Structural Design and System Simulation of A New Multi Fingered Dexterous Hand

Shujun Liu[1, a], Chao Sun[1]

[1]Shandong University of Science and Technology, QingDao 266590, China.

[a]2717151078@qq.com

Abstract

The size of traditional multi-finger dexterous hand is fixed, resulting in limited working space and being unable to adapt to different sizes and shapes of objects. Aiming at the contradiction between the size of the dexterous hand and the working space, this paper proposes a new underactuated multi-finger dexterous hand structure. Dexterous hand adopt a three finger and three joint structure. The three fingers include a fixed finger and two movable fingers. The movable finger can rotate freely on the palm of the hand. The three joints consist of a moving pair and two rotating pairs. The moving pair can play the role of extending the finger. This structure solves the contradiction that the size of the dexterous hand and the grabbing space cannot.

Keywords

Multi-finger dexterous hand; Crawl space; Kinematics; Trajectory planning; Dynamic Simulation.

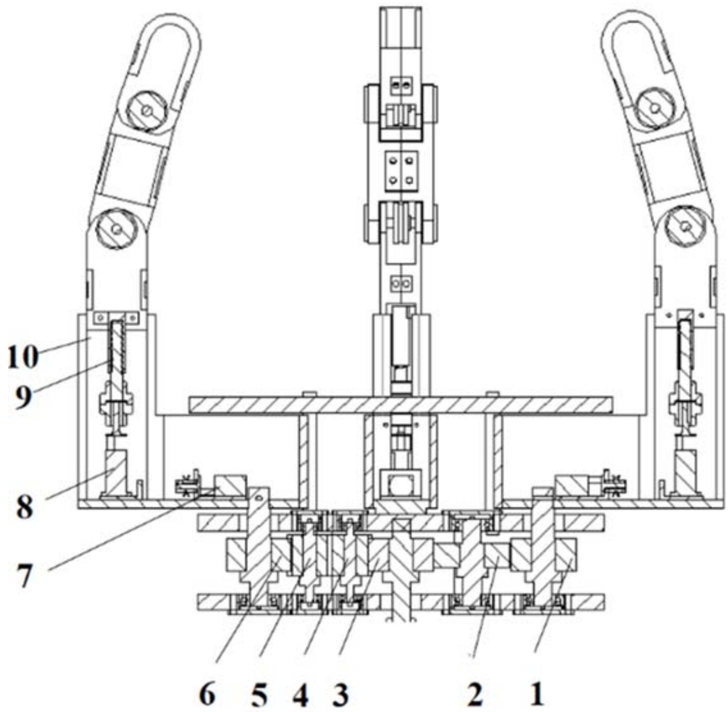
1. Introduction

Firstly, the system Using Solidworks to create a three-dimensional model of the dexterous hand, the configuration of a dexterous hand grasping different objects is simulated; a grabbing method based on fingertip friction is proposed for a small-size object. Next, the D-H parameter method is used to solve the forward and reverse kinematic formulas of the dexterous hand, and the speed of the dexterous hand is analyzed using the Jacobian matrix, which lays a theoretical foundation for trajectory planning. In this paper, the trajectory planning of dexterous hands is performed on the basis of the three-time non-uniform rational B-spline optimization principle based on the shortest path optimization, and compared with the cubic polynomial and cubic B-spline trajectory planning methods to verify the three non-uniform rational B-spline effectiveness and reliability.

Finally, the dynamic equation of dexterous hand is established by using Lagrange method, the model of transmission rope is constructed based on ADAMS, and the dynamics simulation is carried out to analyze the joint torque of the dexterous hand under working condition. The theoretical torque curve based on MATLAB was plotted and compared with the simulation results of ADAMS. The error is within a reasonable range, which verifies the correctness of dynamical theory analysis.

2. The Structure and Working Principle of Dexterous Hand

According to the sectional view of 2-10 and the left view of 2-11, the working process is described in detail as follows: when the external servo motor 11 is started, drive the active gear 3 on the driving shaft to rotate, under the action of the driving gears 2, 4 and 5, make the driven gear 1 and the driven gear 6 rotate in opposite directions, and drive the base knuckle to rotate, so that the rotating fingers on both sides at the same time. Close or away from fixed fingers.When the finger reaches the appropriate position, the tendon-pulley reducer motor 7 starts to start, the steel rope shrinks, through the shaft sleeve to drive the near knuckle pulley shaft 15 rotation, and then drive the middle knuckle pulley shaft 17 rotation, so that the finger complete the bending to grasp the object.When grasping a larger object, the lead screw reducer motor 8 starts and drives the ball screw 9 to rotate through the coupling 12, so that the proximal knuckle 13 can be extended to adapt to grasping.The above working processes are independent and irrelevant, depending on the actual situation.



