Roundabout Collision Avoidance for Multiple Robots based on Minimum Enclosing Rectangle (Demonstration)

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ABSTRACT

This paper describes a novel and dynamic rectangular roundabout ('rectabout') collision avoidance system based on Minimum Enclosing Rectangle (MER) paradigm. The approach is fully decentralized maneuver based on equal priority and involves local views. This maneuver is calculated by each robot involved in the possible collision course separately through its own local view. The virtual MER-based rectabout lies in the position of two robots and also is capable of dealing with static obstacles. Simulated demonstrations indicate that rectabout in conjunction with Minimal Predicted Distance (MPD) ensure that all robots remain free of collision, thereby making the procedure well-suited for real-time applications involving a number of independent robots planning routes to their goal destinations.

Categories and Subject Descriptors

I.2.9 [**Robotics**]: Autonomous vehicles; I.2.11 [**Distributed Artificial Intelligence**]: Multiagent systems

Keywords

Collision Avoidance, Rectangular Roundabout

1. INTRODUCTION

In this study, inspiration for avoiding collisions comes from the use of roundabouts for resolving potential vehicle collisions at road intersections. The idea adopted in this paper is for two robots, when realizing that they may be on a collision course, employing a temporary roundabout that each robot independently locates in the center of two robots' positions. The two robots then adopt common procedures for negotiating the roundabout and thereby avoid colliding with each other until they can resume their desired path. The conflicting robot's position is obtained from observation in the local view. The velocity is obtained via local communication: each robot broadcasts its velocity to neighbour agents only. In this paper we use Minimum Enclosing Rectangle as rectangular roundabout representation. According to MER paradigm including Square (MES), in order to classify the *k-square* with respect to the number of points η present on its boundary, Das et al. [1] investigated all different possibilities of *k-squares*. As a result of their study, no *k-square* is possible with $\eta = 0$ or 1. The only possibility with $\eta = 2$ is that the two points appear at the two diagonally opposite corners of the corresponding *k-squares*. In this study, $k = \eta = 2$ is the MER or MES that the robots are employing, as shown in Figure 1.

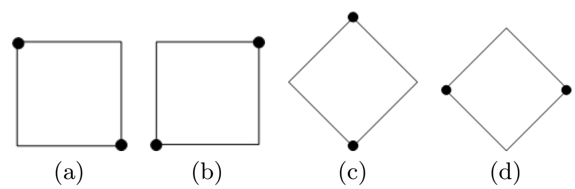

Figure 1: MER of $\eta = 2$, with dots representing the position of the two robots. The orientation of the rectabout can differ according to the velocity.

2. MINIMAL PREDICTED DISTANCE

Olivier et al. [3] proposed a new minimal predicted distance metric to investigate collision avoidance between two walkers. Given two persons with position p_i and p_j, for $i, j = 1, 2, i \neq j$, each person is considered as a moving obstacle for the other. At each instant t, $MPD(t)$ represents the distance at which person i would meet person j if they did not perform motion adaptation after the instant t. According to the model of MPD [3], the future trajectory for each person is modeled as follows:

$$p'(t, u) = p(t) + (u - t)v(t) \tag{1}$$

where u is a future time instant with $u, t > 0$ and $u > t$, $p(t)$ and $v(t)$ are the position and velocity at time instant t, respectively. Their study showed MPD is constant and that walkers adapt their motion only when MPD is very low. Therefore, we can predict potential collisions by computing the absolute distance between p_i and p_j at each time instant t:

$$MPD(t) = \arg\min_{u} \left\| p'_i(t, u) - p'_j(t, u) \right\| \tag{2}$$

3. MER-BASED RECTABOUT MANEUVER

Each robot has 8 moving directions as shown in Figure 2(a) and a wait action, plus a front local view as shown in Figure 2(b) and (c). All robots have a constant speed for simplicity. Our approach requires each robot to consider its

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moves within its front local view at each time step, so each robot potentially has 9 legal actions. Each of these legal actions is a solution to the constraint satisfaction problem in which each robot must determine a move from {*E,S,W,N,NE, SE,SW,NW and wait*} as shown in Figure 2(a), provided that the chosen move does not lead to two robots colliding.

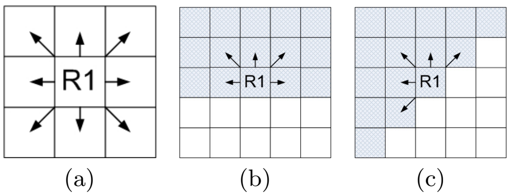

Figure 2: The front local view of R1.

