Fig. 6: Membership functions of GSB

factors. The fuzzifier uses membership functions to fuzzify the normalized physical inputs. Next, the inference engine performs a fuzzy reasoning on control decisions. Finally, the defuzzifier converts fuzzy control decisions into physical control signals.
A control rule can be written as follows:

R_i: If x_1 is X^i_1 and….and x_n is X^i_n then
y_1 is Y^i_1 and….and y_n is Y^i_n

The output of a fuzzy logic controller is expressed as follows:

$$y_i = \frac{\sum_{j=0}^{r} \alpha_j y_j}{\sum_{j=0}^{r} \alpha_j} \tag{2}$$

where,

r = The number of control is rules
α_j = The level activation of rule j

Figure 4 presents the block diagram of the designed control approach, in which three behaviors have been synthesized: Goal Searching Behavior (GOB), Obstacle Avoidance Behavior (OAB) and Fusion Weight Behavior (FWB). A schematic configuration of the robot's path planning is depicted in Fig. 5.

Goal Searching Behavior (GSB): This behavior is composed of two fuzzy logic controllers; the first one computes the robot's linear speed from the distance between the current position of robot and goal position, while the second receives the angle between the robot and its goal. The angle controller keeps the robot heading to its goal while the distance controller regulates the distance between the robot position and its goal. The distance D and the angle φ are given as follow:

Table 1: Rule base of GSB

D	VN	N	M	F	VF		
VGS	VS	S	M	B	VB		
D	NB	NM	NS	ZE	PS	PM	PB
VGS	PB	PM	PS	ZE	NS	NM	NB

Table 2: Rule base of FWB

		D		
τ		N	M	F
d	N	VS	S	M
	M	S	M	B
	F	M	B	VB

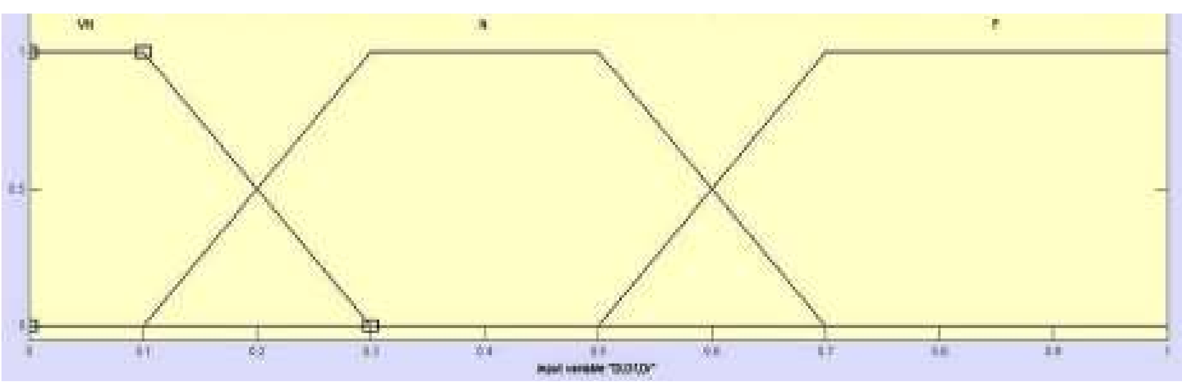
$$\begin{cases} D = \sqrt{(X_g - X_m)^2 - (Y_g - Y_m)^2} \\ \varphi = \theta_m - \theta \\ \theta = \tan^{-1}\dfrac{Y_g - Y_m}{X_g - X_m} \end{cases} \tag{3}$$

Figure 6 presents the different chosen membership functions for the inputs and outputs of the GSB.

