Simulation of Conflict Free Coordination and Automatic Joint Control Method for Cluster Robots

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Abstract: According to the task requirements and system characteristics, the state variables are reasonably selected to construct the state space of the system, and the physical constraints inherent in the system, obstacles imposed from the outside and task constraints are mapped into unreachable areas in the state space, then the reachable areas indicate the range of the robot system's ability to complete tasks. The original manual complex processes will be replaced by robot assembly lines one after another, which poses new challenges to robot technology, especially the coordinated motion system of cluster robots for complex movements. As one of the important means for robots to perceive information, vision technology not only enhances the robot's ability to adapt to and recognize the environment, but also improves its working efficiency. However, as an important branch of the robot field, industrial robots are still faced with the problem of how to develop appropriate vision technology to solve its intelligence and informatization. In this article, the conflict-free coordinated automatic joint control method of cluster robot is studied, and the coordinated planning and control strategy of cluster robot system is discussed.

1. Introduction

The establishment and birth of robotics undoubtedly became one of the great achievements of human science and technology in the 20th century. In the mid-20th century, with the rise of computer and control theory, automation technology gradually developed [1]. On this basis, in order to replace manpower and meet mass production, robot technology came into being. Industrial robots are the application of robots in the industrial field. Cluster robot system is extended from a single mobile robot. Through effective coordination among multiple mobile robots, it can obtain higher flexibility, robustness and work efficiency than a single mobile robot, so it can cope with more complex tasks [2]. The interaction and cooperation of cluster robots is the inevitable development trend of industrial automation and flexibility, which also puts forward higher requirements for their cooperation. In the early robot research, programmable, teaching-and-reproducing industrial robots were mainly used, and then robots with certain sensing ability and adaptability were developed. After that, the robot body was equipped with a variety of advanced sensors and became an intelligent robot with strong adaptability [3]. The target search of swarm robots is divided into single target search and multi-target search, the former is a special case of the latter.

As far as the method of controlling swarm robots to search for a single target is concerned, there is an intentional cooperative method of clearly planning robot behavior. With the improvement of robot technology, the individual ability of mobile robot is constantly improved, and its application field is also expanding, but at the same time, the requirements for the complexity and dynamic performance of tasks performed by mobile robots are more stringent [4]. In the face of increasingly complicated tasks, it is increasingly difficult for a single mobile robot to be competent. The research of robotics has gone through the process from simple structure to complex, single function to diversity, from industrial manufacturing to military reconnaissance, nuclear industry, aerospace, service industry, medical equipment and other fields, and its application scope is getting wider and wider [5]. In the cluster robot system, robots can share information, plan their paths and coordinate

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with each other to complete the scheduled tasks. Among them, the task assignment and path planning of multiple mobile robots are the basis for the normal operation of the system, and the coordinated control among robots is the key for the system to complete the scheduled work. When a cluster robot completes a complex interactive task in sequence, it usually coordinates the robots to proceed in sequence according to the requirements of the operation itself to avoid robot collision [7]. In this article, the conflict-free coordinated automatic joint control method of cluster robot is studied, and the coordinated planning and control strategy of cluster robot system is discussed.

2. Motion planning and coordination based on state space

With the continuous maturity and growth of computer technology, VLSI, control theory, artificial intelligence theory, sensors and other technologies, theories and products, the research of robotics formed by interdisciplinary has entered a new stage. This rigid structure constraint is not actually imposed between robots, but is realized by control strategy, so it is a kind of "virtual structure". This method first needs to apply a virtual force to the virtual structure, which causes the position and direction of the virtual structure to change, and each robot can track the corresponding points in the virtual structure, so as to realize the coordinated movement of the formation. According to the way and characteristics of coarse-grained collaboration, it is subdivided into cooperative collaboration and competitive collaboration [8]. No matter what mode, we must solve the communication interaction problem if we want to work together. State variables include external direct variables and internal indirect variables. The former can be directly observed or measured, such as position and velocity, while the latter can only be obtained by calculation, such as relative position and velocity. Creating an environmental map is a process of extracting the characteristics of the working environment by using the sensing module of the system or each mobile robot and expressing them through an appropriate description. In order to better realize the coordinated planning and control of the swarm robot system, the created map must be convenient for the robot to understand, calculate and transmit, and can add new environmental information in time.

