Sorting path optimization of parallel robot based on improved Genetic Algorithm

Feize Xia¹, Yuan Sun²* and Meng Wang³

¹,²,³ School of mechanical, Shanghai Dian Ji University, Shanghai, Shanghai, 201306, China

*Corresponding author’s e-mail: suny@sdju.edu.cn

Abstract. In industrial production, parallel robot is often used for sorting, battery clamp is divided into two structures, the classification and sorting, for multi-target sorting problems. The motion path of end-effector is planned, the overall sorting path is planned, and the practical problem is transformed into a similar traveling salesman problem. The improved genetic algorithm is proposed to optimize the sorting time sequence, and the optimized path shortens 10.23% total distance on average compared with random sorting and 5.37% total distance compared with fixed longitudinal sorting. The shortening of the total distance can lead to higher sorting efficiency in sorting and increase productivity.

1. Introduction
At the present stage, it has become a trend to introduce technologies such as robots and machine vision into industrial production to improve production efficiency[1]. Delta parallel robot has the advantages of small footprint, strong bearing capacity, high accuracy and fast speed. The sorting system of Delta parallel robot combined with machine vision can adapt to diversified operating environments, significantly improve production efficiency and reduce labor intensity[2]. However, in high-speed motion, problems such as reduced grasping accuracy will occur, resulting in loss of the robot.

In this paper, the Delta parallel robot is used to sort the workpiece. The trajectory design of the end-effector of Delta parallel robot is carried out to improve the grasping speed, reduce the jitter of the robot and reduce the loss and improve the overall sorting efficiency.

2. Single trajectory optimization

2.1. Trajectory optimization
As shown in Fig.1, the Delta parallel robot sorting system consists of a conveyor belt, a parallel robot, a vision module and a control system. The control system adopts upper and lower computers[3]. Fig.2 shows the workpiece to be sorted.

Fig.1 Sorting structure diagram

Fig.2 Sorting workpiece
In order to ensure smooth operation, must optimize the operation of the parallel robot trajectory, the Delta actuator at the end of the parallel robot trajectory approximate portal, arc line method[4], as shown in Fig.3, to be broken down into five parts, including P1-P2, P3-P4, P5-P6 straight-line interpolation, and P2-P3, P4-P5 respectively using circular arc interpolation.

![Fig.3 Sorting trajectory planning](image)

Because the interpolation method will lead to excessive acceleration at the end of the trajectory, a positive modified trapezoidal acceleration change method is proposed for this problem[5]. This method has relatively fast acceleration characteristics[6], but it’s easy to cause the inertia impact of the end-effector. In order to optimize its dynamic characteristics, High order derivative smooth continuous polynomial is used as the transition segment to correct trapezoidal acceleration. The plan is as follows:

\[
S = \begin{cases} 
\left( \frac{t^5}{2\tau^5} - \frac{t^6}{2\tau^4} + \frac{t^7}{7\tau^5} \right)a_{\text{max}} \\
\left( \frac{t^2}{2} - \frac{t^3}{2} + \frac{t^4}{7} \right)a_{\text{max}} \\
- \left[ \frac{(t-4\tau)^5}{2\tau^3} + \frac{(t-4\tau)^6}{2\tau^4} + \frac{(t-4\tau)^7}{7\tau^5} - 3\tau \cdot t + 6\tau^2 \right]a_{\text{max}} \\
- \left[ \frac{(t-4\tau)^5}{2\tau^3} - \frac{(t-4\tau)^6}{2\tau^4} + \frac{(t-4\tau)^7}{7\tau^5} - 3\tau \cdot t + 6\tau^2 \right]a_{\text{max}} \\
- \left( \frac{t^2}{2} - \frac{15\tau}{2} + \frac{113\tau^2}{7} \right)a_{\text{max}} \\
\left[ \frac{(t-8\tau)^5}{2\tau^3} + \frac{(t-8\tau)^6}{2\tau^4} + \frac{(t-8\tau)^7}{7\tau^5} + 12\tau^2 \right]a_{\text{max}} \\
\end{cases} \quad \left[ \begin{array}{c}
0, \\
T \\
8T \\
8T \\
8T \\
T \\
\end{array} \right] \quad (1)
\]

When \( t = 8\tau = T \), 
\[
T = \sqrt{\frac{16S}{3a_{\text{max}}}} \quad (2)
\]

According to equation (1), the displacement, velocity, acceleration and acceleration of polynomial modified trapezoidal acceleration and deceleration algorithm are obtained, as shown in Fig.4.
It can be seen from Fig.4(d) that the change of acceleration is stable, which can prevent jitter caused by acceleration mutation.