1. Drive Gear a 2, Drive Gear a 3, Drive Gear 4, Drive Gear B 5, Drive Gear C 6, Drive Gear B 7, Tendon-pulley Reduction Motor 8, Lead Screw Reduction Motor 9, Ball Screw 10, Sliding Guide

Fig 1. Deterous head

3. Inverse Solution of Single Finger Pose Equation

The inverse kinematics solution is the process of solving the joint angle with the known terminal pose. In the previous section, we discussed the joint angle of dexterous hand, calculated the position and posture of each finger and palm, and then analyzed the inverse kinematics in this section. The kinematic inverse method of dexterous hand [64] is divided into two categories: the closed solution and the numerical solution. The closed solution is to solve the inverse problem by solving the nonlinear algebraic equation by using the uniformity of geometry or algebra; the numerical solution is to solve the unknown angle by using the given forward kinematics solution mapping and the expected configuration.

The coordinate system of dexterous hand is established by using D-H matrix method. On this basis, the forward kinematics and inverse kinematics of dexterous hand are analyzed and solved in detail, and the expression of forward and reverse kinematics is obtained. Finally, the velocity of dexterous hand is analyzed, which lays a solid theoretical foundation for the following trajectory planning and dynamic analysis of dexterous hand.

3.1. Trajectory Planning of Dexterous Hand

3.1.1. Description of Trajectory Planning Problem

The purpose of trajectory planning is to obtain a reliable control algorithm. The displacement, velocity and acceleration of each finger are very important parameters, which can be used to evaluate the performance of dexterous hand. The first derivative of the joint variable to time is speed, and the two derivative of time is acceleration.

In general, a series of expected path points in the Cartesian coordinate system are given first, and then the path points in the joint space, namely the rotation angle of the joint, are obtained by solving the inverse kinematics discussed in the previous chapter. Then the difference of path points in joint space is calculated, and the position, velocity and acceleration curves of each joint are obtained.

The new roof will be exposed when the hydraulic support moves one step. In order to ensure the safety of the filling mining face, the pillar should be immediately lifted. The solenoid directional valve is in the right position, the main inlet pipeline is opened, the liquid flows through the hydraulic control one-way valve to the lower chamber of the column, the upper chamber returns the liquid, and the bracket lifting column makes the roof beam cut and support into the initial support stage; when the reversal valve is in the middle position and the roof pressure increases, the pressure of the lower chamber of the column increases and the resistance increases continuously, when the pressure of the lower chamber is greater than the safety valve. Preset pressure relief, maintain the pressure stability of the lower chamber to avoid damage to components, and can support the roof smoothly; when the end of mining need to move the frame, the reversing valve should be left, the liquid through the hydraulic control one-way valve flow to the upper chamber of the column, the lower chamber back to the emulsion chamber of the pump station, the support column contraction landing frame.

3.1.2. Trajectory Planning Method

Aiming at the problems of low accuracy of joint trajectory and trajectory optimization, this paper uses cubic non-uniform rational B-spline to plan the trajectory of dexterous hand based on the principle of shortest path optimization, and compares it with cubic polynomial and cubic B-spline trajectory planning curves to verify the validity of cubic non-uniform rational B-spline. And reliability.

There are many solutions to the inverse kinematics of dexterous hands. In the case of avoiding collision, the choice is usually based on the "shortest stroke", i.e. a set of solutions with the smallest motion of three joints. In the course of calculation, we can weigh the three joints and follow the principle of "less movement of large joints, more movement of small joints". Large joints move up and down near the knuckles, while small joints refer to the rotation of the middle and distal knuckles.

The inverse kinematics is solved by MATLAB, and the trajectory of dexterous hand is optimized based on the principle of the shortest stroke. The cubic polynomial, cubic B-spline and cubic non-uniform rational B-spline motion curves of each joint of dexterous hand are obtained respectively. All the three planning curves are functions of time t. The total planning time is set at 3s. The curves are independent of each other and have no influence on each other. By deriving the cubic polynomial, cubic B-spline and cubic non-uniform rational B-spline curves, the angular velocity and angular acceleration of each joint trajectory can be obtained. This paper only discusses the joint motion curve of far knuckle based on three trajectory planning.