Virtual structure method can easily define the task of formation and realize high-precision trajectory tracking, but it requires all robots to move in virtual structure mode, which limits its application scope. For tasks such as detection and reconnaissance in unknown environment, the process of map construction is relatively complicated, and it is often necessary to extract environmental information by mobile robots to judge the occupation of each grid unit, and then build a grid environment map of the whole workspace. During the movement of single robot system and cluster robot system, the position, speed and acceleration of the robot are constantly changing to complete the given task. For industrial robots that have calibrated their own parameters, the calibration of the coordinated motion system of master-slave robots is mainly aimed at the calibration of the base coordinate system of master-slave robots. The base coordinate system is a coordinate system fixedly connected with the robot base. For two different robots, the pose relationship between them can be expressed by the pose relationship of the base coordinate system.

In the fuzzy control system, the controller structure can be determined according to the number of input variables and the number of output variables of the path-finding algorithm. Its update status is as follows:

$$w(t) = w_{end} + (w_{start} - w_{end}) \times \exp\left(-k \times \left(\frac{t}{t_{\max}} \right)^2 \right) \tag{1}$$

Among them, k is the control factor; Control the smoothness of w and t curves. Calculate the total path index:

$$S_k = \frac{1}{F}\left(\frac{n+1}{h_y \cdot j} \right) \tag{2}$$

Where S_k represents the distance between the k waypoints; 1/F stands for the return distance of the robot after the task is completed; $h_y \cdot j$ is the adjustment coefficient of the total path; n is the total path index value.

The position, angle, size, speed and acceleration of robots themselves and each other can be used as state variables. When the task only has special requirements for position, the state space can be constructed only by using position variables. There is more than one way to construct the state space, as long as the selected variables can describe the main characteristics of the system and tasks. In theory, whether a grid cell is occupied or not can be clearly detected by the sensor, but because the robot is always in a moving state when collecting environmental information, the sensor signal is noisy, and the detection results at different times may be biased, so it is impossible to accurately judge whether a point is occupied by obstacles only by a single measurement.

If the variables related to robots and tasks are taken as state components to construct a state space, the system status at any time can be expressed by a set of determined values of these variables [9]. Corresponding to a point in the state space, the task execution process is also the trajectory change process of the system state in the state space. Visual positioning is based on computer vision technology. Firstly, the environmental image information obtained by industrial cameras is input into the computer, and the feature information of the target is extracted through the image processing algorithm in the computer. Then, combined with the camera calibration results and the visual algorithm flow, the target is positioned, and then the industrial robot is controlled to the corresponding position to complete the established tasks such as assembly, sorting and grabbing.

3. Kinematics modeling of cluster robot

Before the general state space model of the system is given, the state space is explained first. The state space here refers to the space composed of variables that can represent the current situation of the robot system. For the same robot system, different variables can be selected to construct different state spaces from different angles, and the characteristics of the task and the robot system should be considered comprehensively in the specific construction. Global path planning and local path planning are essentially the same, but each has its own emphasis. Global path planning needs to master the global environment information in advance, and then plan the whole motion path from the starting position to the target position for the robot. The planning process pays more attention to the global quality of the path, but it cannot cope with the dynamic environment [10]. Constructing the state space with all the states of robots and tasks will lead to a high dimension of the space. In order to reduce the dimension, variables directly related to the requirements, characteristics and system characteristics of tasks can be selected. Local path planning can realize small-scale dynamic real-time path planning by processing the local environmental information perceived by the robot without knowing the global information. However, due to the lack of guidance of global information, the planning results often cannot reach the global optimum, and even the correct path may not be found.

