Mobile Robot Control Using Fuzzy Logic

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Abstract:

In this work , intelligent fuzzy controller for mobile robot in various (known and unknown) environments is build to control of mobile robot. A successful way of structuring the navigation problem treat with the issues of individual behavior design and action coordination.

The inputs to the proposed fuzzy control method consist of a heading angle between a robot and a specified target and the distances between the robot and the obstacles to the left, front, and right to its locations, being acquired by sensors. The output of controller are the speeds of right and left wheels. Simulation results verified the effectiveness of the controller.

Key words : Mobile Robot , Environment ,Fuzzy Logic , Obstacle avoidance,.

الخلاصة:

في هذا العمل مسيطر مضبب ذكي للروبوت المتحرك في مختلف البيئات (معروفة و غير معروفة) يتم بناؤه للسيطرة على الروبوت المتحرك.الطريقة الناجحة لتشكيل مسألة القيادة مرتبطة مع مسائل تصميم سلوك مستقل وتنسيق الفعاليات.

المدخلات لطريقة المسيطر المضبب المفترض تتكون من الزاوية الرأسية بين الروبوت والهدف المحدد والمسافات بين الروبوت و العوائق إلى مواقع اليسار ، اليمين و الأمام للروبوت ، المكتسبة بواسطة المتحسسات .المخرجات للمسيطر هي سرع العجلات اليمنى واليسرى .نتائج المحاكاة تؤكد فعالية هذه المسيطر .

الكلمات المفتاحية: الروبوت، البيئة، المنطق الضبابي، تجنب العوائق.

1 Introduction

Current developments of mobile robot have attracted the attention of researchers in the areas of engineering, computer science, mining and others. This is due to the high potential of mobile robots application. Autonomous mobile robots are robots which can perform desired tasks in unstructured environments without continuous human guidance [Frank and Goswami, 2004;Ibrahim and Fernandes, 2004];[Kim and Cho, 2006];[Waterman, 1989]. Many kinds of robots are *autonomous*.

A fully autonomous robot in the real world has the ability to:
- Gain information about the environment.
- Travel from one point to another point, without human navigation assistance.
- Avoid situations that are harmful to people.
- Repair itself without outside assistance.

A robot may also be able to learn autonomously. Autonomous learning includes the ability to:
- Learn or gain new capabilities without outside assistance.
- Adjust strategies based on the surroundings.
- Adapt to surroundings without outside assistance.

Navigation for mobile robots can be well-defined in mathematical (geometrical) terms. It also involved many distinct sensory inputs and computational processes. Elementary decisions like turn left, turn right, run or stop are made on the basis of thousands of incoming signals [David, 1990; Gallistel, 1990; Parhi, 2005]. Navigation is traditionally defined as the process of determining and maintaining a trajectory to a goal location [Gallistel, 1990].

Humans have uncertain and imprecise information. The main advantages of a fuzzy navigation strategy lie in the ability to extract heuristic rules from human experience, and to obviate the need for an analytical model of the process [Seraji and Howard, 2002].

In this search, Fuzzy Logic System (FLS) is used to produce the control inputs for the robot with inputs from various sensors. Sensor signals are fed to the FLS, and the output provides motor control commands (e.g., turn right or left). The FLS learns the full dynamics of the mobile robot online. Fuzzy controller for mobile robot has three inputs and two outputs. Both inputs and output have three membership functions. Each membership function is considered as triangular membership function. This search provides a Fuzzy logic framework to be implemented in the mobile robot for behavior design and coordination.

2 Kinematic Model:

Assumption considered for analyzing path constrained of a wheeled mobile robot:

• There are no flexible parts in the wheeled mobile robot.
• There is no transitional slip between the wheels and the surface.
• There is enough rotational friction between the wheels and the surface; so, the wheels can rotate without disturbance.
• The two driving wheels are identical.

The navigation for a two-wheeled mobile robot is controlled by the speed change of the robot. The kinematical scheme of a mobile robot can be depicted as in Fig. 1, where V is the centre velocity of the robot, V_L is the velocity of the left wheel, V_R is the velocity of the right wheel, r is the radius of each wheel, L is the distance between two wheels, x and y are the position of the mobile robot, and θ is the orientation of the robot.

According to the motion principle of rigid body kinematics, the motion of a mobile robot can be described using equations (1) and (2), where ω_L and ω_R are angular velocities of the left and right wheels respectively, and ω is the centre angular velocity.

