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STEERING MOBILE ROBOT USING FUZZY LOGIC APPROACH

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Abstract:

The fuzzy logic provides a method for combining sensor data from all sensors which present different information. This work presents control architecture for behavior-based mobile robot which is able to interact with an unknown environment using a reactive strategy determined by sensory information. Recent research in robotics aims to construct autonomous and intelligent robots, which can plan its motion in a self-motivated environment. Autonomous mobile robots are progressively more used in well-structured environment such as warehouses, offices and industries. Author designs a fuzzy logic approach and propose an obstacle avoidance algorithm for a path planning in unknown environment for a mobile robot. The ultrasonic sensors are working for detecting the distance to obstacles and their positions. An angular velocity control for left and right wheels are implemented by a fuzzy logic approach. In this paper, a new approach to a rule-based fuzzy controller is proposed which is induced from the consideration of the distance to obstacles and the angle between the robot and the goal.

Keywords: Fuzzy logic approach, mobile robot, obstacle avoidance, ultrasonic sensor.

I. Introduction:

The main intention of mobile robotics is the construction of autonomous systems that are capable of moving in real environments without the help of a human operator. There are several difficulties in the reaching of this objective, due principally to the fact that real environments are, generally, uncertain, unknown and dynamic [1-3]. The robot has the ability to plan motion and to navigate autonomously avoiding any type of obstacles [4-5]. The robot is expected to carry out only simple tasks through its sensory inputs [6]. The control problem for the two-wheel mobile robots is how to independently control the left-wheeled motor and right-wheeled motor. The mobile robot is guided by online sensor information acquired while navigation is performed.

The fuzzy logic approach has widely used for one of efficient means in unknown and complex industrial environments. In many research results, a fuzzy logic approach has usually implemented for improving the efficiency of obstacle avoidance and path planning of mobile robot at unknown environments. Many algorithms were addressed in related journals for obstacle avoidance and path planning of a mobile robot [7]. In this work we propose a fuzzy logic based control approach for path tracking of an indoor mobile robot. The ultrasonic sensor is used for positioning and identifying the detection of an obstacle. Here the left and right wheels' angular velocities are controlled by a fuzzy logic approach. The methods for fuzzification and reasoning are singleton and Mamdani's method, respectively.

II. Previous Work Done:

T. Jin [7] presents hierarchical behavior-based control architecture was introduced. This structure was motivated by the hierarchical nature of behavior as hypothesized in ethological models. S. Jin et al. [8] present a new approach to design a fuzzy controller for increasing the ability of mobile robot to react to dynamic environment. L. Xu et al. [9] presents fuzzy logic systems have a complex rule table for achieving different control objectives. Many algorithms were addressed in related journals for obstacle avoidance and path planning of a mobile robot. B. Huang et al. [10] presents the path planning research for mobile robot based on the artificial potential field. B. J. Choi [11] presents new approach to design a fuzzy controller for increasing the ability of mobile robot to react to dynamic environment.

Limitations of Previous Work:

In the conventional fuzzy logic system, the number of control rules is forty nine for each wheel. So, we examine the fuzzy control rules of the conventional system and then make another control rules from eight conditions of positions of obstacles and three parts of the angle between the robot and the target position.

III. Proposed Kinematics Model of the Robot:

A kinematics model of a mobile robot used in this work is shown in Figure 1.

Accelerations of left and right wheels are ω_L and ω_R respectively. Assume that the contact between the wheels and the ground is pure rolling and non-slipping [11]. The relationship between left and right wheels of velocity and acceleration is as follows:

$$V_L = r\omega_L \quad and \quad V_R = r\omega_R, \quad \text{.................. (1)}$$

where r is a radius of the wheel. The linear velocity of the mobile robot is V. Linear velocities for the left and right wheels are V_L and V_R, respectively. The relationship between ω_L, ω_R, V_L and V_R is as follows:

$$V = \frac{V_R + V_L}{2} = r\left(\frac{\omega_R + \omega_L}{2}\right), \qquad \omega = \frac{V_R - V_L}{L} = r\left(\frac{\omega_R - \omega_L}{L}\right), \quad \text{.......... (2)}$$

Now author can summarize a dynamic model for the mobile robot as follows:

$$x' = V\cos\theta, \quad y' = V\sin\theta, \quad \theta' = \omega, \quad \text{..................... (3)}$$

$$\begin{bmatrix} x' \\ y' \\ \theta' \end{bmatrix} = \begin{bmatrix} \cos\theta & 0 \\ \sin\theta & 0 \\ 0 & 1 \end{bmatrix} . \begin{bmatrix} V \\ \omega \end{bmatrix}$$

IV. Design of Fuzzy Logic Approach:

The conventional fuzzy logic method mainly includes fuzzification, knowledge base, fuzzy reasoning and defuzzification. The fuzzification converts the accurate input variables into input grades named as fuzzy variables. The knowledge base is used to store applicable data and control rules. The fuzzy reasoning generates fuzzy results from inferencing of the knowledge base and the inference engine. The defuzzification converts fuzzy variables to accurate output variables. It's typical architecture is shown in Figure 2.

1. Fuzzification:

The inputs for the proposed fuzzy logic approach are distances measured from the obstacle to the sensors and the angle between the robot and the goal. The sensors are located at left, right, and front sides of the robot. The angle means an angle between robot's orientation and target position. The output variables are velocities of the left and right wheels. Linguistic variables "near" and "far" are taken for the distance from the obstacle to the sensor. Eight conditions are defined by the location of the obstacles like Table 1. The domain for the angle between the robot and the target position is constructed with {left, front, right}. Here "left" means that the goal is located at the left side of the robot. The domain for velocities of the left and right wheels is constructed with {slow, L-slow, mid, L-fast, fast}, where L and mid stand for "Little" and "middle", respectively.

