The design and implementation of trajectory planning based on 4 DOF industrial robot

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Abstract. With the rapid progress of science and technology, industrial manufacturing and processing technology have also developed rapidly. Industrial robots are widely used in many industrial fields. In this paper, the design and implementation of trajectory planning based on 4 DOF industrial robot is accomplished. Firstly, trajectory planning of the 4 DOF industrial robot is analyzed. Secondly, the operation path is planned, and detailed operation steps are designed. Finally, the simulation verification process of trajectory planning for the 4 DOF industrial robot is completed, and some research results are obtained.

Keywords: 4 DOF industrial robot, Trajectory planning, Simulation.

1 Introduction

Industrial robot is a multi-joint manipulator or multi-freedom machine device widely used in industrial field [1], it can realize various industrial processing and manufacturing functions. Industrial robots are widely used in electronics, logistics, chemical industry and other industrial processing fields. In this paper, 4 DOF industrial robot is taken as the research object, combined with the experimental platform principle, to complete design and implementation of trajectory planning and simulation [2,3].

2 Trajectory planning analysis

Trajectory planning requires the robot arm to arrive at the location of the material, move the material to the processing position [4], restore the initial position and posture, and wait for the next material, so as to carry out the cycle work. The path analysis of material location and processing location is given below. The operation trajectory of the mechanical arm is shown in Figure 1.

3 Operation path planning

The robot used in this design is a specific industrial robot according to the working environment, the working space meets the needs of field operations, the operation accuracy

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is lower, it can carry out long-term repetitive operations, and the joint motion range is ideal. The task is to carry out material handling. There is no specified requirement for the motion between interpolation points, so the simplest operation trajectory satisfying the field operation is set according to the operation trajectory diagram, and the spatial interpolation points P1, P2, P3 and P4 are set. In this design, the quintic polynomial trajectory planning algorithm is selected. The robot can complete the work within the specified time, and the movement of each joint is gentle and the impact is small.

The operation requires the robot arm to arrive at the location of the material, move the material to the processing position, restore the initial position and wait for the next material, which is a working cycle.

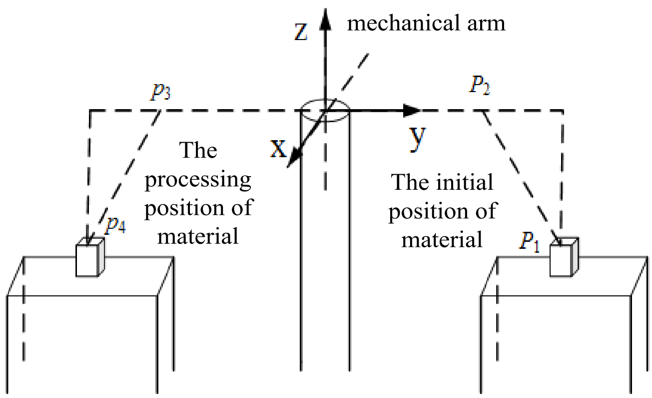


Fig. 1. Schematic diagram of operation trajectory.

Detailed operation steps are: Arm drop → hand claw grab material → arm lift → waist rotation → arm drop → hand claw release → Arm lift → waist rotation. In the specific planning process, the third step of arm lift is followed by the fourth step of waist rotation, and the seventh step of arm lift is followed by the waist rotation to restore the initial state. It is because that the synchronous operation process can save time, but the requirements for the working scene are high and the robot life is damaged. The robot operation path is represented by dotted lines in the operation trajectory diagram. The specific operation process of the robot is as follows.

Step1: The initial position of the robot end effector P1(170°,20°,-70°), it is in waiting for the material state. The joint angles relative to the reference coordinate system are [0°, 0°, 0°], the angular displacement of the waist joint is 0°, the upper arm remains horizontal state, and the forearm is perpendicular to the upper arm.

Step2: When the preset waiting time is reached, the robot starts operation, and terminating position P2(163.92°, 20°, -119.617°), and joint angle [0, $\pi/6$, -$\pi/5$, π], the waist joint is maintained in the initial state, the shoulder joint is moved 30°, and the elbow joint is rotated -36°, so that the hand claw is lowered from point P1 along the planned path to point P2.

Step3: The hand claw is closed to grasp the work piece.

Step4: After the completion of the grasp, keep the waist still, and use the rotation of the shoulder and elbow to make the claw quickly rise from P1 to P2 along the planned route.