2.2. Overall sorting path optimization

Nowadays, many studies focus on single trajectory optimization without focusing on overall sorting path planning[7]. Random sequential sorting and fixed vertical sorting are mostly adopted, which is relatively single. Now, overall sorting path is optimized to improve efficiency. Seeking the shortest path of sorting, this problem is similar to the traveling salesman (TSP) problem[8]. The artifacts and placed on the conveyor belt for the two big urban agglomeration, the end of the actuator for the traveling salesman, urban agglomeration in the dynamic change of workpiece, traveling salesman, alternately in the two big urban agglomeration. A path planning method for dynamic workpiece sorting based on improved genetic algorithm is proposed. The specific process is as follows:

As shown in Fig.5, point O is the starting position of the end-effector, and the grasping sequence is O→A_i→A_{i+1}→A_{i+2}. As can be seen, each grasping stroke is different. In the process of the end-effector grasping, the conveyor belt also maintains a uniform motion state. Under ideal conditions, the end-effector and the workpiece to be captured reach the same position at the same time. Starting when the end of the actuator in O, at this time, the artifacts i in A_i, the artifacts i + 1 in A'_{i+1}, when the artifacts i is captured, the end-effector and the artifacts i should arrive at A_i at the same time, when the artifacts i grab completed and placed it, the artifacts i + 1 position from A''_{i+1} to A'_{i+1}, in the end-effector motion process, The artifacts changes from A'_{i+1} to A_{i+1}. The motion time of the artifacts shall be equal to the motion time of the end-effector, i.e. \(\frac{3\theta_{\text{max}}}{16}T_{OA_i}^2\). Among them:

\[
S_{OA_i} = \frac{3\theta_{\text{max}}}{16}T_{OA_i}^2.
\]

\(S_{OA_i}\) represents the distance of the workpiece from A_i to A_i, and \(S_{OA_i}\) represents the distance of the end-effector from point O to point A_i.

12 times per beat as a sorting task, the total travel is \(\sum 2S_{OA_i}\).
2.3. Improved genetic algorithm path optimization

2.3.1. Algorithm overview.
It's principle is the use of biological "survival of the fittest" evolutionary law. The parameters of the problem to be solved were encoded into chromosomes, and the information of chromosomes in the population was exchanged by means of selective crossover and mutation, and the chromosomes satisfying the optimization goal were generated[9]. The workflow is shown in Fig.6.

![Genetic algorithm workflow](image)

Fig.6 Genetic algorithm workflow

2.3.2. Coding improvement.
The point where the workpiece is placed is numbered O, will stay on the conveyor belt sorting number (1 - n), the part with the position of the workpiece was fetching as (A1-A_n), chromosome is defined as A linear sequence, random one path coding (O→A1→O→A2→…→A_i→O), will appear alternately in the code number O and A use of chromosomes, According to odd and even split into two codes, respectively (A_1→A_2→…→A_i) and O, coding O as the fixed point, only need to operate on the former.

2.3.3. Fitness function.
Fitness function value is the basis for evaluating the quality of a chromosome, this problem is equivalent to the TSP problem that has been grouped, directly making each group the shortest path[10], and the fitness function can be obtained as follows:

\[
F = \sum \frac{1}{2S_{OA_i}}
\]

2.3.4. Improvement of genetic operator.
The crossover variation of genetic operators directly affects the efficiency and convergence speed of genetic algorithm. According to the size of individual fitness value, the operation of survival of the fittest is adopted to generate a new population, and the fitness of each chromosome is divided by the sum of fitness, as the selection probability of each chromosome; The crossover operation determines the global search ability of genetic algorithm. Mutation operation determines the local search ability of genetic algorithm. Under the condition of real-time performance of each beat calculation, a predetermined number of iterations is adopted as the termination condition.
3. Experimental Verification

Using the trajectory of the end-effector of the improved parallel robot and according to the sorting time sequence optimized by the improved genetic algorithm, the workpiece grabbing experiment was carried out. The conveyor belt speed is set as 50mm/s, the number of sorting per beat is 12, the initial population number is 100, and the number of iterations is 200. If optimization is feasible, the total path through the sorting will be shorter than the traditional sorting path. Simulated as shown in Fig.7.

