MOTION CONTROL OF WHEELED MOBILE ROBOTS

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ABSTRACT

This article presents strategy for navigation of a wheeled mobile robot in unstructured environments with obstacles. The vehicle has two wheels independently to control the angular velocity. This work deals with mobile robots modelling then control strategies and simulation results. Simulation results recommends fuzzy logic controller for the wheeled mobile robot motion in unstructured environments.

KEY WORDS

intelligent wheeled mobile robot, motion control, unknown and unstructured environments, obstacles, fuzzy control strategy

CLASSIFICATION

ACM: D.1.1.
JEL: Z19

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INTRODUCTION

Nowadays, there has been a growing interest in control of motion robot in an unstructured environment [1]. In this subject there are a lot of works and applications. For instance, NASA is using mobile robots to explore Mars surface [2]. Unstructured environment may have some obstacles. For this reason, wheeled mobile robots must be able to detect the environment. For this, ultrasonic sensors and a stereovision system should be around the vehicle to provide control.

The technological stage of motion mechanisms, sensor devices allow pointing the researches to the development of control strategies to solve complex problems that the robot must deal with. When the vehicle moves towards the target detected an obstacle or slope, it is necessary an avoidance strategy. For effective operation of intelligent robots, they are equipped with system of perception of the environment and systems for situation analyzing and decision making, and they perform motion planning [3].

Fuzzy controller is proposed to the wheeled mobile robot motion in unstructured environments that including obstacles. Fuzzy reactive control is investigated for automatic navigation of an intelligent mobile robot. Fuzzy controller includes collision and obstacle avoidance between robots. Navigation control of the robot is realized through fuzzy coordination of all the rules. Three simple navigation strategy: seek-goal, traverse-terrain, and avoid obstacles [1-5].

This paper presents a how to control of motion and velocity of vehicle in an unstructured environment that contains obstacles with using ultrasonic sensors and a stereovision system.

The article is organized as follows:
- Section 1: Introduction.
- Section 2: Mobile robots modelling.
- Section 3: Control strategy for mobile robots.
- Section 4: Simulation results.
- Section 5: Conclusion.

MOBILE ROBOT'S MODELLING

The mobile robot has two driving wheels fixed. The two fixed wheels are controlled independently by motors. The robot consists basically of ultrasonic sensors in the front, to the right and to the left of the vehicle [1]. The wheels are controlled on velocity and sense of turning. The sensors provide the distance data of possible obstacles in short range.

The resultant motion is described by the linear velocity $v(t)$, the direction $q(t)$ and a rotational motion (rotational velocity) $w(t)$.

Kinematics model for wheeled mobile robots; there are two identical castors of the mobile robot. There is no transitional slip between the wheels and the surface. Here is enough rotational friction between the wheel and the surface; so, the wheels can rotate without disturbance. For low rolling velocities this is a reasonable wheel moving model.

Suppose that the robot moves on a plane with linear velocity expressed in the local frame as $v = [\ V_x, V_y, 0\ ]^T$ and rotates with an angular velocity vector $\omega = [\ 0\ 0\ \omega\ ]^T$.

If $q = [\ X\ Y\ \theta\ ]^T$ is the state vector describing generalized coordinates of the robot (i.e., the COM position, X and Y and the orientation θ of the local coordinate frame with respect to the inertial frame). The mobile robot's configuration is generally defined five variables. Such as:

$$q = [x, y, \theta, \varphi_r, \varphi_l]^T \tag{1}$$

where θ is the orientation angle of the mobile robot, x and y are two coordinates, $\varphi_r(t)$ and $\varphi_l(t)$ the rotation angle of the right and left driving wheel, respectivelly [7]. This motion is shown in Figure 1.

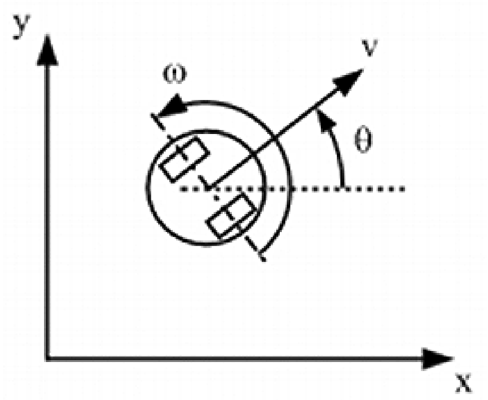

Figure 1. Explanation of the robot motion.

CONTROL STRATEGY FOR MOBILE ROBOTS

In this section contains the proposed control strategy for motion mobile robots. Fuzzy control is applied to the navigation of the autonomous mobile robot in unstructured environments with obstacles. The control scheme can be described as an open loop control law, where the input variables are previously defined and available under the format of a vector containing the discrete-time constant control values. These values are used to command the independent wheel velocities. This control law may, command the robot towards a physical obstacle. Therefore, the controller still must solve the problem of obstacle and workspace boundary avoidance. The robot must change its trajectory when it goes into a physical obstacle or a workspace boundary. When the robot depth sensors detect an obstacle approximation, it changes the direction of movement respecting the strategy described [11, 12].

