OBSTACLE AVOIDANCE FUNCTION USING A REACTIVE FUZZY CONTROLLER FOR AUTONOMOUS MOBILE ROBOT

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Abstract:*Obstacle avoidance is one of the function of autonomous navigation for mobile robots. The potential field method is efficacious with the good results it returns; this method has undergone considerable improvements as its extension to the size of obstacle and robot, but provides a disadvantage that is the rigorous local minima. The idea of our fuzzy approach is to keep the specificity of this model at treatment from a distance of the obstacle.*

Keywords:*Local navigation, Potential field, Obstacle avoidance, Fuzzy logic.*

1. Introduction

Humans have a remarkable ability to navigate using only vision, and alleviate different form of obstacle. The robotics seeks to automate a mobile machine in his environment and to perform the tasks entrusted to it without human intervention.

The Fajen and Warren's model of human navigation takes the relative heading and distance to the goal and obstacles and computes an angular acceleration to steer the robot towards the goal and away from obstacles [1].

For specific reason as treatment the area obstacle and others, Wesley H. Huang, Brett R. Fajen, Jonathan R. Fink and William H. Warren extended the model Fajen and Warren that adapt on obstacles extension using the angular width of obstacle instead of the distance [2].

Among the recent developments in autonomous navigation, the introduction of new technics such as fuzzy logic. The reactive strategies are based on ultrasonic sensory information and only the relative interactions between the mobile robot and the unknown environment have to be assessed. In this case, a structural modeling of the environment is unnecessary [3].

This original work handles the problem motion control of a mobile robot to permit the displacement by initial position from any desired destination while avoiding obstacles collide with. We propose here to study the navigation of a nonholonomic mobile robot tricycle pattern (see Section IB) to move in a structured environment and strewn with obstacles. For to mature, we are developed an intelligent control architecture capable to get self-satisfied autonomy in mobile robot in order to enable it to move safely, avoiding static obstacles according to their widths. It is a reactive control architecture based on two fuzzy behaviors:

- Go to target, this one allows mobile robot to join the target previously defined.
- Obstacle avoidance, allows the mobile robot to react eventual obstacles.

In this paper, the fuzzy controller is applied to the autonomous navigation of mobile robots in an unknown environment with obstacles [4] [5].When the mobile robot to come towards the target while avoiding an obstacle, a strategy is necessary. While the mobile robot is moving, it is important to come to a compromise between avoiding obstacles and to come towards the desired position. With obstacles present in the unknown environment, the mobile robotreacts based on both the sensed information of the obstacles and the relative position of the target [6]. This application allows to determine in real time the angular velocity to be assigned to the mobile robot to enable it to navigate in an unknown environment.

2. Kinematics model of mobile robot

Considering a frame of reference OXY which define variablesφ_g,d_g, $\varphi_o$et d_o that change with the change of the position of the mobile robot. However, these variables can be expressed as a function of position (x, y) of the mobile robot (seeFig. 1).As an example we study here the movement of a mobile robot in a two-dimensional space, satisfying the constraints of obstacle avoidance, to get a known target Cartesian coordinates.

$$\varphi_g = \tan^{-1}\left(\frac{Y_g - y}{X_g - x}\right) - \theta$$
$$d_g = \left[(X_g - x) + (Y_g - y)\right]^{1/2} \qquad (1)$$
$$\varphi_o = \tan^{-1}\left(\frac{Y_o - y}{X_o - x}\right) - \theta$$
$$d_o = \left[(X_o - x) + (Y_o - y)\right]^{1/2}$$

Where:
φ_g is the target angle relative to the mobile robot
d_g is target distance relative to the mobile robot
φ_o is obstacle angle to the robot mobile
d_o is obstacle distance relative to the mobile robot

3. Kinematics constraints of mobile robot

The mobile robot used in the simulation is non-holonomic tricycle pattern. Here's kinematic constraints defined from the Cartesian plan [7]:

$$\dot{x} = \upsilon \cos(\theta)$$
$$\dot{y} = \upsilon \sin(\theta) \qquad (2)$$
$$\dot{\theta} = \omega$$

