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Real Time Navigaion Strategy of a Robile Robot Using Artificial Potential Field

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Abstract This paper proposes some dynamic navigation strategy for a mobile robot among multiple moving obstacles. The control force of the robot which consists of repulsive and attractive force is based on the artificial potential field. The artificial potential fields is derived with position or(and) velocities of the objects. The simulation results shows the properties of the proposed strategies.

1. Introduction

In recent years, productivity of the industry closely depends on the trasportation of raw material within the factory. Mobile robots gains growing attention as an effective methods partly because of its flexibility. Eessential problems for navigation of the robot involves collision avoidance with other moving or stationary objects. As an effective and compact method for it, intensive research focuses on it. However it has some inherent drawbacks as follows. 1. Trap situations due to local equilibrium zone 2. No passage between comparatively dense obstacles 3. Oscillations at some situations in the presence of obstacles. These demerits of the method can be remedied partially with some particular techniques proposed by some researchers. The navigation problem of a mobile robot among multiple moving obstacles is tackled as a basic target to enhance conventional strategies.

This paper proposes a new dynamic navigation strategy for a single mobile robot in an environment of multiple moving obstacles with potential field approach by considering both of the positions and velocities of the moving robots. Making use of the previous information for the object, more effective motion of the robot can be established. In the proposed navigation algorithm, the following advantages can be obtained 1. Paths can be found by adjusting the constants of the repulsive force with closedly spaced obstacles.

Waren[1] proposed a technique for coordinating the paths of multiple robots in the presence of moving and stationary obstacles by prioritizing the robots. In [2], a navigation strategy of a bar shaped robot was presented using harmonic potential functions to the obstacle avoidance problem. Tilove[3] approaches to local obstacle avoidance for mobile robots based on the method of artificial potentials and also discussed the problems of stability and convergence. The problems of on line navigation for a single mobile robot in an environment of multiple moving obstacles was addressed by Tsubouchi and Hirose[4]. Koren and Borenstein[5] addressed potential field mothods and their inherent limitations for mobile robot navigation.

The paper proposes navigation strategies of mobile robot by considering artificial potential field produced with positions or (and) velocities of objects.

2. Preliminaries

Some assumptions are imposed on the proposed approach 1. All of the objects are spherically shaped and point massse at the center of spherical domain, 2. The robot can obtain necessary information such as positions, velocities of the moving objects with suitable sensory system. 3. The constraints on driving force of the robot is not considered. The proposed strategy is applied for both with and without limitation of the reaching range of the sensory system of the robot. The driving force of the robot is based on the repulsive and attractive force generated by considering all of relative positions and velocities of the robot and obstacles within the detectable region of the robot. Under the assumption of point masses, the dynamics equation of each object has the form of

$$m_i\ddot{r}_i(t) + b_i\dot{r}(t) = f_i(t) \qquad (1)$$

where m_i denotes the mass, b_i (> 0), the friction coefficient, and f_i the control force of the robot i. f_i consists of the repulsive and attractive force caused by the goal points and environmental obstacles.

3. The Proposed Navigation Strategy

3.1 Homing Navigation

For the simplest case, the homing navigation strategies in which the robot navigations with no obstacles is considered. The control force for homing navigation strategy is given by

$$f(t) = \begin{cases} f_c\left(\frac{e(t)}{\|e(t)\|} - \alpha g(\dot{r}(t))\right) & \text{if } e(t) \neq 0 \\ 0 & \textit{otherwise} \end{cases} \qquad (2)$$

where f_c is a positive constant, and α is a given positive rate coefficient. The function $g = g(\dot{r})$ on $R^3 \to R^3$ satisfies $\langle \dot{r}, g(\dot{r}) \rangle < 0$ for all $\dot{r} \neq 0$, and $g(0) = 0$. The oscillatory behavior depends on the coefficient α.

3.2 Navigation Among Moving Obstacles

3.2.1 Strategy I

In Strategy I, the control forces with the form of (3) are based on the relative positions between the robot and the goal point and among the robots.

$$f_i(\dot{r}_i(t), \dot{r}(t)) = f_{gi}\frac{r_{gi} - r_i}{\|r_{gi} - r_i\|} - f_{gi}\alpha_i g(\dot{r}_i) + \sum_{\substack{j=1 \\ j \neq i}}^{l} f_{pij}\left(\frac{r_i - r_j}{\|r_i - r_j\|^3} - \frac{r_{gi} - r_j}{\|r_{gi} - r_j\|^3}\right) \qquad (3)$$

where l denotes the number of object within the detectable range of robot i. f_{gi} and f_{pij} are specified positive constants, r_{gi} is the goal position of the object i.