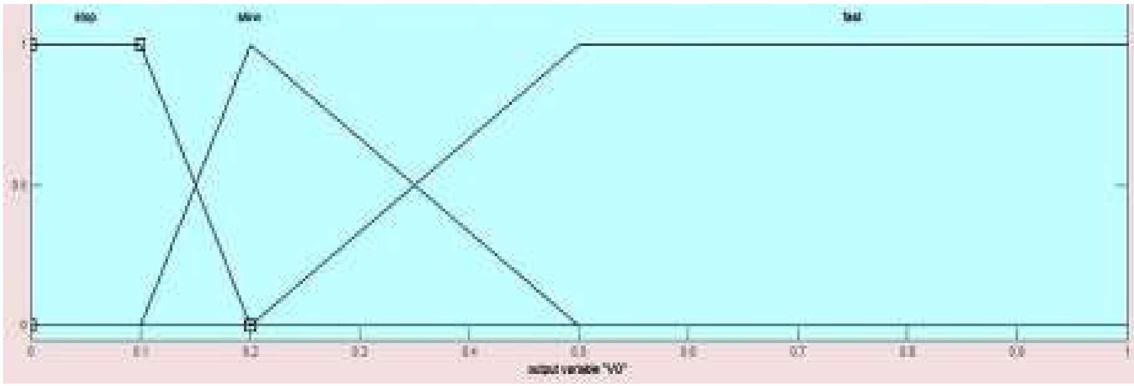
Table 1 shows the rule's base of distance controller (VN = very near, N = near, ZE = zero, F = far, VF = very far) and angle controller (NB = negative big, NM = negative middle, NS = negative small, ZE = zero, PS = positive big, PM = positive middle, PB = positive big) for GSB.

Obstacle Avoidance Behavior (OAB): This behavior aims to help the mobile robot to move freely without collision of obstacles that could exist in its surrounding environment. The fuzzy logic controller designed for this behavior receives three inputs (dL,dp,dR), which represent the left, front and right distance from the current position of the mobile robot to the nearest obstacle to compute the linear and angular mobile robot's velocities.

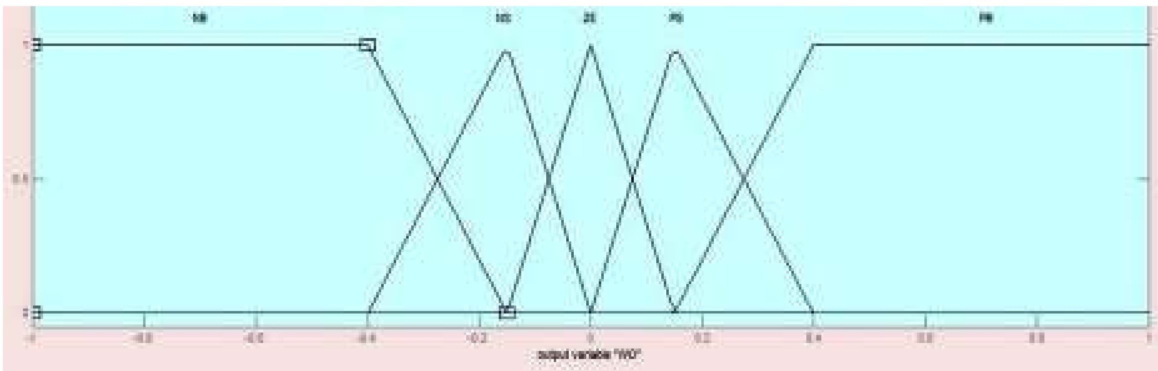
Figure 7 presents the different chosen membership functions for the inputs and outputs of the OAB



(a) Distance (d_L, d_F, d_R)



