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Global Optimal Time Trajectory Planning of Construction Machinery Robot Considering Ant Colony Algorithm

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Abstract: In the practical application of industrial robots, efficiency and quality are important indicators to evaluate the performance of robots. In the continuous path path planning, reasonable path planning and time optimization are crucial to the efficient, accurate and reliable operation of industrial robots. In this paper, on the basis of consulting and analyzing the research of domestic and foreign experts and scholars on trajectory planning, the ant colony algorithm(ACA) is proposed and applied to the optimal time(OT) trajectory global planning of construction machinery robot(CMR) for research and analysis. the ACA is used to optimize the RT of the joints. The planning goal of the optimal RT of each joint of the robot is achieved.

1. Introduction

The accuracy of industrial robot's motion track directly affects the processing quality of products. Once the actual motion trajectory of the robot end deviates from the theoretical trajectory, it will have a serious impact on the surface accuracy of the work piece, which will not only reduce the assembly accuracy of the product, but also affect the reprocessing and operation safety, and cannot meet the production and use requirements. The primary task to improve the motion accuracy is trajectory planning, so as to better complete the specified tasks. If we optimize the time of the robot on the basis of ensuring stable operation, we can meet the high efficiency requirements of the manufacturing industry. In this paper, ACA is introduced to study the OT trajectory global planning of CMR.

The research on OT trajectory global planning of CMR considering ACA has been analyzed by many scholars at home and abroad. Wang T proposed an improved whale optimization method

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(IWOA) based on the whale optimization algorithm (WOA) and differential evolution algorithm (DE) [1]. In order to guide the robot arm accurately, Sadiq A T has upgraded the path planning to optimize the motion of the robot arm. The navigation of a two degree of freedom robot is analyzed, and a free Cartesian space is constructed to detect the free space, thus ensuring collision free path planning. An improved ant colony optimization algorithm is proposed to obtain the optimal path planning satisfying the moving target. The results prove the accuracy and efficiency of the proposed method in realizing the optimal path and trajectory [2].

In this paper, the general problem of trajectory planning is discussed, and the trajectory planning of robot aiming at time optimization is deeply analyzed; the basic principle of ACA is introduced briefly, which improves the optimization performance of the algorithm. In view of the coincidence that the pheromone distribution is equal at the initial stage of the ACA, which leads to the phenomenon that the search time is too long, this function increases the information gain and improves the productivity on the basis of the initial distribution of pheromones Ability to work together. Optimal trajectory planning is one of the most important robot control problems; Finally, MATLAB program is compiled to simulate the first three joints of the robot, and the analysis shows that the method in this paper has achieved good results in time optimization of each joint under the premise of meeting the constraint conditions of the robot [3-4].

2. Path Planning of CMR Considering ACA

2.1. Robot Path Planning Joint Space Interpolation

The joint variables of corresponding points can be obtained through kinematics inversion. At this time, the trajectory points of each joint are interpolated to obtain a smooth fitting function. The motion trajectory of each joint of the robot from the initial point to the planned target point through each given intermediate trajectory point can be expressed by this function expression. Ensure that all joints reach the set track point and target point at the same time [5-6].

Using the index of energy optimization in trajectory planning can bring many advantages. On the one hand, using this standard can produce a smooth trajectory, which is easier for the robot to track. On the other hand, it can reduce the pressure on the robot driver and manipulator structure. In addition, it can save energy, which is also important in some cases, for example, in some cases where energy resources are scarce (space robots, undersea exploration). In some documents, it is proposed to combine energy and time optimally in an objective function [7]. The motion planning problem of PUMA560 robot is optimized by using the quadratic programming (SQP) method. In this paper, the objective cost function balances the execution time, the average force of the manipulator and the energy consumed in the task execution. This method will bring good effect and reduce the tracking error; the structural pressure of the driver and operator is reduced; the resonance phenomenon of the robot is reduced; it can produce more coordinated movement [8-9].

In order to obtain a practical trajectory, the maneuverability is taken as a decision index of robot trajectory planning. However, if the robot is planned in the joint space, the singular point problem does not need to be considered. In order to make the machine trajectory have the performance of all the above indicators, the simplest way is to introduce ACA into a cost function for OT trajectory planning [10-11].