3.2.2 Strategy II

In most cases of potential field approaches, the relative position between objects are considered for deriving the interactive forces of the robots. However, considering the relative velocities provides its motion with smoothness.

$$\begin{aligned} f_i(r_i(t), \dot{r}(t)) = {} & f_{gi}\frac{r_{gi} - r_i}{\|r_{gi} - r_i\|} - f_{gi}\alpha_i g(\dot{r}_i) \\ & + \sum_{\substack{j=1 \\ j \neq i}}^{l} f_{pij}\left(\frac{r_i - r_j}{\|r_i - r_j\|^3} - \frac{r_{gi} - r_j}{\|r_{gi} - r_j\|^3}\right) \\ & + \sum_{\substack{j=1 \\ j \neq i}}^{l} f_{vij}\left(\frac{\dot{r}_i - \dot{r}_j}{\|\dot{r}_i - \dot{r}_j\|^3} - \frac{\dot{r}_{gi} - \dot{r}_j}{\|\dot{r}_{gi} - \dot{r}_j\|^3}\right) \qquad (4) \end{aligned}$$

3.2.3 Strategy III

To avoid the undesirable oscillation of the robot around the goal point as shown in strategy II, the relative positions replaces the relative velocities in the repulsive term.

$$\begin{aligned} f_i(r_i(t), \dot{r}(t)) = {} & f_{gi}\frac{r_{gi} - r_i}{\|r_{gi} - r_i\|} - f_{gi}\alpha_i g(\dot{r}_i) \\ & + \sum_{\substack{j=1 \\ j \neq i}}^{l} f_{pij}\left(\frac{r_i - r_j}{\|r_i - r_j\|^3} - \frac{r_{gi} - r_j}{\|r_{gi} - r_j\|^3}\right) \\ & + \sum_{\substack{j=1 \\ j \neq i}}^{l} f_{vij}\left(\frac{\dot{r}_i - \dot{r}_j}{\|r_i - r_j\|^3} - \frac{\dot{r}_{gi} - \dot{r}_j}{\|r_{gi} - r_j\|^3}\right) \qquad (5) \end{aligned}$$

4. Simulations

Fig. 1 shows the homing navigation of the robot. It is notable that the rate of oscillation depends on the attrative coefficient f_{gi}. The bigger it is, the less oscillatorily the robot navigates. With strategy II, the robot avoids the moving obstacles smoother than with strategy I. However the velocity term in repulsive force produces undesirable oscillation around the goal point. Strategy III compensates the oscillatory behavior of the robot around the goal point.

5. Proof of Convergence

One of the most important part of the potential field method is to find the convergent region. The convergent region of the strategy I can be shown in [6]. Some modification of the proof of case (I) will give us the region of convergence of case (II) and (III).

6. Concluding Remarks

This paper proposes some efficient navigation algorithm of the mobile robot among moving obstacles in both free and bounded space. The study on region of convergence for both of strategy II and III are on the way.

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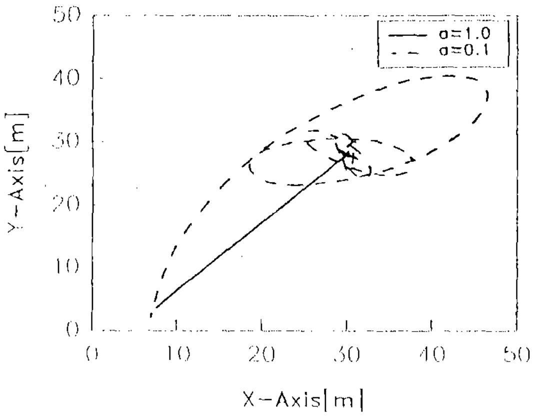

Fig. 1 Homing Navigation
(m=1.0, f_c=10, β=0.1, α=0.01, 0.1)

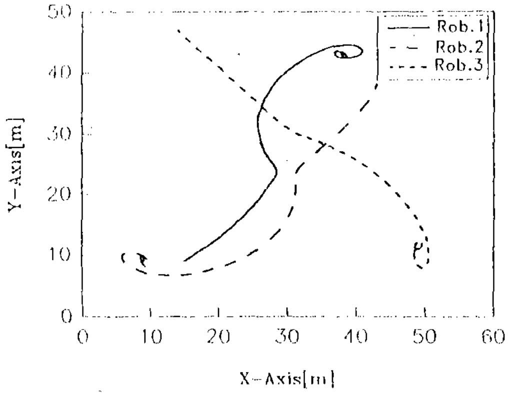

Fig. 2 Navigation strategy I
(f_r=20, m=10, f_R=1, β=0.1, α=0.8)

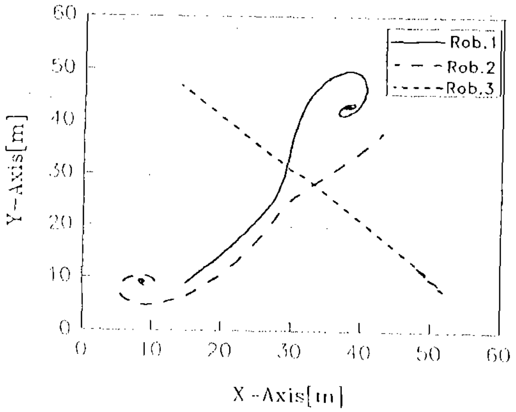

Fig. 3 Navigation strategy II
(v_f=0.1, f_r=10, β=0.5)

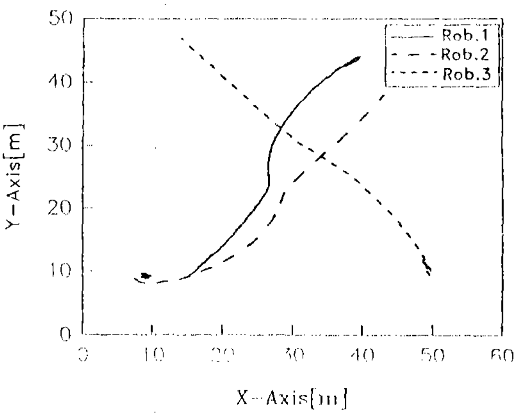

Fig. 4 Navigation strategy III
(v_f=20, f_r=10)