(b) Linear speed V_{OA}



(c) Angular speed w_{OA}

Fig. 7: Membership functions of GSB

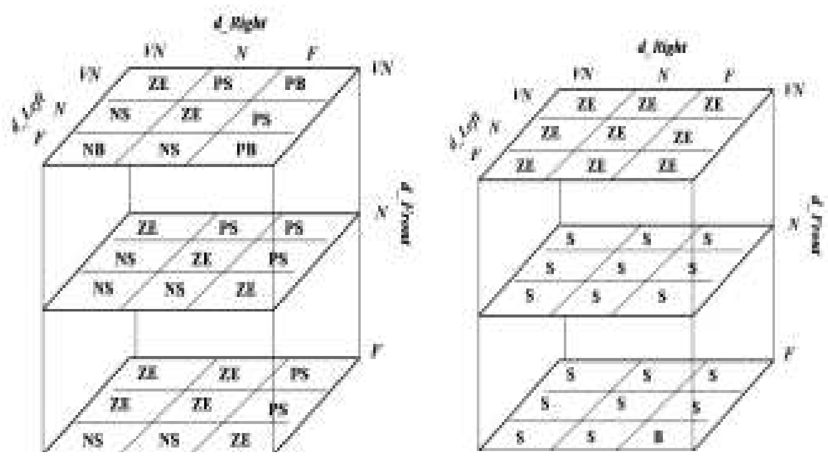


Fig. 8: Rule base of OAB

Figure 8 shows the rule's base of the OAB fuzzy logic controller (dL, dp, dR): VN = very near, N = near, F = far;: ZE = zero, S = small, B = big;: NB = negative big, NS = negative small = positive middle, PB = positive big).

Fusion weight behavior (FWB): This behavior combines the results of the two behaviors GSB andOAB to compute the mobile robot's velocities using the following equation:

$$\begin{cases} V = \tau V_{GS} + (1-\tau)V_{OA} \\ w = \tau w_{GS} + (1-\tau)w_{OA} \end{cases} \quad (4)$$

At each decision point, the coefficient τ is the result of fuzzy logic system which receives two inputs

D and d = min dL, dp, dR). It expresses the degree of activation of each behavior. The mumbership functions of the inputs *(D, d)* and output τ are depicted in Fig. 9.

Table 2 shows the rule base for the FWB fuzzy logic system (N = near, M = middle, F = far, VS = very small, S = small, B = big, VB=very big).

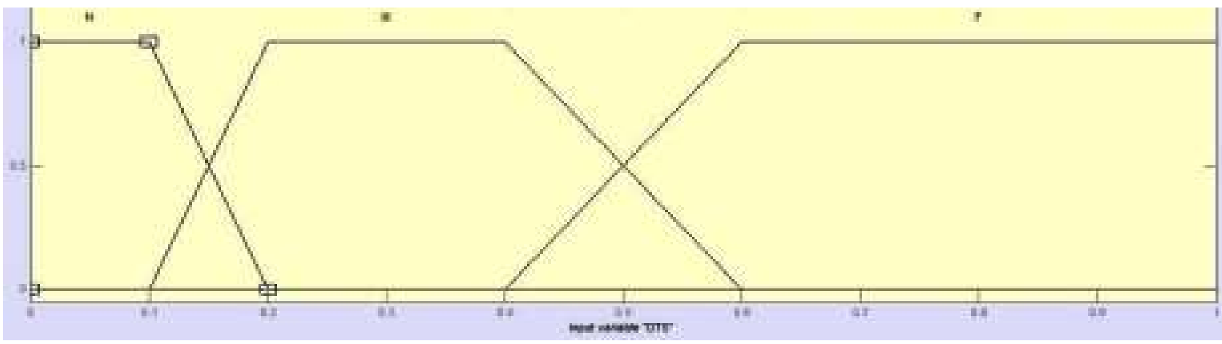
RESULS AND DISCUSSION

In order to verify the validity of the intelligent controller presented in this paper, different simulations have been carried out using MATLAB 7.0.