Fuzzy logic controller used in mobile robot navigation is one of the proposed strategy. The approach is to extract a set of fuzzy rule set from a set of trajectories provided. For this purposes the input to all the fuzzy logic controller are left obstacle distance, right obstacle distance, front obstacle distance and target angle considered [13]. The fuzzy rules help the robots to avoid obstacles and find targets. At first, there are two simple behaviours:

- reach the target, and
- avoid the obstacles.

The reach the target behaviour as well as avoid obstacles behaviour depends on artificial vision information and is the primary task for the mobile robot [14]. It has the highest priority and takes place only if an obstacle appears on the robot path. These controllers are sufficient to guarantee satisfactory navigation performances for the mobile robot in most of the navigation tasks, [15-20]. The control structure in shown in Figure 2.

The fuzzy sets for the output variables of the wheel angular speed correction $\Delta\omega = \omega_r - \omega_l$ (turn-right, zero and turn-left) of the mobile robot are shown in Figure 3.

The output variables are normalized between: $\Delta\omega \in$ [–20 rad/s, 20 rad/s]. The other output variable of the fuzzy controller is vehicle velocity. The output variables are normalized between so that velocity is in the interval [–10 m/s, 20 m/s].

The fuzzy sets for the output variables – low and high velocity – are shown in Figure 4.

Fuzzy supervisor, in order to safely reach the target, a fuzzy supervisor determines the priority of execution for the three elementary behaviours [17, 18].

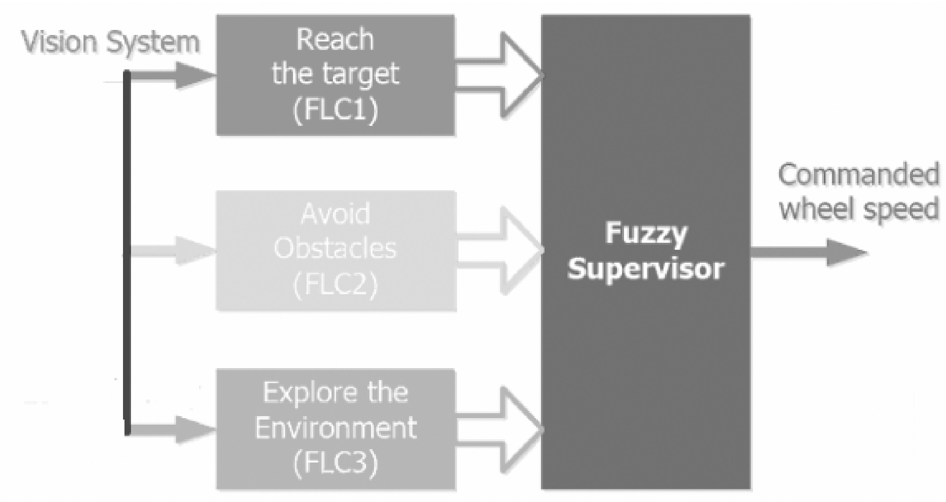

Figure 2. Diagram of the control structure.

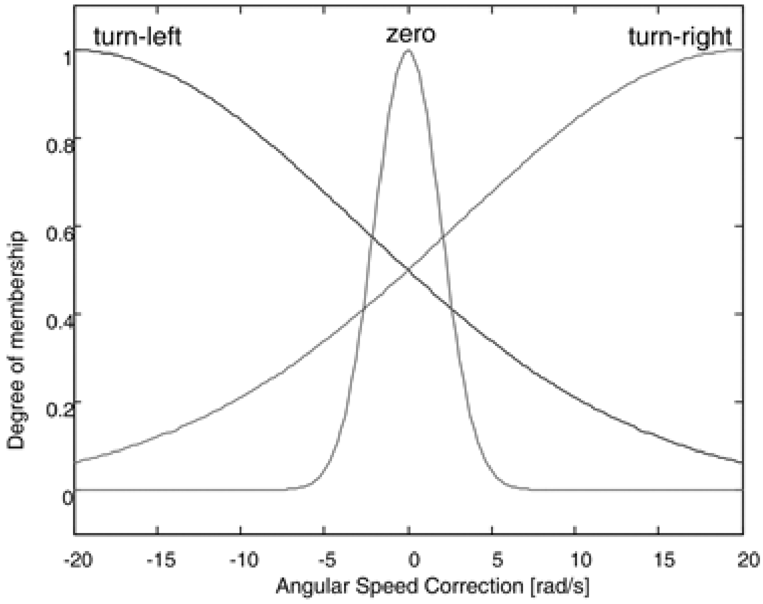

Figure 3. Membership functions of the angular speed difference $\Delta\omega$.

