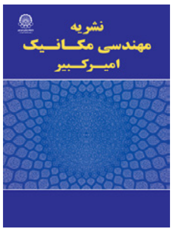

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Path Design and Control of a Moving Social Robot in an Environment with Moving Obstacles in Order to Reach a Moving Target through Fuzzy Control

S. D. N. Tanha, M. H. Korayem* , S. F. Dehkordi

Department of Mechanical Engineering, Iran University of Science and Technology, Tehran, Iran

ABSTRACT: In this paper, the main objective is to design a fuzzy control system for path planning and controlling a moving robot in a social environment with obstacles. The proposed control algorithm establishes an appropriate path to reach the target without collision with obstacles by receiving the target position frequently. When the obstacles examined, it is assumed that fixed and moving obstacles have existed in the environment. Moreover, the robot movements are adjusted in such a way that they do not cause fear or change in human behavior. The fuzzy system used in the paper has four inputs (distance between obstacle and robot, the relative angle of the obstacle, the rate of the obstacle approaching the robot, and relative angle of the target), and two outputs (linear velocity and angles of the robot base). The suggested robotic system is examined in different states by considering diverse motions of obstacles and targets. Furthermore, the designed control system is implemented on the laboratory robot to validate the proposed method. In addition to the design of a graphical user interface, some changes have also been made to the function of its mechatronics system. Finally, the results obtained from simulation and laboratory systems are evaluated and compared.

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1. INTRODUCTION

The robot in social robotics is used as an aid to people in accomplishing their living affairs and as a smart tool to help educate, treat, and provide social services in public and recreational places. One of the prerequisites for the presence of a robot in the community is its ability to route and navigate without causing disturbance to people present in the environment and without collision with the fixed and moving obstacles. The mobile robot can be used in the case which is used as a leader in public environments with social predefined duties.

Mandava et al. [1] provided a potential field-based algorithm for path planning and controlling robots with nonholonomic constraints in the presence of fixed obstacles. Korayem et al. [2] dealt with mathematical modeling and optimal path planning for a moving robot, which used an open-loop controller to track the path. Akka and Khaber [3] applied the Takagi-Sugeno fuzzy model to obtain an optimal path with no collision with obstacles. Azzabi and Nouri [4] used a smart potential field for path planning and avoidance of collisions with obstacles. Hu and Yang [5] used the genetic algorithm and optimized robot path planning in the presence of moving obstacles.

In this paper, a fuzzy logic-based and potential field control method designed for path planning and controlling the robot's motions in a dynamic social environment. This situation includes fixed and moving obstacles, including humans, which is assumed in the experimental and simulation conditions. The proposed method for controlling the robot motions is composed of decisions making based on human logic; that is, the use of qualitative values. Moreover, the kinematic model used for simulating and controlling the robot based on the acceleration computations significantly. The main innovation of the paper is how to select inputs and outputs of fuzzy logic, as well as the use of fuzzy rules to move the robot in the vicinity of obstacles as the same of human motor behavior.

2. HYPOTHESES OF THE PROBLEM AND SOLVING METHODS

In the problem raised, a list of different states, which may be a robot face with, has been provided and given to people as a questionnaire. For each state, the most frequent response is chosen as the fuzzy rule. Then, for each predicted state, a solution is chosen according to the conditions. Finally, the path and favorable kinetic parameters are established. Subsequently, the required control commands are generated by solving the kinematic or inverse dynamics of the robot in order to achieve optimal parameters. After administering initial laboratory tests and measuring the robustness of the created control logic, a final decision is made on how the robot model should be accurate, and what parameters and errors can be ignored.

A questionnaire containing different states, which a person may face, is prepared without referring to the fact that

*Corresponding author's email: hkorayem@iust.ac.ir

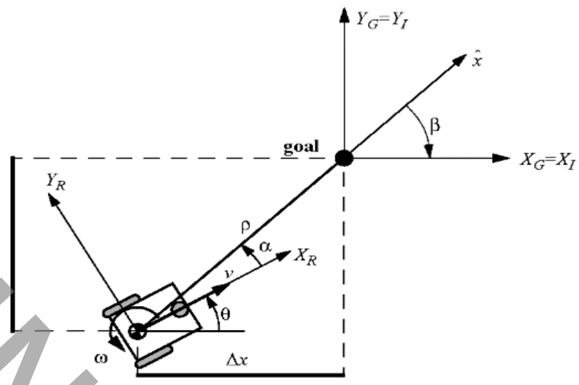

Fig. 1. Schematic of a two-wheeled differential moving robot and target position on the inertia coordinate system.

