Advances in Machinery, Materials Science and Engineering Application IX
M. Chen et al. (Eds.)

doi:10.3233/ATDE230521

Research and Simulation of Robot Cluster Motion Based on Flocking Algorithm

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Abstract. The research on robot cluster control and collaborative motion has gradually become an important issue in the research of cluster robots A clustering control and collaborative motion algorithm based on the Flocking algorithm is proposed to address the above issues, which mainly includes three parts: robot cluster path planning, cluster object avoidance, and cluster formation control Firstly, a stable cluster formation is observed through the cluster control of the Flocking algorithm, which enables it to have the ability of cluster collaborative motion Based on this, an improved A * algorithm can be used to plan a cluster movement path At the same time, in the collaborative motion of robot clusters, dynamic and static objects can be avoided through the DWA algorithm, there quickly reaching the destination Solve the problem of cluster control and collaborative motion of robots in complex environments, and finally verify the effectiveness and rationality of the algorithm through simulation experiments.

Keywords. Flocking algorithm, A*algorithm, DWA algorithm, robot cluster control, collaborative movement

1. Introduction

Due to the research on intelligent robot technology and the continuous development of artificial intelligence, the research on cluster intelligent robots has gradually become one of the focuses of intelligent research. For example, large-scale multi robot relay communication, joint search of multiple unmanned robots, and frequently occurring multi human machine formation performances in daily life all require a common technology behind these application scenarios, which is multi-agent motion control technology. In reality, the motion scene also contains a variety of challenges, such as obstacles with different shapes, robust control with certain invulnerability, etc. Therefore, an effective cluster intelligent robot control system with flexible obstacle avoidance capability is the technical foundation of these efficient application scenarios. Cluster intelligent robots are not simply the superposition of intelligent robots, but rather the combination of multiple intelligent robots to achieve centralized collaborative control without erasing the characteristics of a single robot. This not only makes up for the shortcomings of a single intelligent robot executing tasks, moreover, it better leverages the advantages of cluster intelligent robots. Compared with cluster

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intelligent robots, single intelligent robots have advantages in execution efficiency and success rate in simple or complex tasks and various environments, and are widely used in various fields.

2. Research on Cluster Control and Obstacle Avoidance Algorithms

2.1. Introduction to Flocking Algorithm

The advantage of the Flocking algorithm [1] is that it can simulate the complexity of group behavior and can simulate various different patterns of group behavior, such as aggregation, splitting, aggregation, separation, etc. In addition, the Flocking algorithm can also simulate various complex behaviors, such as the mutual influence between each individual in the population and the overall behavioral trends of the population. The Flocking algorithm has four simple rules that, when combined, provide a realistic form of group behavior similar to that of a flock of birds or fish for an autonomous agent group. These four rules are separation principle, queuing principle, aggregation principle, and avoidance principle.

(1) Separation principle: When orienting, avoid crowding with local float companions. Regularly detect nearby companions to avoid crowding.

(2) Formation principle: The average heading of the local float companion. Detect the heading and speed of neighboring companions, obtain the average value, and adjust oneself.

(3) Aggregation principle: Move towards the average position of the local float companion during orientation. That is to detect the neighboring companions, average their positions and adjust their matching course

(4) Avoidance principle: To avoid colliding with obstacles or enemies in local areas. That is, "looking forward for a certain distance", adjusting the course and speed of the enemy to avoid obstacles.

*2.2. Introduction to A * Algorithm*

The A * algorithm [2] is a traditional [3] search method that is the most effective in solving the shortest path in a static network. The central idea of the A * algorithm is to obtain the shortest path from the initial bit through the minimum cost calculation, by continuously searching for neighboring nodes until the endpoint.

The formula expression of the A * algorithm is:

$$f(n) = g(n) + h(n) \tag{1}$$

In the expression: f (n) is the minimum cost estimate from the initial state to the target state through state n, known as the cost function; G (n) is the minimum cost from the initial state to state n in the state space, known as the heuristic function; H (n) is the minimum estimated cost of the path from state n to the target state, known as the evaluation function.

For path search problems, the state is the node, and the cost is the distance. The key to finding the optimal solution for the shortest path lies in the selection of h (n), which represents the estimated distance from state n to the target state. Therefore, the selection of h (n) is roughly similar to the three situations in table 1.

Table 1. Different weights of A * algorithm h (n).