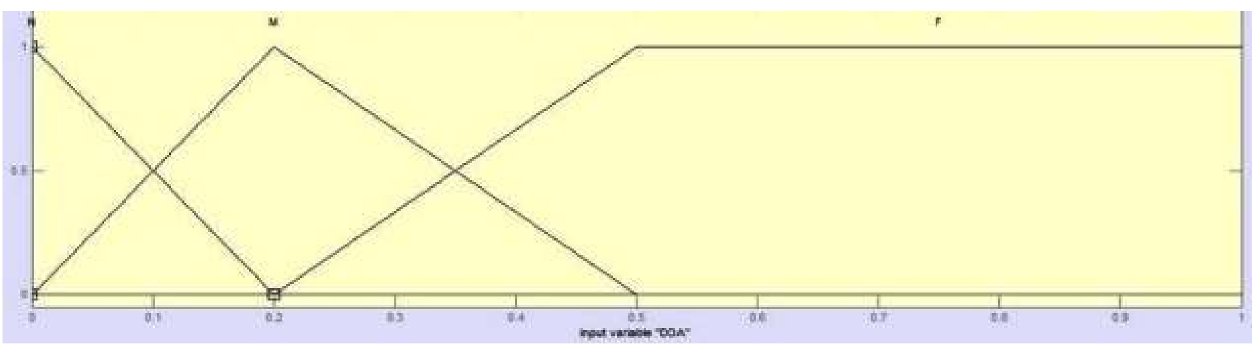
We have first simulated the goal searching behavior GSB. As shown in Fig. 10, the mobile robot can reach the goal easily from different start positions of the robot which prove that the designed controller to assure this behavior works very well.

Then, we have tested the whole algorithm in an unknown environment with multiple obstacles in two scenarios:

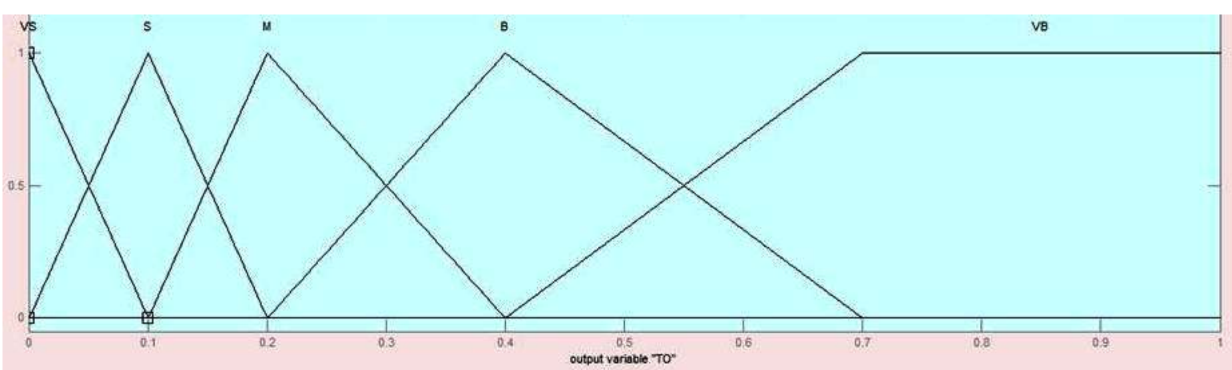
In scenario 1, the environment contains 6 obstacles. Figure 11shows that the robot moves toward the goal and avoids all obstacles that it could exist in its way to reach the goal. We can also see that when the robotdetects an obstacle, the OAB contributes more than TSB in the mobile robot's velocities and the inverse when there are no obstacles, so the FWB assures a good performance in such as tasks due to its variable fusion weight coefficient τ .