Fig.7 Sorting optimization curve

In order to verify the efficiency of using the improved genetic algorithm, the total distance of the traditional random sorting and fixed vertical sorting was compared with the sorting optimized by the improved genetic algorithm, and the shortening conditions were calculated respectively, and average calculated by formula \( \frac{x_1 + x_2 + \cdots + x_n}{n} \), Specific data reference table 1.

| The serial number | Random sorting | Fixed longitudinal sorting | Optimization of sorting | Shorten percentage /% |
|-------------------|----------------|----------------------------|-------------------------|-----------------------|
| 1                 | 8081.80        | 7605.32                    | 7204.15                 | 10.86%                | 5.27%                |
| 2                 | 7954.29        | 7696.57                    | 7167.35                 | 9.89%                 | 6.88%                |
| 3                 | 8102.14        | 7712.10                    | 7295.16                 | 9.96%                 | 5.41%                |
| 4                 | 8013.65        | 7596.73                    | 7108.72                 | 11.29%                | 6.42%                |
| 5                 | 7996.72        | 7554.12                    | 7301.94                 | 8.69%                 | 3.34%                |
| 6                 | 8003.20        | 7656.37                    | 7257.83                 | 9.31%                 | 5.21%                |
| 7                 | 8094.19        | 7628.96                    | 7279.49                 | 10.07%                | 4.58%                |
| 8                 | 8112.94        | 7580.23                    | 7186.92                 | 11.41%                | 5.19%                |
| 9                 | 7974.27        | 7598.29                    | 7149.30                 | 10.35%                | 5.91%                |
| 10                | 8061.85        | 7636.68                    | 7219.28                 | 10.45%                | 5.47%                |
| The average       | 8039.51        | 7626.54                    | 7217.01                 | 10.23%                | 5.37%                |

By comparison, the optimized sorting path is better, shortening 10.23% on average compared with random sorting path and 5.37% compared with fixed vertical sorting path.

4. Conclusion

In this paper, a sorting path optimization method based on improved genetic algorithm is proposed to solve the sorting path optimization problem of randomly distributed workpiece on a conveyor belt. In tests, the optimized sorting path more shorter than random fixed longitudinal sorting and sorting, increased by 10.23% and 5.37% respectively, and proves that the algorithm can effectively improve the efficiency of the sorting of the Delta parallel robot, a single sorting path to prevent the jitter caused by acceleration mutation, has high accuracy and stability, and can be applied in practical engineering.
References

[1] Wu, X.Q., Huang, J.C., Zhou, L., Lin, J. (2019) Design of intelligent sorting system for parallel robot. J. Mechanical and electrical engineering., 2: 224-228.

[2] Yang, L., Chen, L.S., Xie, Y.C., (2021) Design of intelligent chip sorting Production Line based on Robotstudio. J. Computer Measurement and Control., 8: 137-141.

[3] Zheng, C.H., Ye, Z.Q., Fu, H.X., (2015) Design and implementation of intelligent dense cabinet based on upper and lower computer structure. J. Journal of qiqihar university: natural science edition., 5: 28-32.

[4] Yin, G.L., Bai, R.L., Wang, Y.J., Li, X., (2015) A time-optimal trajectory planning method for parallel robots. J. Computer engineering., 10: 192-198.

[5] Li, X.H., (2016) Design and Research of Visual Sorting and Tracking System for Delta Parallel Robot. D. South China University of Technology., Guang Zhou.

[6] Wang, Y.J., Bai, R.L., Ji, F., (2016) A time optimal trajectory planning method for Delta robot. J. Computer engineering., 12: 295-301.

[7] Feng, L.H., Zhang, W.G., Gong, Z.Y., Lin, G.S., Liang, D.K., (2014) Research progress and status quo of Delta series parallel robots. J. Robot., 3: 375-384.

[8] Wang, Z., Liu, R.M., Zhu, Y.G., Wang, X., (2019) An improved genetic algorithm for solving TSP problem. J. Electronic measurement techniques., 23: 91-96.

[9] Xu, G.S., Xu, Z.Y., Zhou, J.J., Zhang, W.J., Shao, Z.P., (2021) Research on Path Planning Algorithm of Inspection Robot Based on Genetic Algorithm. J. Mechanical Design and Manufacturing Engineering., 06: 93-98.

[10] Zhou, R., Ma, H.W., (2021) Laser cutting collaborative operation path planning based on improved genetic algorithm. J. Logistics technology., 10: 50-55.