State	Function	Result
H (n)<h * (n)	F (n)=g (n)+h (n)	Short path and time consumption
H (n)=h * (n)	F (n)=g (n)+h (n)	Long path and short time consumption
H (n)>>h * (n)	F (n)=h (n)	Long path and short time consumption
H (n)=0	F (n)=g (n)	Short path and long time consumption

The advantage of the A * algorithm is that it can adapt to any environment and has a direct representation of the searched path. It is a relatively direct algorithm and is often used to solve path planning problems. The disadvantage lies in the lack of dynamism, which can only search for paths against fixed obstacles, and the node search volume is large. When the environment is large, the algorithm efficiency is not high, and the A * algorithm only searches for a feasible path, not the optimal solution.

2.3. Introduction to DWA Algorithm

The principle of the DWA algorithm [4] is mainly to sample multiple sets of velocities in velocity and space (linear velocity, angular velocity), simulate the motion trajectories of these velocities within a certain time, and evaluate these trajectories through evaluation functions to select the optimal trajectory corresponding to the driving robot motion. The kinematics model of the robot is as follows.

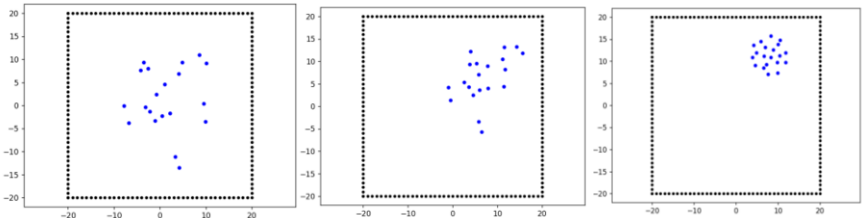
$$\begin{cases} x(t) = x(t-1) + v(t)\Delta\cos(\theta_{t-1}) \\ y(t) = y(t-1) + v(t)\Delta\sin(\theta_{t-1}) \\ \theta = \theta_{t-1} + \omega(t)\Delta t \end{cases} \tag{2}$$

Among them $x(t)$, $y(t)$, θ_{t-1} θ are the pose information of the robot at time t, and are the pose information at time t-1.

3. Simulation Experiments and Data Analysis

3.1. Flocking Algorithm Simulation Experiment

In a 40 * 40 map, 20 intelligent robots [5] are randomly initialized within the range of [-15, 15]. The changes in the cluster robots at different time intervals T are shown in figure 1.



(a) T0 (b) t1 (c) t2

Figure 1. Simulation of Flowing Algorithm.

*3.2. A * Algorithm Simulation Experiment*

The simulation experiment was conducted on a 70x70 static obstacle map established in a grid like manner, which includes black static obstacles, red planned routes, green starting points, and blue ending points. The simulation results obtained by comparing the traditional A * algorithm and the improved A * algorithm in planning paths in the map are shown in figure 2.

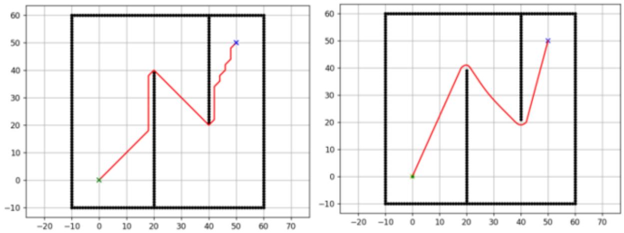


Figure 2. Comparison of path planning.

*3.3. A * Algorithm Combined with DWA * Algorithm Simulation Experiment*

(1) Conduct simulation experiments in an environment with known dynamic obstacles, where the map contains black static obstacles and known yellow dynamic obstacles. The dynamic obstacles move up and down repeatedly in the yellow area. The simulation test results of obstacle avoidance algorithm [6] are shown in figure 3.

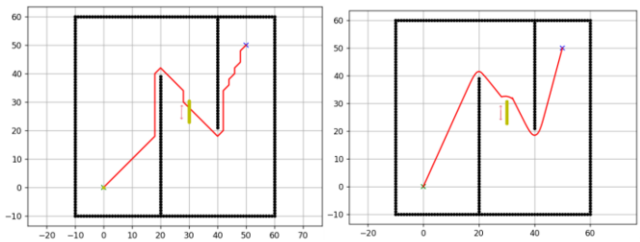
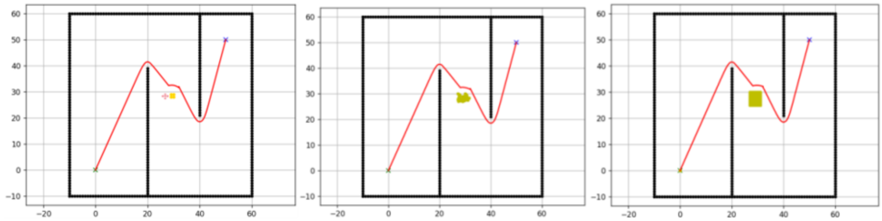


Figure 3. Comparison of known dynamic observer path planning.