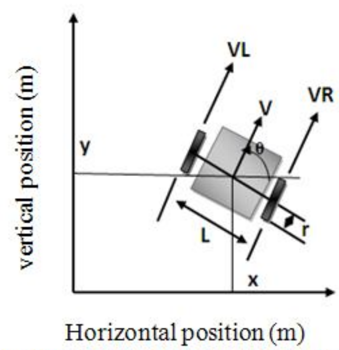

Fig.1 Kinematical Scheme of the Mobile Robot

$$V_R = r\, W_R \qquad ,V_L = r\, W_L \qquad (1)$$

$$W = (V_R - V_L)/L \qquad ,V = (V_R + V_L)/2 \qquad (2)$$

This result:

$$W = (r/L)*(W_R - W_L) \qquad ,V = (r/2)*(W_R + W_L) \qquad (3)$$

The position of the robot in the unknown environment in any moment, is defined in the reference coordinates; $[X, Y]$. Considering the equations (1) and (2), the kinematic model of such a robot, is defined with the below equations:

$$X = V \cos\theta \qquad (4)$$

$$Y = V \sin\theta \qquad (5)$$

$$\theta = W \qquad (6)$$

It should be mentioned that the robot movement is divided into two:

- Turning situ and positioning in a new direction.
- Moving in a direct path in the new direction till reaching the new point.

$$\begin{bmatrix} V_x(t) \\ V_y(t) \\ \theta(t) \end{bmatrix} = \begin{bmatrix} \cos\theta & 0 \\ \sin\theta & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} V(t) \\ W(t) \end{bmatrix} \qquad (7)$$

3 Fuzzy logic :

Intelligent controller for mobile robot enables the robot to avoid the obstacle and improve target seeking ability. In the absence of the obstacle, robot moves towards the endpoint (goal), otherwise the robot will react to the obstacles and its relative position from the goal, based on the information gained from the sensor located in the center robot. While moving towards the goal (with the obstacle avoidance strategy), the robot changes it's angular velocity and linear velocity.

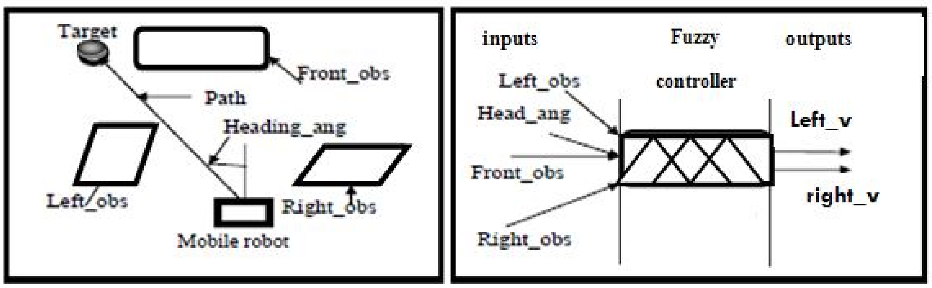

Fig. 2(a). Fig. 2(b).

Fig.2:Fuzzy logic techniques for behavior based control of mobile robot.

The fuzzy controller used for leading the robot, has: 4 inputs and 2 outputs as follows (Figure (2)).

Inputs: The four numerical inputs are fuzzified by the membership functions . These membership functions are defined based on the expert knowledge . Three inputs of fuzzy controller are the distances from robot to the left , front and right obstacles . One input represent the head angle between robot location and goal position .

Three triangle membership functions considered for each input of fuzzy system as shown in the fig. 2(b), membership functions for distances are:

- Near.
- Medium.
- Far.

Three triangle membership functions considered for head angle of fuzzy system are:

- Front.
- Left.
- Right.

Outputs: The two numerical outputs are fuzzified by the membership functions as shown in Figures 2(b) . These membership functions are defined based on the expert knowledge .

Three triangle membership functions for velocity are:

- Slow.
- Medium.
- Fast.

The distance D can be calculated by applying the distance formula using the two value of dx and dy . where dx and dy are the difference in distance between the robot and the destination point in x and y coordinate .the following equations in calculating the input variables are :

$$\textbf{\textit{Distance}} = \sqrt{(dx)^2 * (dy)^2}$$

$$\Theta = \tan^{-1}(dy/dx).$$

Here , Θ is the desired angle that the robot should face every instance as it goes to the destination point .

3 The Fuzzy Rules:

The main idea in the fuzzy algorithm is the usage of the lingual rules when facing conditions produced by controlling a process. In this search, the lingual rules are inspired by the human behavior. The fuzzy rules are an if- then statement that consist of a premise (antecedent) and consequent .

According to the Table (2), if the distance between the robot and the obstacle is far, reaching the goal point is the first priority; otherwise the first aim would be increasing the distance between the robot and the obstacle Table (1).