In the process of obstacle recognition, the robot needs to divide the outline of the obstacle into N equal parts, that is, there are N points in the outline of the obstacle, and each point is taken as a coordinate value, then the coordinate of the obstacle is $(x_i, y_i) i = 1,2,\ldots,N$. N is the number of equal points of the outline of the obstacle, and the center coordinate of the obstacle is (x_c, y_c):

$$\begin{cases} x_c = \frac{1}{N}\sum_{i=1}^{N} x_i \\ y_c = \frac{1}{N}\sum_{i=1}^{N} y_i \end{cases} \tag{3}$$

Set the distance from any point on the outline of the obstacle to the center as r_i:

$$r_i = \sqrt{(x_i - x_c)^2 + (y_i - y_c)^2} \tag{4}$$

Then the eigenvector formed by the distances from all equipartition points to the center of gravity is:

$$R = (r_1, r_2, r_3, \ldots, r_N) \tag{5}$$

The above feature vectors can be Fourier transformed by the following formula:

$$\begin{cases} a_n = \dfrac{1}{N} \sum\limits_{i=1}^{N} r_i \exp(-j2\pi ni / N) \\ i = 1,2,\ldots,N \end{cases} \tag{6}$$

The problem of motion priority is considered in the collision avoidance strategy, and the shortest cycle time for double robots to complete automatic detection tasks is the optimization goal. Because the oscillation of syringe takes the longest time in the whole detection cycle, reducing the idle waiting time of oscillator is taken as the measure price to determine the motion state of robot. Because the short-time operation link has more time to wait, while the long-time operation link needs to reduce the waiting time and give priority to the interactive area, so that the running time of the whole platform is optimized.

The path planning of cluster robots is an extension of the path planning of a single robot. In order to deal with the complex and changeable cluster robot system, besides the factors such as path length, smoothness and obstacle avoidance ability, the coordination and collision avoidance among robots must also be considered. The centralized system structure needs a unified planning unit, which can be a planning platform located on the upper layer of the mobile robot group or a member of the mobile robot group. On the basis of fully understanding the environment and tasks, the planning unit evaluates and plans the route to be taken by each mobile robot to ensure the minimum total execution cost of the system [11]. In order to deal with the compatibility problem of global optimization and local flexible coordination of path planning for cluster robot system, a path planning system with global and local double-level coordination is designed based on hybrid control system. The crossing process is mainly realized by finding all the same path points in the two paths, randomly selecting one point from them and exchanging the paths after that point; The mutation is to randomly select two path nodes except the start point and the end point in the path, remove the path between these two points, and reconnect these two nodes by initializing the feasible path to form a different path. In the process of mutation, it may be impossible to generate a continuous path. At this time, it is necessary to re-select two path nodes and perform the above operations again until the mutation is completed. According to the above steps, a high-quality global path can be planned for the robot through repeated iterative evolution. The test results of obstacle recognition accuracy of swarm robots using particle swarm optimization (PSO) algorithm are shown in Figure 1. The test results of obstacle recognition accuracy of swarm robots using this algorithm are shown in Figure 2.

The robot obstacle recognition model based on this algorithm is better than PSO in both accuracy and efficiency. According to the optimized solution, the destinations of different mobile robots are assigned, and each mobile robot moves to the destination respectively, and avoids obstacles according to local information in the movement to ensure the safety of the mobile robots, and finally reaches the destination. First, according to the global environment map coordinate system and the task assignment planning results, the central controller plans a high-quality global path for each mobile robot from the beginning and the end position to their respective target task positions, and then tracks and predicts the planned global path so as to timely judge the positions where each robot may interfere or collide during the operation of the system, so as to avoid the collision through the local small-scale path coordination planning of individual mobile robots. If the original map of the environment is found to be wrong or the topological structure of the environment has changed during the operation of the individual mobile robot to the destination, the path specified by the planner is not feasible. In this case, this open-loop structure can not guarantee the completion of the task. In order to minimize the workload of local path coordination among robots during task execution, the double-level coordinated path planning system puts forward new requirements for the global path of the system, that is, the global path of each mobile robot needs to minimize the intersection and interference between different robot paths while meeting the requirements of low path cost, few corners and effective obstacle avoidance, so as to ensure the safe and efficient operation of the system.