2.2. Overall Scheme Design

First, the improved ACA is applied to plan an optimal path without hitting a wall in a globally known static environment. The robot uses sensors to update the environment information in real time. When the environment information changes (with unknown dynamic obstacles added), the improved ACA is called again for secondary obstacle avoidance optimization. At this time, the optimization path obtained in the global environment is the initial path of the secondary optimization process, and finally a short and smooth path is found, at the same time, it can avoid the optimal feasible path of dynamic and static obstacles [12]. The overall process of path planning is shown in Figure 1.

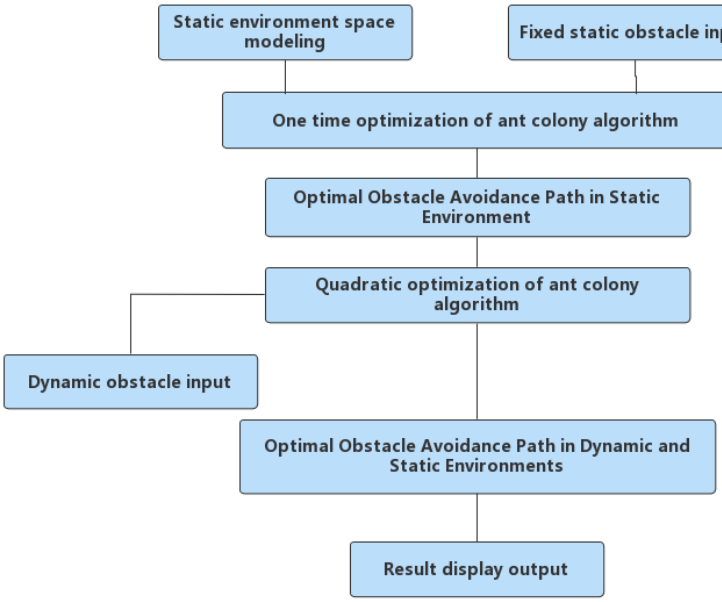

Figure 1. Overall flow chart of path planning

When moving in the environment, if the maximum number of steps of the mother ant is not limited, this may happen: the ant has not found the target, so it will always move in the environment, hindering the detection of other ants, making the system easy to fall into deadlock; The ants have moved many steps to find the target, and there are even rings in the path [13-14].

3. Design of ACA

3.1. Initial Pheromone Distribution

During the initial population generation, because the pheromone distribution difference on each path is not obvious, the probability of ants moving in each feasible direction at a certain point is almost the same, so it will take a long time for the pheromone advantage on the better path to become obvious, so the search time for the initial feasible solution of the ACA is too long, and most of the time is used for the construction of the solution [15-16]. Therefore, this paper introduces the pheromone gain to carry out the initial distribution of pheromones.

For a link, the average value of the information gain of the two endpoints of the link constitutes the information gain of the link. The information gain Gain formula of the road section is as follows:

$$Gain = \frac{1}{2}\left(\frac{d_{CH}}{d_{Ci} + d_{iH}} + \frac{d_{CH}}{d_{Cj} + d_{jH}} \right) \tag{1}$$

where dCH represents the distance between the starting point and the target point, dCi and dCj represent the distance between the starting point and nodes i and j, and diH and djH represent the distance between the target point and nodes i and j.

At the same time, mixed pure components are added for minor adjustment to prevent falling into local optimum. Mixed Pei has a delicate internal structure, and is characterized by randomness, ergodicity and regularity. It is extremely sensitive to initial conditions, and can traverse all states without repeating its own laws within a certain range. It can effectively jump out of the local optimum. Therefore, it is reasonable to introduce mixed pure components here. The initial pheromone distribution formula is as follows:

$$\sigma_{(i,j)}(t_0) = (Gain + q\Delta\gamma) \times \sigma_0 \tag{2}$$

Where, represents the pheromone constant, and q ∈ [0,1] represents the mixed impact; The action intensity of the component, $\Delta\gamma$ Represents a mixed pure component.