4 Robot behavior:

The mobile robot has three wheels ,mobile robot with two driving wheels, arranged parallel to each other , which are driven separately by two independent motors, and one castor is provided for stability of the robot is modeling a three wheeled mobile robot . The front wheel is a castor wheel.

The relations between the rigid body motion of the robot, the angular velocity and driving controls of the wheels guarantee that the motion of robot is stable.

According to the information acquired by the robots using their sensors, some of the fuzzy control rules are activated. The outputs of the activated rules are combined by fuzzy logic operations to control the velocities of the driving wheels of the robots. These are denoted by left_v and right_v, for the velocity of the left wheel and the velocity of the right wheel of each robot respectively. These parameters can be used to generate different fuzzy rules. e.g.

Rule: If *(left-obs is far and right-obs is medium and front-obs is near and head-ang is N)* Then *(left-v is slow and right-v is medium).*

By fuzzy reasoning and the centre of maxima defuzzification method, Rule related to the *obstacle avoidance wall-following* and *target seeking* behaviors, are weighted to determine an appropriate control action.

4.1 Obstacle avoidance:

When the acquired information from the sensors shows that there exist obstacles nearby robot, it must reduce its speed to avoid obstacles. When a robot is close to an obstacle, it must change its speed and steering angle to avoid the obstacle. The fuzzy rules used for obstacle avoidance by the robots are listed in the following as rules 1 to 27. All the rules in the table are obtained heuristically.

Table 1:List of rules for obstacle avoidance.

RuleNo:	(Action)	(Left_obs)	(Right_obs)	(Front_obs)	(Head_ang)	(Left_V	Right_V)
1.	AO	Near	Near	Near	Any	Slow	Fast
2.	AO	Near	Near	Medium	Any	Slow	Slow
3.	AO	Near	Near	Far	Any	Med	Med

4.	AO	Near	Medium	Near	Any	Med	Slow
5.	AO	Near	Medium	Medium	Any	Med	Slow
6.	AO	Near	Medium	Far	Any	Fast	Med
7.	AO	Near	Far	Near	Any	Fast	Slow
8.	AO	Near	Far	Medium	Any	Med	Slow
9.	AO	Near	Far	Far	Any	Fast	Med
10.	AO	Medium	Medium	Near	Any	Fast	Slow
11.	AO	Medium	Medium	Medium	Any	Slow	Slow
12.	AO	Medium	Medium	Far	Any	Fast	Fast
13.	AO	Medium	Near	Near	Any	Slow	Fast
14.	AO	Medium	Near	Medium	Any	Slow	Med
15.	AO	Medium	Near	Far	Any	Slow	Med
16.	AO	Medium	Far	Near	Any	Med	Slow
17.	AO	Medium	Far	Medium	Any	Med	Fast
18.	AO	Medium	Far	Far	Any	Fast	Med
19.	AO	Far	Near	Near	Any	Slow	Med
20.	AO	Far	Near	Medium	Any	Med	Fast
21.	AO	Far	Near	Far	Any	Med	Fast
22.	AO	Far	Medium	Near	Any	Slow	Fast
23.	AO	Far	Medium	Medium	Any	Slow	Med
24.	AO	Far	Medium	Far	Any	Med	Fast
25.	AO	Far	Far	Near	Any	Fast	Slow
26.	AO	Far	Far	Medium	Any	Fast	Med
27.	AO	Far	Far	Far	Any	Fast	Fast

When the robot sense obstacle near to it or the robot moves at curved and narrow roads, it must reduce its speed to avoid collision with obstacles. In this case, its main reactive behavior is decelerating for obstacle avoidance.

4.2 Target seeking behavior:

When the acquired information from the sensors shows that there are no obstacles around robot, its main behavior is target steer. List of some rules for target seeking are shown :

Table 2: List of rules for target seeking .

RuleNo:	(Action)	(Left_obs)	(Right_obs)	(Front_obs)	(Head_ang)	(Left_V	Right_V)
34	TS	Far	Far	Far	Positive	Fast	Med
35	TS	Far	Far	Med	Negative	Med	Fast
36	TS	Far	Far	Far	Zero	Fast	Fast
37	TS	Far	Far	Med	Positive	Slow	Med
38	TS	Far	Med	Far	Negative	Med	Fast
40	TS	Med	Far	Far	ZERO	Fast	Fast

Here, the 34 and 35 for realizing this behavior as follows:

If *(left-obs is far and right_obs is far and front-obs is far and head-ang is P)* Then *(left-v is fast and right-v is med).*

If *(left-obs is far and right_obs is far and front-obs is medium and head-ang is N)* Then *(left-v is med and right-v is fast).*

These *fuzzy* logic rules show that the robot mainly adjusts its motion direction and quickly moves to the target if there are no obstacles around the robot. In general, the weights of the behaviours, *obstacle avoidance* and *target steer,* depend largely on the distances between the robot and the obstacles to the left, front, and right locations.