Our rectabout method is a pairwise deconfliction maneuver and includes two phases - a conflict detection phase and a deconflict phase. Given a robot A_i and number n of neighbour robots $A = \{A_1, A_2, ..., A_j\}$ with $j \in n$, if two robots paths conflict, the rectabout is computed by the two robots' position over MER. The function is denoted as $MER(p_i, p_j)$. Let R^{ij} represent the rectangle, thus we have $R^{ij} = MER(p_i, p_j)$, and $p_i, p_j \subset R^{ij}, \eta \equiv 2$. That is, the boundary of the rectangle is also included in the rectangle. Then, a new velocity is calculated by R^{ij}. This procedure is repeated until the deconfliction motion is found (including a wait action) for all the neighbour robots. Given $n > 0$, the rectabout is calculated as follows at each time step:

1. Estimate motion state pairwise for robot i with neighbour robots A_j with $i, j \in n, i \neq j$ by $MPD(A_i, A_j)$.

2. Repeat until there is no conflict: If there is conflict, then compute R^{ij} by $MER(p_i, p_j)$. If no solution is found, then wait action and terminate.

3. Find the other two diagonally opposite corner positions p'_i and p'_j.

4. Calculate the new velocity by two points p_i and p'_i.

Figure 3 illustrates Robot 1 (R1) computing pairwise virtual rectabouts to avoid collisions with two other robots R2 and R3 (a). First, R1 calculates a rectabout to avoid R2 and plans a move NW (b). However, R3 is also in conflict, so (c) R1 calculates another rectabout and planned move W to avoid R3 (d). Similarly, other two robots use the same procedure to deconflict.

4. SIMULATED DEMONSTRATIONS

We have conducted a number of simulations. Through these simulations, we tried to evaluate the following three aspects of the proposed approach: (1) Capability: can the approach deconflict between robots in path conflict? (2) Solvability: is the approach able to cope with both static obstacles and moving robots at the same time? (3) Adaptability: is the approach adaptable to all possible collisions [2] in a dense environment?

The scenarios are simulated in a 10 by 10 grid. The first scenario employs three robots R1, R2 and R3 moving to their goal position G1, G2 and G3, respectively. R1's trajectory is in conflict with R2 and R3's trajectory because their paths cross each other. R1 computes rectabouts corresponding to

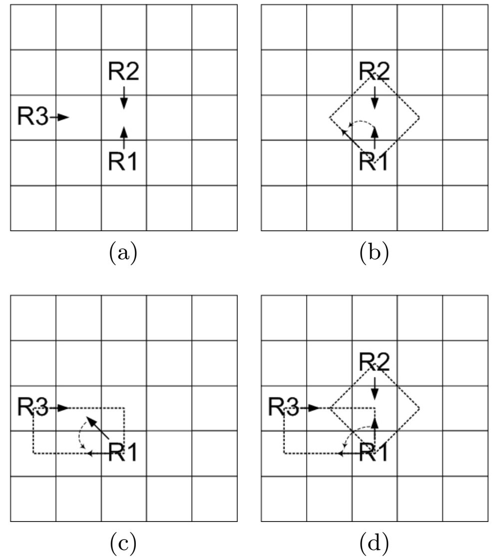

Figure 3: Illustration of how rectabouts resolve conflicts between three robots. Robot 1 computes virtual rectabouts by pairwise based on MER for deconfliction.

R2 and R3's velocity. R1 re-plans a new velocity for only one move. After one move, R1 resumes its goal-directed path. Similarly, R2 and R3 follow the same procedure to change their original velocity to avoid each other. The second scenario is 5 robots and the central area is occupied by fixed obstacles. The last scenario is 16 robots where all robots densely locate in the center of the environment towards their goal position. In this scenario, robots using MER roundabout may cause deadlock, the wait action is used while the robot is involved in deadlock and only takes one time step. Robots will follow their goal-direction again after one time step. As seen in this scenario, MER-based rectabout collision avoidance maneuver is adaptable to all possible collisions in [2] and to deadlock. The video link is http://youtu.be/Kd7qYkUtGUw.

5. CONCLUSIONS AND FUTURE WORK

A novel MER-based roundabout collision avoidance maneuver is presented. Also, MPD is applied for the first time to deal with robot collision problems. In future work we will proof rectabout theoretically. Furthermore, the approach can be applied to solve traffic jam deadlock in future application.

6. REFERENCES

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