From the comparison of the two simulation results shown in figure 3, it can be seen that the traditional A * algorithm path planning does not have the function of dynamic obstacle avoidance. However, the fusion of improved A * and DWA algorithms can provide a path that avoids dynamic obstacles at the planning point, thereby achieving the effect of dynamic obstacle avoidance in the obstacle map with known movement directions.

(2) Conduct simulation experiments in a dynamic environment with unknown obstacle movement direction, where the map contains black static obstacles and yellow dynamic obstacles with unknown movement direction. The dynamic obstacles move randomly throughout the entire map. Perform algorithm simulation tests on the map and the results are shown in figure 4.



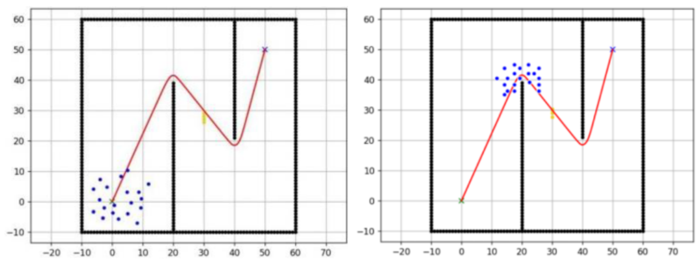
(a) Obstacle initial state (b) Obstacle movement path (c) Obstacle swelling treatment

Figure 4. Dynamic object avoidance of objects in unknown direction.

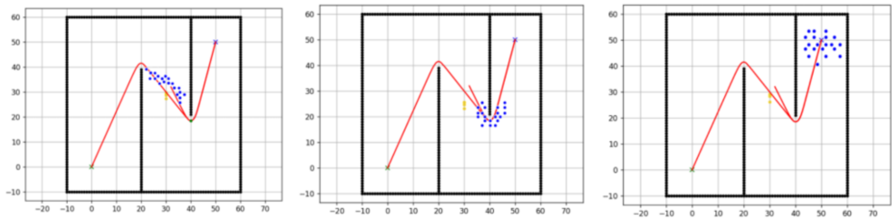
From the comparison of the three images shown in figure 4, it can be seen that the fusion improvement A * and DWA algorithm can detect the presence of dynamic obstacles while planning the path. If there are obstacles with unknown movement directions, the obstacle area will be expanded and treated as static obstacles, thus achieving the effect of dynamic obstacle avoidance for unknown movement directions.

*3.4. Flocking Algorithm Combined with A * and DWA Algorithm Simulation*

Place 20 intelligent robots in a 70 * 70 grid map for movement, initialize near the initial point (0,0), and move from the initial point (0,0) to avoid dynamic and static obstacles to the endpoint (50,50). Among them, the A * algorithm is used to plan the path to avoid static obstacles, the Flocking algorithm is used for cluster formation control for collaborative motion, and the DWA algorithm is used for real-time obstacle avoidance to avoid dynamic obstacles. After avoiding obstacles, the path is re planned through A *. The multi segment simulation test results with time interval T from the initial point are shown in figure 5.



(a) T0 (b) T1



(c) T2 (d) T3 (e) T1

Figure 5. Collaborative Motion Simulation of Cluster Intelligent Robots.

4. Conclusion

The strategy for local dynamic path planning in dynamic obstacle environments has been adjusted, accelerating the speed of A * algorithm path planning. Finally, the rationality and effectiveness of this algorithm have been verified through simulation, which has important theoretical guidance significance for the research of swarm intelligent robot motion [7]. This article only considers the simulation implementation of collaborative motion and obstacle avoidance of cluster intelligent robots in free space. The research on collaborative motion and obstacle avoidance of cluster intelligent robots [8] in non free space still has potential value, and the research focuses on collaborative motion of cluster intelligent robots in small environments. For complex areas with large scales, research on collaborative motion and cluster control algorithms of cluster intelligent robots still needs to be in-depth, We will continue to conduct research on cluster intelligent robots in the future.

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