3.2. Improve the Construction Efficiency of Initial Feasible Solution

In order to improve the performance of the algorithm and pay full attention to the cooperation of the insect population, we designed an anti-parallel search strategy, that is, from the beginning, we divided all the insects into two groups with the same number and the destination to find the opposite path [17]. Because the use of this search algorithm not only improves the productivity of the original feasible solution, but also reduces the search space of the algorithm by half, ensuring the diversity of the search, making the search difficult to stop.

In view of the phenomenon that the average distribution of pheromones at the initial stage of the ACA leads to too long search time, this paper adds information gain to carry out the initial distribution of pheromones; In order to improve the construction efficiency of the initial feasible solution and give full play to the ability of ants to cooperate with each other in path finding, this paper draws on the parallel search strategy of ants facing each other proposed in the literature, and on this basis, a new ant encounter discrimination strategy is proposed to determine when ants meet, which ensures the integrity of all feasible path search and makes up for the shortcomings of the original method that is easy to lose some feasible paths; The pheromone mutual guidance strategy is designed, and the path selection probability formula is newly designed [18].

4. Experimental Analysis of OT Trajectory Global Planning of Robot Based on ACA

To verify the effectiveness of the proposed ACA based OT trajectory global planning of CMR. According to the mechanical arm parameters of PUMA560 robot, this paper obtains the constraint conditions of joint velocity, acceleration and acceleration, as shown in Table 1 and Figure 2, and carries out experimental analysis.

Table 1. Comparison table of constraint condition data of each joint of robot

Joint	Speed	Acceleration	Acceleration
1	100	45	60
2	95	40	60
3	100	75	55
4	150	70	70
5	130	90	75
6	110	80	70

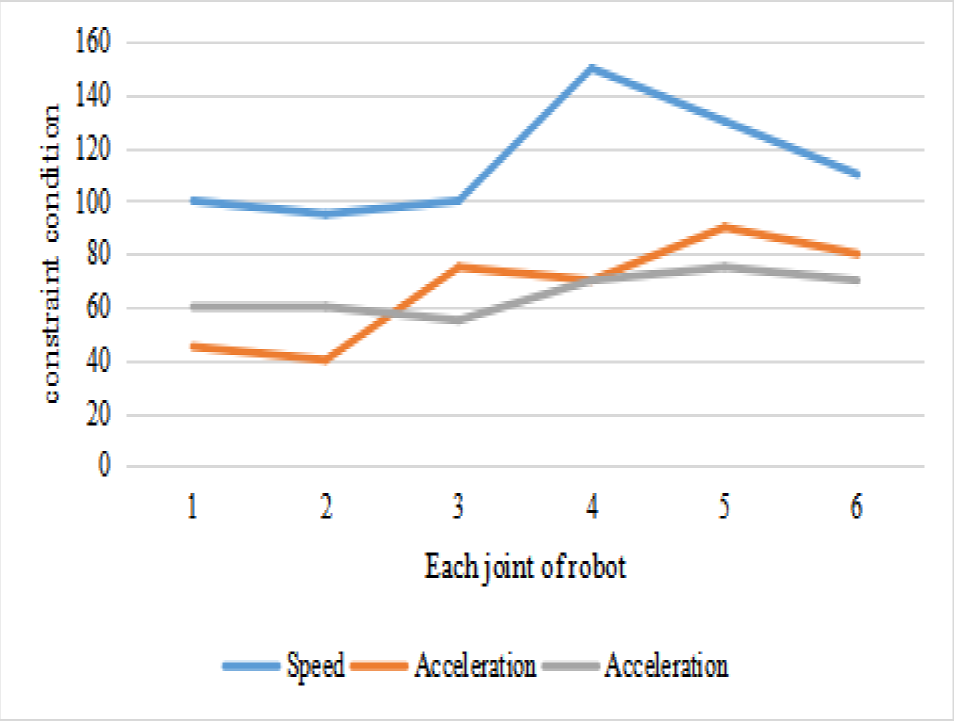

Figure 2. Constraints of robot joints

The data in the table represents the absolute value of the upper limit of the parameter. In this paper, an ACA is used to optimize the robot quintic polynomial function in the shortest time. In the optimization process, each joint track is composed of 7 polynomial function curves, and the optimization accuracy is 0.001 s. The optimization results are shown in Table 2 and Figure 3.