5 Fuzzy Inference Mechanism:

Fuzzy inference is the process of formulating the mapping from a given input to an output using fuzzy logic. The mapping then provides a basis from which decisions can be made, or patterns discerned. The process of fuzzy inference involves Membership Functions and If-Then Rules. The used inference fuzzy mechanism is the MAMDANI (Min-Maxinferences).

6 Defuzzification:

There are several ways for performing defuzzification. The strategy selected here is the center of maxima method.

7 simulation Results and discussions:

The simulations were conducted with the visual basic language . To show the effectiveness and the robustness of the proposed method, simulation results on mobile robot navigation in various environments are explained.

The obstacle avoidance behavior is activated when the reading from any sensors are less than the minimum threshold values. This is how the robot determines if an object is close enough for a collision. When an object is detected too close to the robot, it avoids a collision by moving away from it in the opposite direction.

When the acquired information from the sensors shows that there are no obstacles around robot, its main reactive behaviour is target steer. Intelligent controller mainly adjusts robots motion direction and quickly moves it towards the target if there are no obstacles around the robot as shown in Figures 5,6,7. In the proposed control strategy, reactive behaviors are formulated by fuzzy sets and fuzzy rules, and these fuzzy rules are integrated in one rule base.

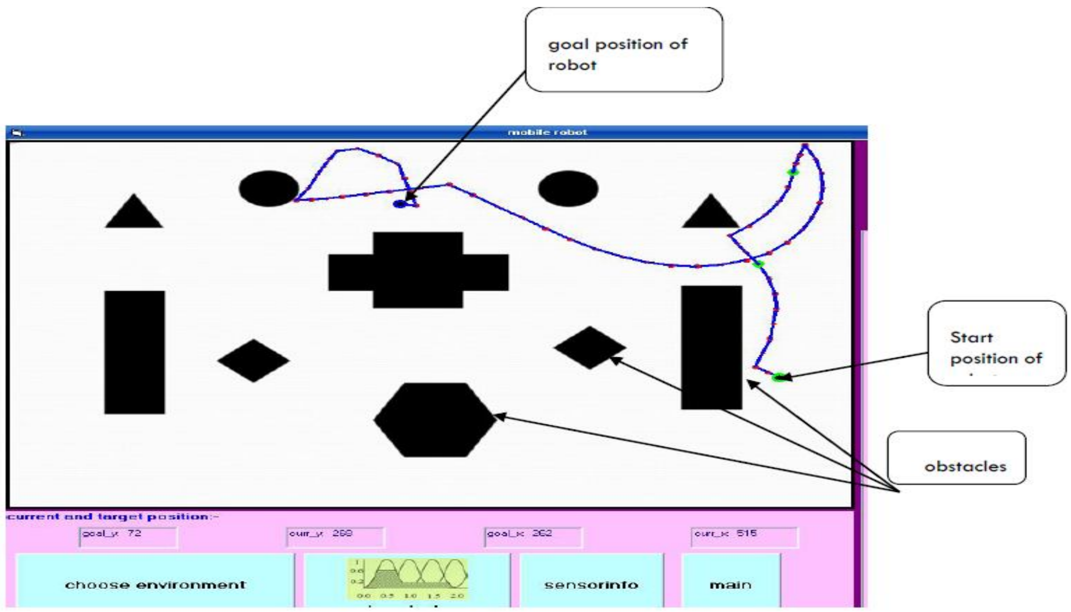

Fig. 3 :Obstacle avoidance behaviour .