2. Generation of Control Rules:

The control rules could be induced by empirical knowledge. They are shown in Table 2 and Table 3 for left and right wheel, respectively. The rules were basically generated by eight conditions from D1 to D8. For example, the condition D1 means that obstacles are located at near to the front, left, and right sides. The angle "Right" means that the goal is located at the right side of the robot. Rule base is composed of many fuzzy implication relations, which are obtained based on lots of experiments, observation and operation experience. The general principle is on the completeness of the premise. In order to simplify the design process of the fuzzy logic system, a smaller number of rules are better. In [8], the conventional fuzzy logic system had 98 rules, that is, 49 rules were required for each wheel of left and right.

Table 1. Eight conditions according to the detection of obstacles

	Left-obstacle	Front-obstacle	Right-obstacle
D1	near	near	near
D2	near	near	far
D3	near	far	near
D4	near	far	far
D5	far	near	near
D6	far	near	Far
D7	far	far	Near
D8	far	far	far

Table 2. Fuzzy control rules for the left wheel

Angle	D1	D2	D3	D4	D5	D6	D7	D8
Left	Slow	L-Slow	Mid	L-Slow	Slow	Slow	Mid	L-Fast
Front	L-Slow	L-Slow	L-Fast	Mid	Slow	L-Slow	L-Slow	Fast
Right	L-Slow	L-Slow	Mid	L-Fast	Slow	L-Slow	Slow	Fast

Table 3. Fuzzy control rules for the right wheel

Angle	D1	D2	D3	D4	D5	D6	D7	D8
Left	L-Slow	Slow	Mid	Slow	L-Slow	L-Slow	L-Fast	Fast
Front	Slow	Slow	L-Fast	L-Slow	L-Slow	Slow	Mid	Fast
Right	Slow	Slow	Mid	Mid	L-Slow	Slow	L-Slow	L-Fast

The meaning of several rules of Table 2 and 3 is as follows:
R01:
IF the condition is D1 and the angle is Left,
THEN the left wheel is Slow (V_L = Slow) and the right wheel is Little Slow (V_R =L-Slow).
....
R24:
IF the condition is D8 and the angle is Right,
THEN the left wheel is Fast (V_L =Fast) and the right wheel is Little Fast (V_R =L-Fast).

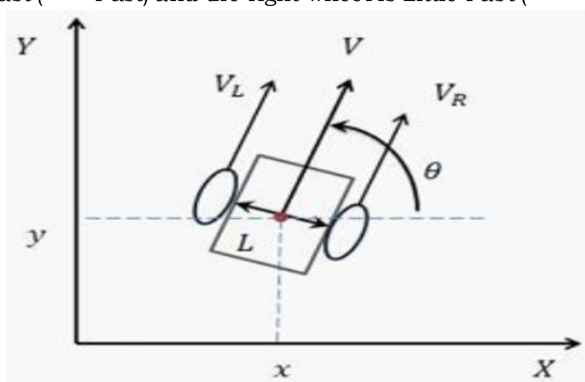

Figure1. Kinematics Model of the Robot

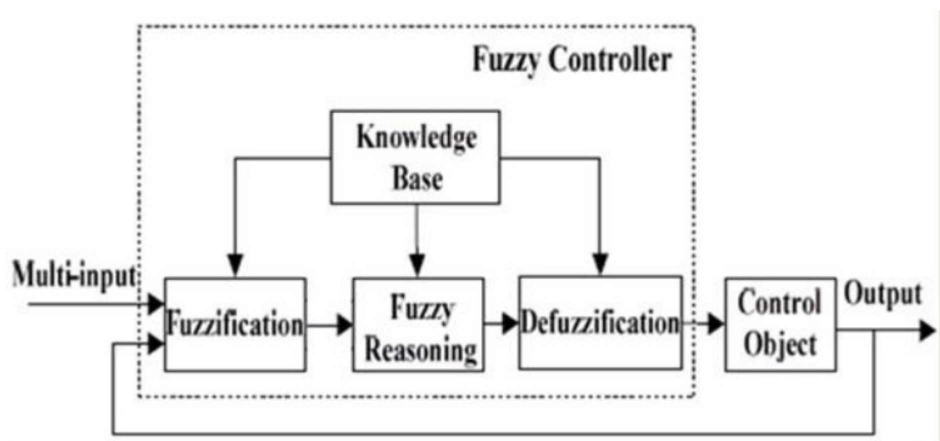

Figure 2: Structure of a fuzzy logic approach

3. Defuzzification:

Many defuzzification algorithms have been reported. There are several common methods, such as maximum membership grade, median clustering, average maximum membership grade and weighted average method. We here use the center of gravity, (COG) method.

$$Z_a = \frac{\int \mu_c(z).zdz}{\int \mu_c(z)dz} \quad \text{.......................................} (4)$$

where $\mu_c(z)$ is degree of membership, z is steering angle, and Z_a is a crisp value.

V. Conclusion:

In the design process of fuzzy logic based obstacle avoidance by using fuzzy logic control approach, the velocities of the two wheels were separately controlled. Their outputs for the fuzzy control system were the velocities of the left and right wheels. And their input variables were positions of obstacles and the angle between the robot and the target position. Here positions of obstacles were categorized by eight conditions. The angle of input variable was divided by three part of front, left, and right. Therefore, the number of total control rules was reduced to 24 as compared to the conventional rules for each wheel of the robot. The proposed fuzzy logic system showed a good performance with small control rules and fast travelling time.

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