Step5: The waist joint rotates 180° and moves horizontally along the arc trajectory to the point P3.

Step6: Keep the waist still, using the rotation of the shoulders and elbows, it can quickly move from P3 point to P4 position along the planned route.

Step7: It opened the hand claw to loosen the work piece.

Step8: The paw rises rapidly along the original path to point P3.

Step9: waist joint counter-clockwise rotation 180°, along the arc trajectory flat movement to point P1.

Step10: The terminal actuator is located at P1, waiting for the state of the material, which is the initial position.

The material transfer is achieved by repeating the above cycle.

4 Verification of the simulation

The simulation verification process of the robot is as follows.

Step1: Mechanical arm modeling, using the revised D-H parameter table[5, 6]

Step2: Limit the angle of each joint

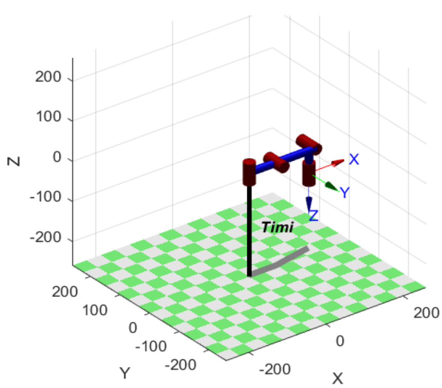
Step3: Model generation

Step4: In this design, a continuous operation track is formed by connecting the end of the interpolation points, the whole process of uniform speed running, the interpolation algorithm chooses the fifth polynomial interpolation. The specific information at P1, P2, P3 and P4 is shown in Table 1.

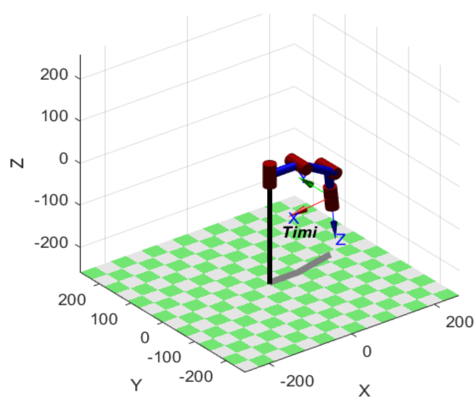
Table 1. Joint angles and orthogonal coordinates in key points.

key points	Joint angles	orthogonal coordinates
P1	[0,0,0,0]	(170,20,-70)
P2	[0, π /6 ,- π /5, π]	(163.92,20,-119.617)
P3	[π ,0,0,0]	(-170,-20,-70)
P4	[0, π /6 ,- π /5, π]	(-163.92,-20,-119.617)

The simulation results are shown in Figure 2(a), Figure 2(b), Figure 2(c) and Figure 2(d).