4. Extension toobstacle widths

To allow the mobile robot to avoid an obstacle on its width it is modelled by its angular width, it also changes with the changing of the position of mobile robot:

$$\theta_o = 2\tan^{-1}\left(\frac{r_o}{d_o}\right) \qquad (3)$$

Where:
r_o is the obstacle radius

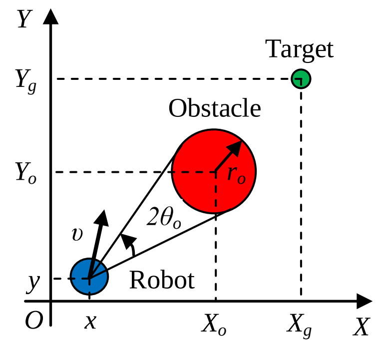


Fig. 1. Position of mobile robot and definition of variables in the Cartesian plan model.

5. Reactive design of fuzzy control of mobile robot

The fuzzy control constitute two fuzzy controllers which contain two inputs and one output each, the structure thereof is shown in Fig. 2.
In our controller, the fact of increasing the number of fuzzy sets for the partition of the variables does not affect the processing time, we propose a fuzzy controller with two to three fuzzy sets, which will improve the resolution of our fuzzy controller. This is to specify the variation range of variables: the universe of discourse, which is divided into intervals (in fuzzy sets or linguistic values). This partition, which to be made of to fix the number of values and distribute them on the area, is based on knowledge of the system and according to desired precision. The membership functions are explained in the following figures. The decision surface of the fuzzy controller is given in Fig. 3.

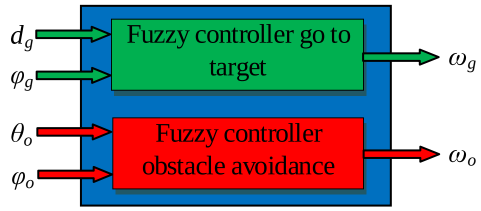


Fig. 2. Both controllers fuzzy control.

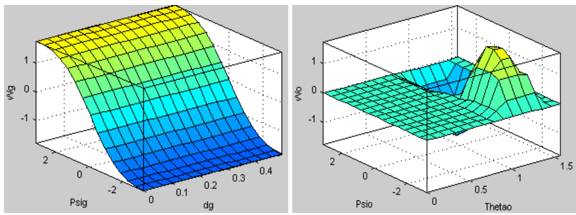


Fig. 3. Decision surface of the proposed fuzzy control controllers.

5.1 Fuzzy controller go to target

This fuzzy controller is designed to steering the mobile robot towards desired position. It constitutes two inputs (d_g, φ_g) and an output ω_g which is the angular velocity of the mobile robot.
d_g is expressed by two fuzzy sets (Near and Far) in a universe of discourse $d_g \in [0,0.5](m)$ (Fig. 4(a)),φ_g by three fuzzy sets (Left, Target-direction and Right) in a universe of discourse $\varphi_g \in [-3.14,3.14](rad)$ (Fig. 4(b)),ω_g by three fuzzy sets (Turn-left, Turn-right and Zero) in a universe of discourse$\omega_g \in [-5,5](rad/s)$ (Fig. 6).
The fuzzy rules of the controller are:

If φ_g is Right Then ω_g is Turn-right
If φ_g is Left Then ω_g is Turn-left
If d_g is Far and φ_g Target-direction Then ω_g is Zero

5.2 Fuzzy controller obstacle avoidance

This fuzzy controller is conceived to allow the mobile robot to avoid collisions with obstacles. It also constitutes two inputs (θ_o, φ_o) and an output ω_o which is the angular velocity of the mobile robot.
θ_o is also expressed by two fuzzy sets (Big and Small) in a universe of discourse $\theta_o \in [0,1.57](rad)$(Fig. 5(a)),$\varphi_o$ by two fuzzy sets (Left and Right) in a universe Speaking $\varphi_o \in [-3.14,3.14](rad)$(Fig. 5(b)),$\omega_o$ also by three fuzzy sets (Turn-left, Turn-right and Zero) in a universe of discourse $\omega_o \in [-5,5](rad/s)$ (Fig. 6).
The fuzzy rules of the controller are:
If θ_o is Big and φ_o is Right Then ω_o is Turn-left
If θ_o is Big and φ_o is Left Then ω_o is Turn-right
If θ_o is Small Then ω_o is Zero