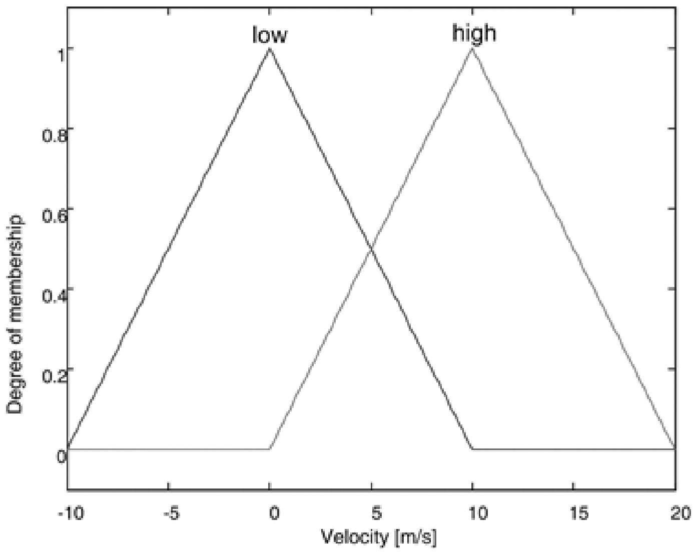

Figure 4. Membership functions of the velocity of the mobile robot.

SIMULATION RESULTS

The control strategy was tested through simulations of robot motion. The motion command was provided by the two independent wheels velocities, $w_l(t)$ (left wheel) and $w_r(t)$ (right wheel), formatted on two vector of consecutive discrete-time instants of control application. Fuzzy control is advantageous in terms of avoiding obstacles and response times [21-25].

In particular, the navigation strategy proved to be extremely sensitive to the balance between avoid obstacle and reach the target behaviours. Simulation results are shown in Figure 5.

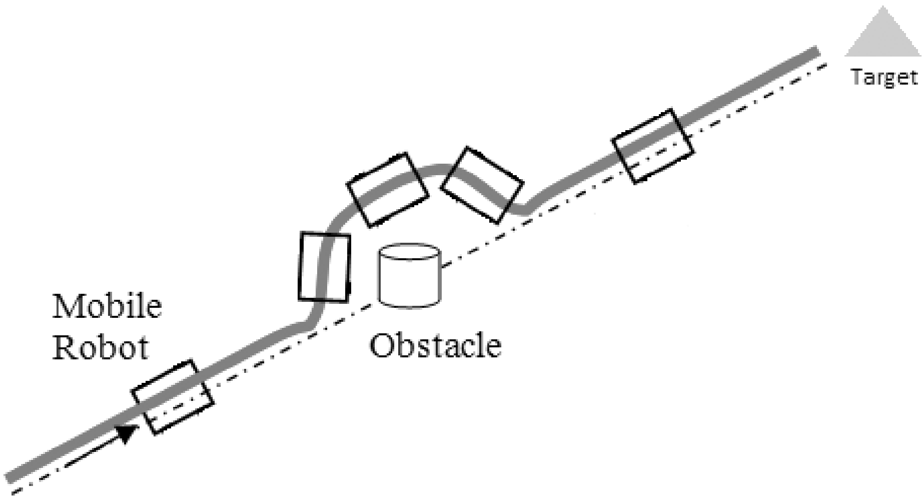

Figure 5. Obstacle avoidance trajectory of mobile robot.

CONCLUSIONS

This articlepresents modeling, control strategies and simulation results of the motion of wheeled mobile robots. Kinematics model for wheeled mobile robots; there are two identical wheel of the mobile robot. Fuzzy logic strategy has a modular structure that can be extended very easily to incorporate new behaviours. Mobile robot navigation strategies using fuzzy logic have major advantages over analytical methods also simulation results recommends fuzzy logic controller for the wheeled mobile robot motion in unstructured environments (obstacle avoidance behaviour and velocity control of vehicle).

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UPRAVLJANJE MOBILNIM ROBOTOM S KOTAČIMA

B. Kocaturk

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SAŽETAK

U radu je opisana strategija navigacije mobilnog robota s kotačima u nestrukturiranoj okolini s preprekama. Za Vozilo ima dva neovisna kotača za upravljanje kutnom brzinom. Rad modelira mobilne robote s kotačima, zatim navodi strategije upravljanja i rezultate simulacije. Rezultati simulacije upućuju na korištenje upravljačkih jedinica s neizrazitom logikom, u slučaju mobilnih robota s kotačima u nestrukturiranim okolinama.

KLJUČNE RIJEČI

inteligentni mobilni robot s kotačima, upravljanje gibanjem, nepoznata i nestrukturirana okolina, prepreke, strategija neizrazitog upravljanja