Table 2. Joint optimization results at different time intervals

Time interval	Joint 1	Joint 2	Joint 3
h1	2.785	2.113	3.349
h2	2.032	2.128	2.064
h3	2.316	1.764	1.626
h4	1.578	1.918	1.659
h5	1.824	1.706	2.113
h6	1.487	1.874	1.629

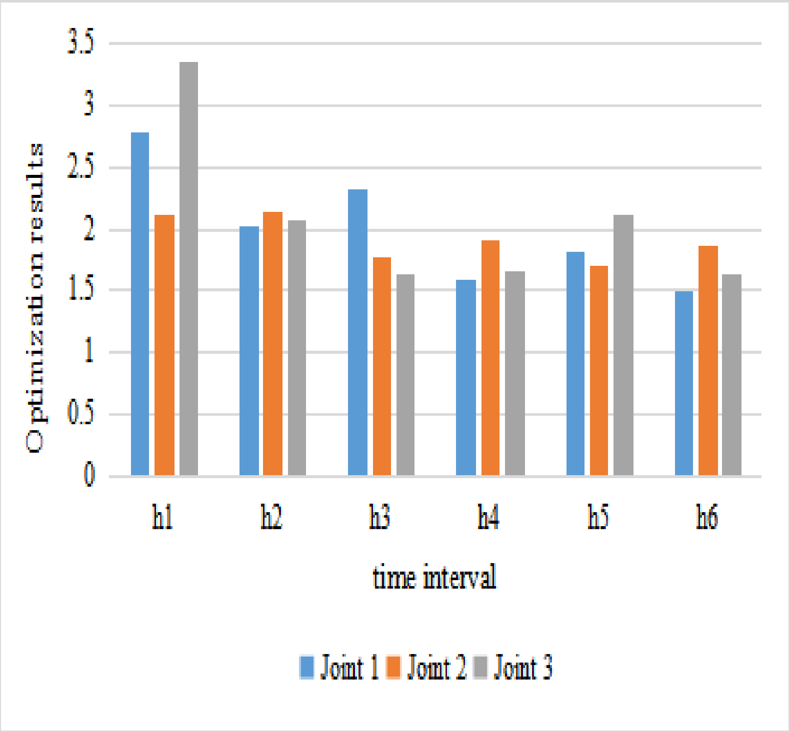

Figure 3. Optimization results of each joint

It can be seen from the above chart that the RT of the robot joint has been greatly shortened after the optimized operation under the constraint conditions of speed, acceleration and acceleration, which better achieved the planning goal of time optimization. And compared with the optimization results of the robot joint RT using the compound optimization algorithm, the ACA used in this paper has a better optimization effect on the shortest time.

In the scheme of using the ACA proposed in this paper to optimize the RT of each joint, the angular displacement, velocity and acceleration curves of joint movement are relatively smooth, which can reduce the impact and vibration of the manipulator, ensure the smooth operation of the robot, and help improve the quality and efficiency of work. And the total time of joint motion is obviously shortened, which shows that the method described in this paper can achieve the goal of time optimal planning.

5. Conclusion

In this paper, a more reasonable ACA is used to optimize the trajectory of each joint of the robot to achieve the goal of time optimal planning. However, there are still some areas that need to be improved and further studied in this paper: this paper only plans the optimal RT of the robot, and can also further study the multi-objective optimization of minimizing energy consumption or combining the two; This paper discusses the situation that there are no obstacles in the robot's moving space, while in actual operation, the robot faces a working environment full of various obstacles. Therefore, obstacle avoidance can be taken into account when optimizing the trajectory of the robot. Finally, the robot trajectory planning method studied in this paper is offline, without considering the real-time nature of the planning task. How to combine off-line planning with real-time tracking to guide the actual operation of the robot is also the next goal to be studied.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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