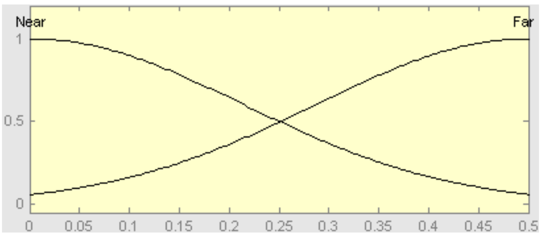


Fig. 4(a).Membership function of d_g.

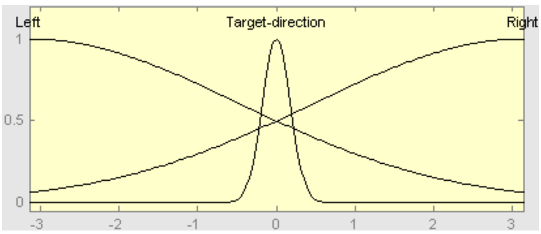


Fig. 4(b).Membership function of φ_g.

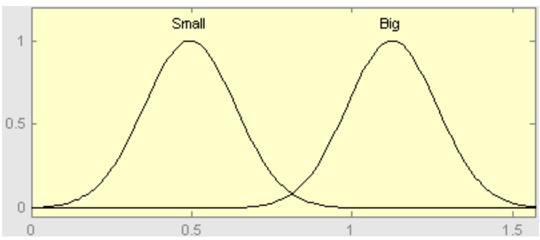


Fig. 5(a). Membership function of θ_o.

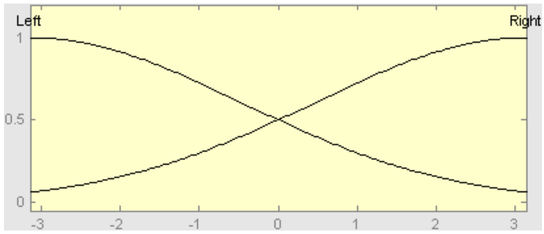


Fig. 5(b).Membership function of φ_o.

The membership function of the output of each fuzzy controller is given in Fig. 6.

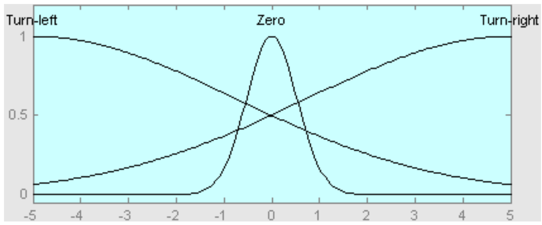


Fig. 6. Membership function of ω_g and ω_o.

6. Simulation

The simulation allows to point up the performances of our control architecture. Given the environment variable definition (Fig. 1), we simulate the same configurations for the both models the trajectory of the mobile robot toward the target while avoiding any obstacles.

The global simulation scheme is given on Fig. 7.

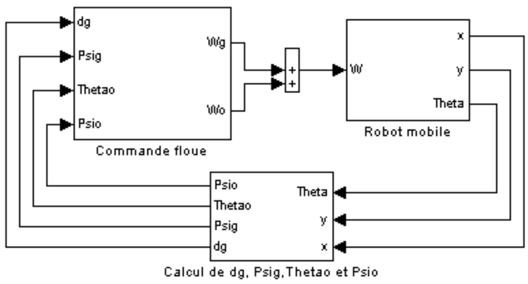
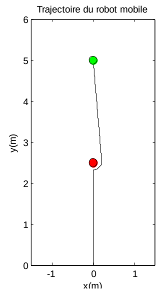


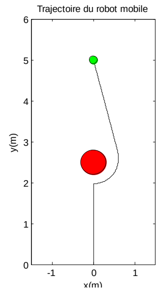
Fig. 7. Schematic simulation system of mobile robot navigation.