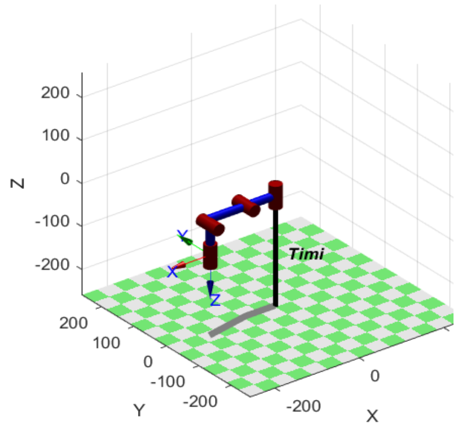


(a) Robotic arm position at p1

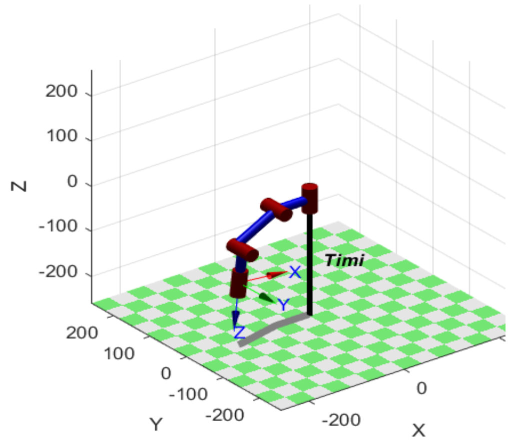


(b) Robotic arm position at p2

https://doi.org/10.1051/e3sconf/202452201035



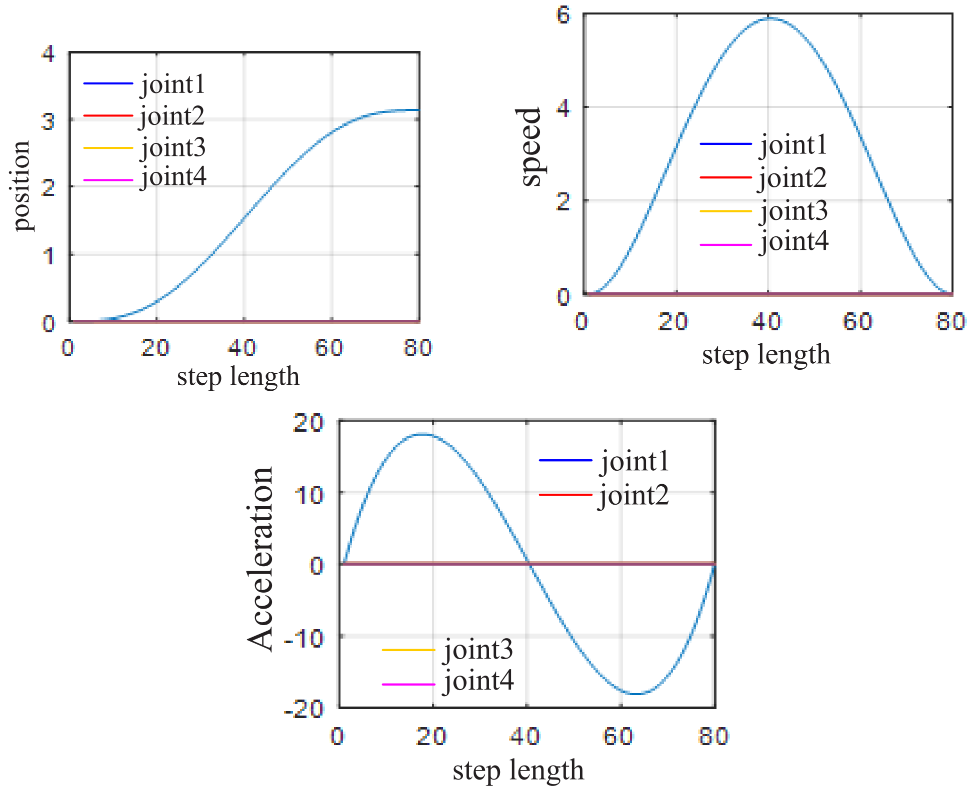
(c) Robotic arm position at p3



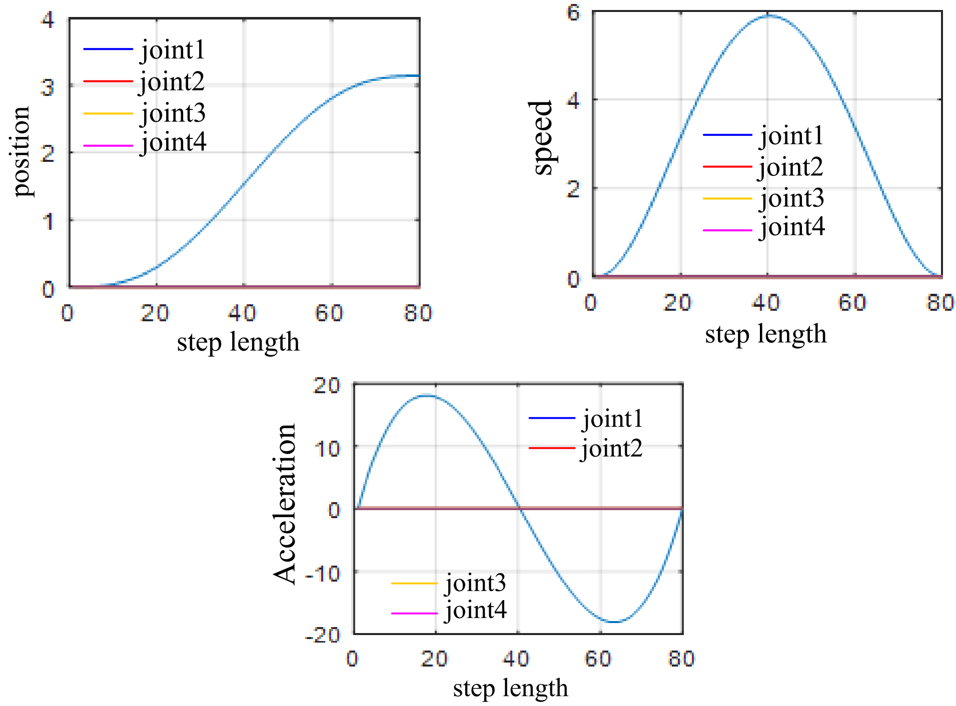
(d) Robotic arm position at p4

Fig. 2. Material handling simulation.