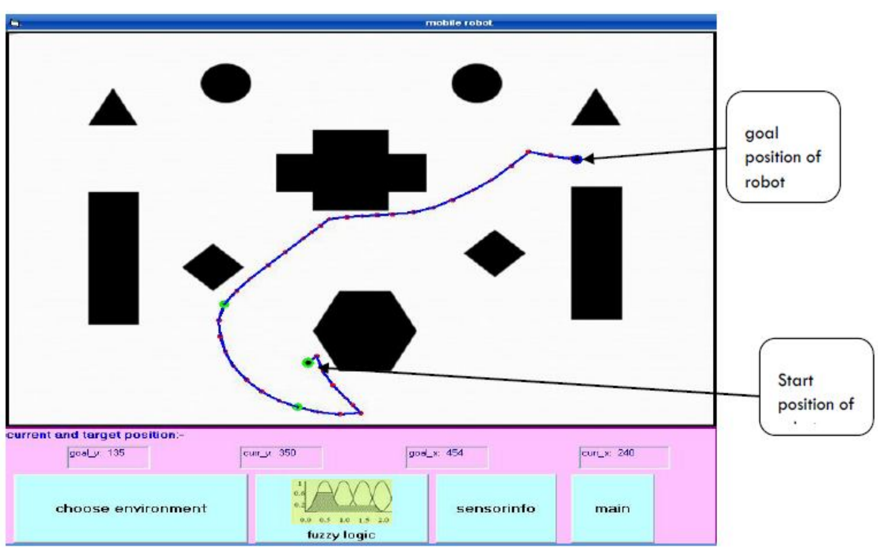

Fig. 4 :Obstacle avoidance behaviour .

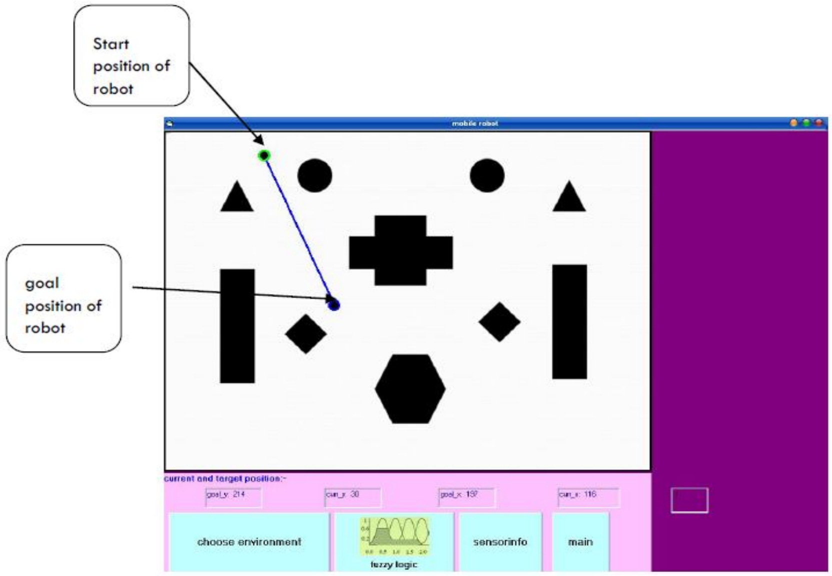

Fig. 5 :Target seeking behavior without obstacles in the path of robot.

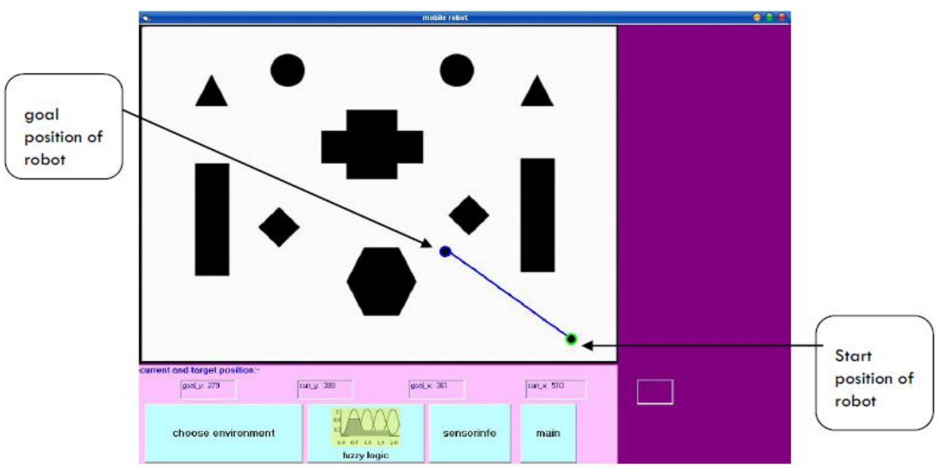

Fig. 6 :Target seeking behavior without obstacles in the path of robot.

5 Conclusions

This paper shows the fuzzy logic method for intelligent navigation control of mobile robots. Very well agreement between the simulation and experimental results show the robustness of the fuzzy controller.

Planning systems may use a number of techniques to make the planning process practical. Determining the state of the world and guiding action requires the ability to gather information about the world, though sensors such as sonar or cameras. These sensors data have been used by the fuzzy controller for navigational task.

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