(a) Distance D



(b) Distance d



(c) Coefficient τ

Fig. 9: Membership functions of FWB

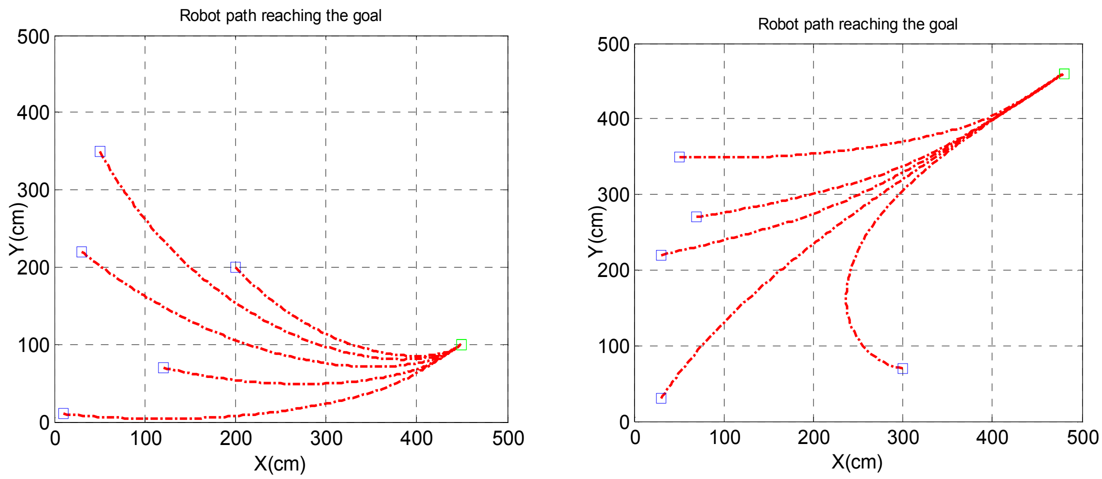


Fig. 10: Robot trajectory in GSB

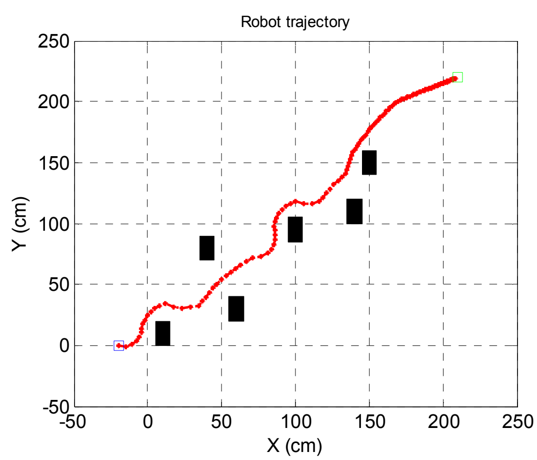


Fig. 11: Path planning with 6 obstacles (scenario 1)

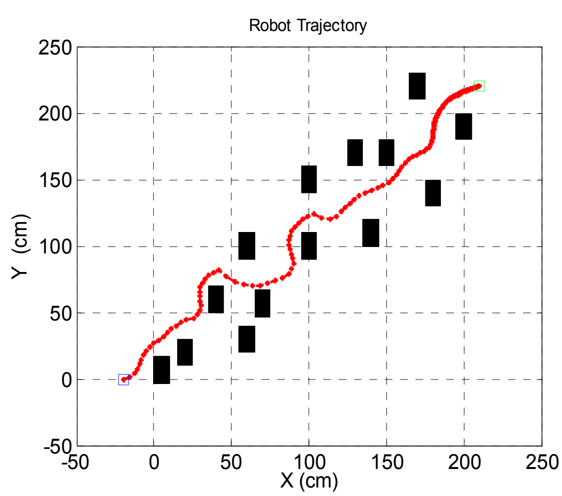


Fig. 12: Path planning in a cluttered environment (scenario 2)

The environment in scenario 2 is more cluttered, but even in such conditions, the results are satisfactory (Fig. 12).

CONCLUSION

In this study, we have presented a simple intelligent controller based on architecture behavior and fuzzy logics for the path planning with obstacle avoidance of a mobile robot in an unknown environment.

Through the above results, fuzzy logic and architecture behavior offer a successful solution to deal with uncertainty of sensor's information and complexity of the surrounding environment.

Simulations results show that the proposed controller enables the robot to reach safely the goal without obstacle's collision, so its performance is quite effective and can be used widely in practice due to its simplicity.

Further research may be directed to optimize the fuzzy logic control using the genetic algorithms for more effectiveness and flexibility of the mobile robot.

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