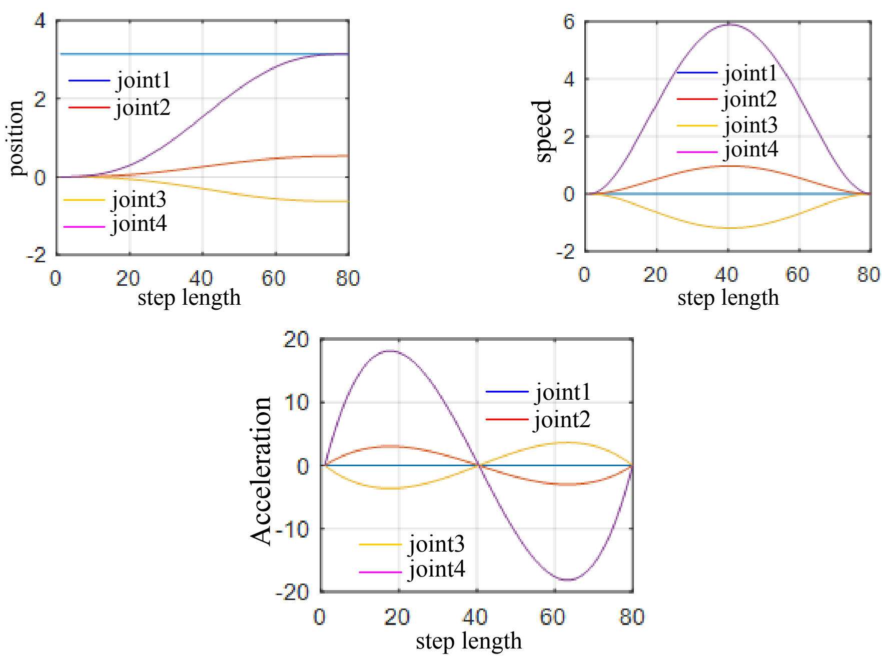
The operating parameters of joint angles are shown in Figure 3(a), Figure 3(b) and Figure 3(c).



(a) operating parameters of P1→P2



(b) operating parameters of P2→P3



(c) operating parameters of P3→P4

Fig. 3. The operating parameters of joint angles of P1, P2, P3 and P4.

5 Conclusions

In this paper, the trajectory planning is designed and realized by combining the 4-DOF industrial robot and the simulation platform. The analysis of trajectory planning of the 4 DOF industrial robot is completed, the operation path planned is realized based on detailed operation steps. Finally, the simulation verification process of trajectory planning for the 4 DOF industrial robot is completed. The simulation results show that the operation process of the four joints conforms to the joint motion constraint of the robot. and some research results are obtained.

This work was supported by the Scientific research ability improvement fund project of Lanzhou Resources & Environment VOC-Tech University(Grant No. X2023A-07).

References

1. Liu L. 2014 Design and Achievement of trajectory planning of the Four-DOF SCARA Manipulator (Hefei: Anhui Polytechnic University)
2. Xing T T. 2012 Kinematics and dynamics analysis and simulation of loading and unloading manipulator (Qingdao: Qingdao University of Science and Technology)
3. ZHANG P X, YAN J H, JIA Q L. 2011 Kinematics analysis of six-DOF manipulator Manufacturing automation vol 33 pp.68-71
4. Shin K G, Mckay N D. 1985 Minimum-time control of robotic manipulators with geometric path constraints. IEEE Trans. Automatic Control vol 30 pp.531-541
5. Gou F Y, Mei T, Zhao J H. 2014 Problems and improvement of D-H method for establishing connecting rod coordinate system China Mechanical Engineering vol 25 pp.2710-2714
6. Yuli WEI. 2023, Kinematics Analysis and Modelling Based on 4 DOF Industrial Robot. Journal of Physics: Conference Series, 2562, 012076