A. **Fuzzy controller**

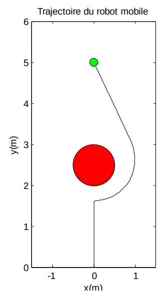
A(a)



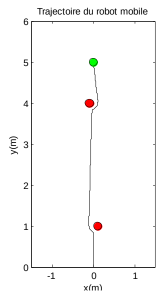
A(b)



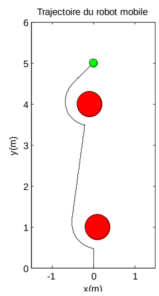
A(c)



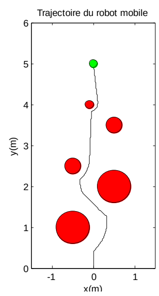
A(d)



A(e)

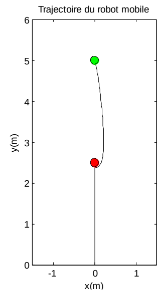


A(f)

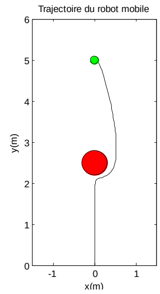


B. **Potential field function**

B(a)



B(b)



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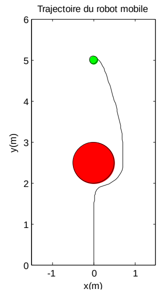

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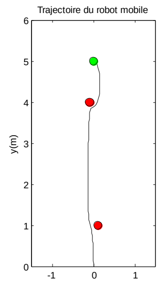

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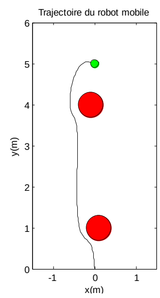
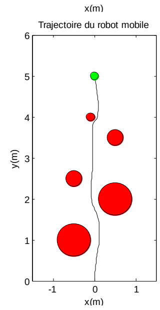


B(f)



7. Comparison and Interpretation of Results

In this paper, we have established two important results. The first by fuzzy logic, the second by a potential field function. Both methods satisfy the kinematic constraints of the mobile robot and not require knowledge of the structure of the environment. We have therefore two reactive methods for obstacle avoidance, which exploit different configurations of the environment, that is to say different positions of the target, different positions of static obstacles with theirs expansion of width, thus different means to generate the control and measure variables characteristics of the target and obstacles.

According to figures A (a-e) and B (a-e) for a single obstacle, the trajectory of mobile robot is natural look in B (a-e) than in A (a-e) with fuzzy control, increasing the size of obstacle is important the mobile robot travel with a greater curvature radius before reaching the target (A (b-e) and B (b-e)). The potential field function at obstacle avoidance allows the mobile robot to execute several maneuvers in a short-time to avoid the obstacle which gives in trajectory of a mobile robot a continuous curvature. Contrary to fuzzy logic, fuzzy controller stops the mobile robot at the time of avoiding an obstacle to enable it to execute a single maneuver to the right or left according to mobile robot position toward the obstacle (A (f) and B (f)).

The principal objective of our work is the real time processing of the obstacle size. This particularity is introduced into the potential field function then they exploited in the fuzzy logic, test for different sizes and different configurations of the environment, fuzzy control has responded on objective.

8. Conclusion

The potential field function is completely reactive and simple to compute, directly applicable to steering nonholonomic vehicles, and produces smooth, natural looking paths. The modification of the original modeluses the obstacles angular width rather than distance. Because the angular width of obstacles, not their distance, is used, our method is somewhat conservative — a large distant obstacle can have the same angular width as a closer small obstacle.

The fuzzy control exploits four interactive variables between the mobile robot and unknown environment to generate the angular velocity that leads the mobile robot to its target and that it avoids obstacles which occupy environment. We have implemented our model of fuzzy logic on a mobile robot and have undertaken simulations with multiple obstacles of varying sizes.

The fuzzy controller is reactive, when the vehicle is moving towards the target and an obstacle is detected, an avoiding strategy is fast reacts, during a pause, the mobile robot execute an immediate maneuverability ordered by the fuzzy controller around this obstacle. We proposed fuzzy reactive navigation strategy of collision-free motion in an unknown environment with obstacles.

Finally, fuzzy reactive controller is powerful in view of the short reaction time and fast decision-making strategy of the obstacle avoidance.

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