the questionnaire is to be used to control the robot. Then, we ask people to imagine themselves under conditions defined in the questionnaire and choose what decisions they will be made under each condition. Ultimately, any decision that has the highest response in the questionnaire is chosen as the fuzzy rule. The fuzzy rules base is composed of a set of if-then fuzzy rules. This part is considered as the heart of a fuzzy system that includes the following rules:

The rules are as follows:

IF

X_1 is A_1 AND … X_n is A_n

THEN

Y_1 is C_1 AND … Y_n is C_n

Consider the robot in Fig. 1 that can move in the *XY* Cartesian system. The angle between the axis connected to the robot (X_R) around the reference coordinate system (X_I) is called the vertex angle θ. Moreover, the angle between X_R and the vector connecting the center of gravity of the robot to the position is called target α. With regard to the nature of the motion of a two-wheeled differential moving robot with a two-wheel drive, the linear speed of the robot is in line with X_R. Therefore, the linear velocities and robot rotation are equal to:

$$v = \frac{\omega_1 + \omega_2}{2} r = V_{X_I} \cos\theta + V_{Y_I} \sin\theta \quad (1)$$

$$\delta\theta = \frac{\omega_1 - \omega_2}{2} \mu = \omega \delta t \quad (2)$$

3. IMPLEMENTATION OF THE SCOUT ROBOT HARDWARE AND TEST ENVIRONMENT

This section aims to provide activities for the implementation of the Scout robot hardware and laboratory environment. Therefore, the basic elements of the Scout robot, including drives, hardware modules, and control board used in this study will be examined. Moreover, the laboratory environment and arrangement of the obstacles will be examined. Fig. 2 depicts the hardware diagrams used in this robot.

4. EXPERIMENTAL RESULTS

in order to evaluate the designed controller performance in situations where the target position is variable, a simulation was performed in the presence of a moving obstacle, assuming that the target position is varied. Fig. 3 demonstrates this simulation results. According to the Figure, the robot successfully crossed the obstacle. Moreover, the navigated path pattern is the same as the simulated path, and the only difference is in the end section of the path and time of reaching the target.

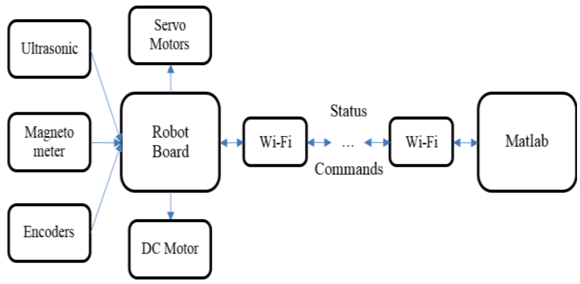

Fig. 2. A chart of the robot control with MATLAB software.

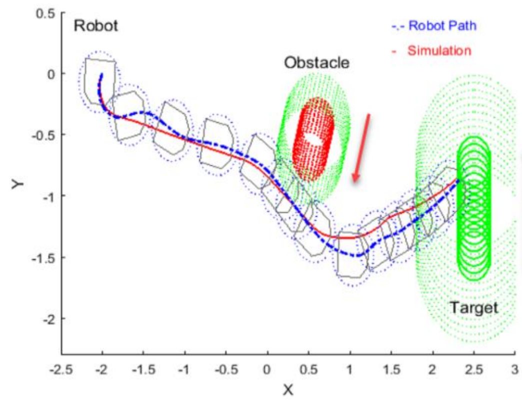

Fig. 3. Results of practical testing and simulation of robot path planning in the presence of a moving obstacle and reaching the moving target under initial conditions of θ = 90˚

5. CONCLUSION

This paper provided the control algorithm of a moving robot with regard to the obstacles in both moving and fixed modes in the case where its control target varies with time. In this case, the plan is in such way that if the environment, in which the robot moves, is dynamic and the obstacles have the same human performance, the robot slows down to 65% of the maximum allowed speed, would adjust its motion in an environment with 800 mm radius in order to prevent collision and create fear. According to the changes in the position of the target over time and in the presence of obstacles, the used fuzzy algorithm has been defined in a manner that its motion is fast and is adjusted in the shortest possible direction. In order to investigate the results and the obtained control algorithm, a moving robot was implemented. Experiments revealed that a robot at a distance of 800 mm to the center of the obstacles decreases its speed to a maximum of 35%.

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