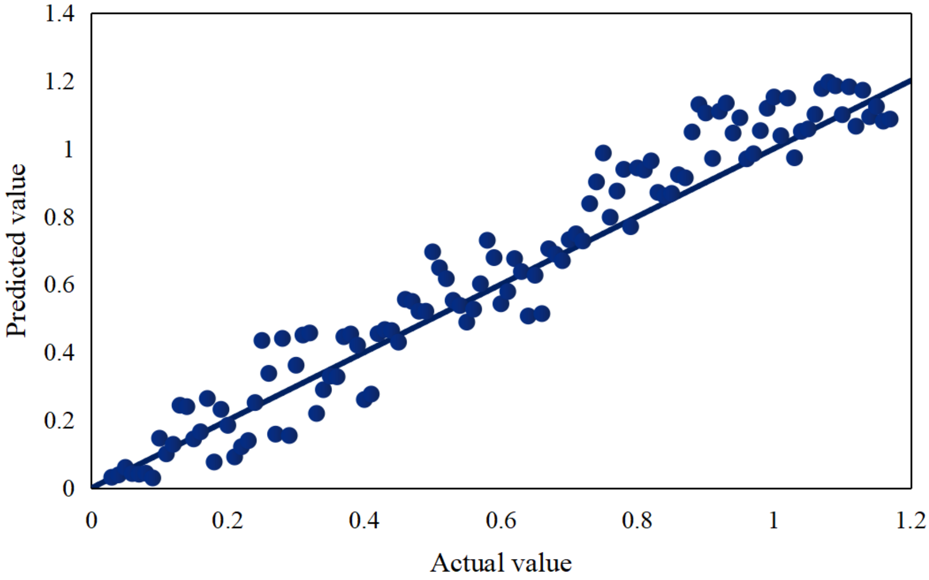

Figure 1 Accuracy test of PSO algorithm

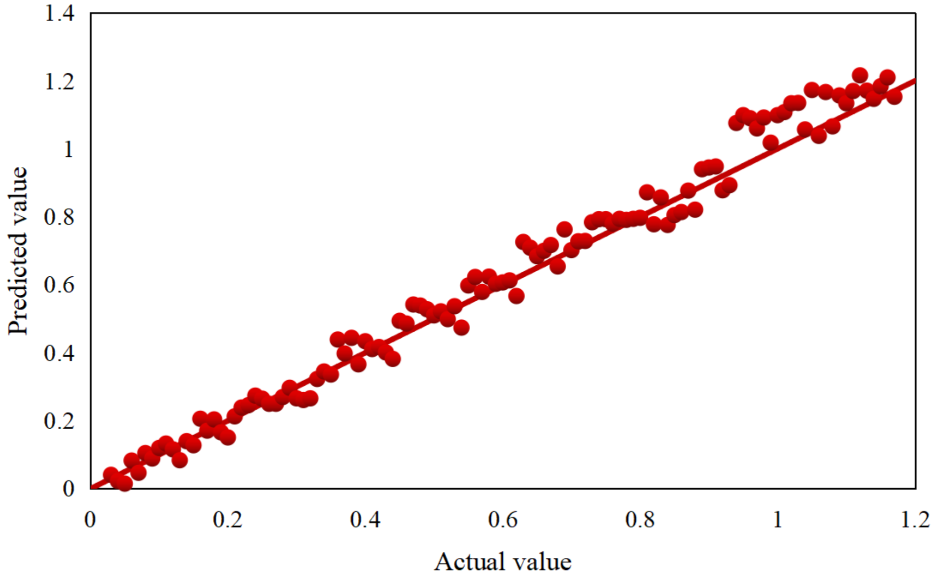

Figure 2 Accuracy test of the algorithm in this article

4. Conclusions

After robots are widely used in industrial fields, the complexity of their movements is getting higher and higher, and it is difficult for a single robot to meet the requirements. Cluster robot system is extended from a single mobile robot. Through effective coordination among multiple mobile robots, it can obtain higher flexibility, robustness and work efficiency than a single mobile robot. In the cluster robot system, robots can share information, plan their paths and coordinate with each other to complete the scheduled tasks. Among them, the task assignment and path planning of multiple mobile robots are the basis for the normal operation of the system, and the coordinated control among robots is the key for the system to complete the scheduled work. In this article, the conflict-free coordinated automatic joint control method of cluster robot is studied, and the coordinated planning and control strategy of cluster robot system is discussed. The simulation results show that the robot obstacle recognition model based on this algorithm is better than PSO in both accuracy and efficiency.

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