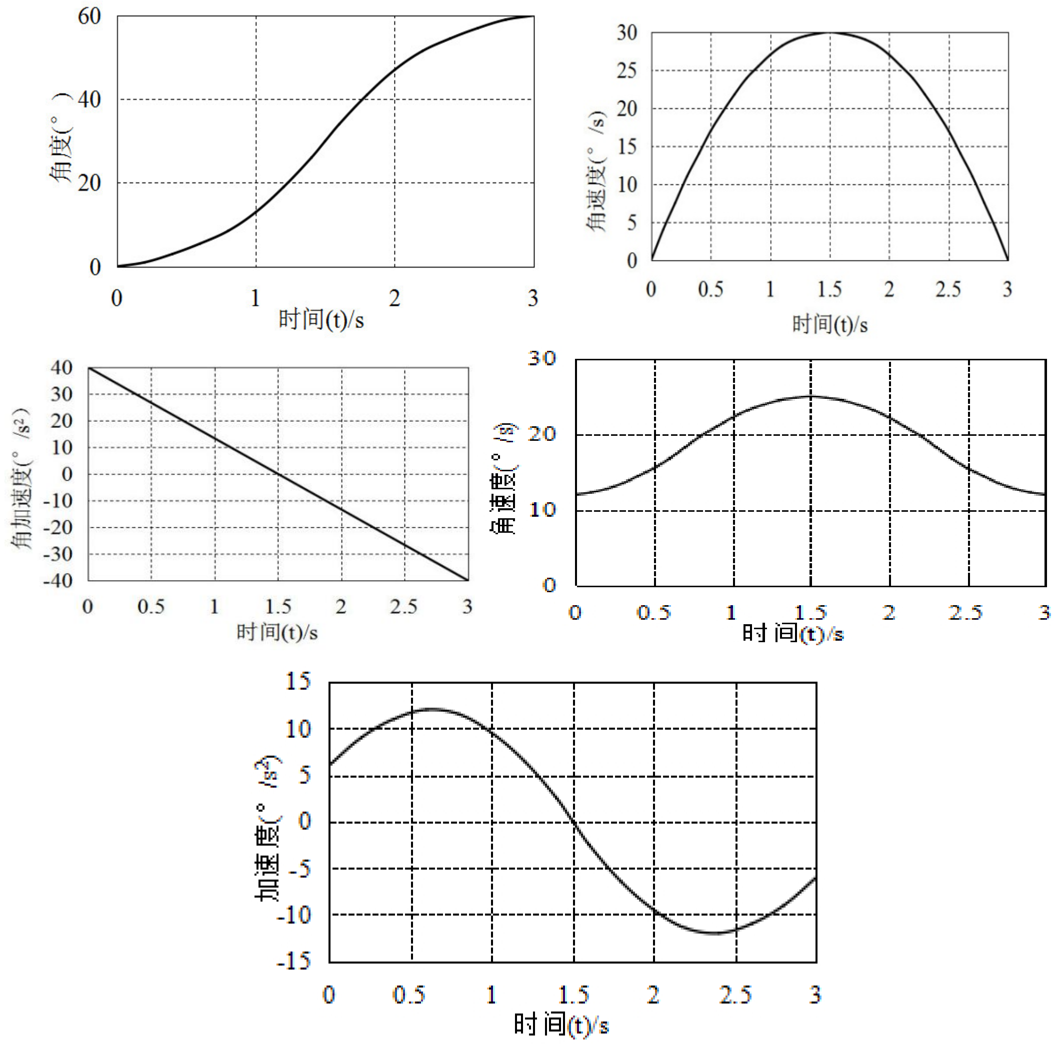


Fig 2. Distal knuckle joint motion curve with three non-uniform rational B spline programming

As shown in Fig. 2, the angular displacement curves obtained by the three methods are not very different, but strictly speaking, the angular displacement curves of cubic non-uniform rational B-spline are gentler than the other two curves. The trend of angular velocity of cubic polynomial and cubic B-spline is similar, they fluctuate up and down between [0,40], but the angular velocity of cubic non-uniform rational B-spline fluctuates slightly up and down 20. The trend of angular acceleration between cubic polynomial and cubic B-spline is not much different, and both are between [-80, 80]. The cubic non-uniform rational B-spline is between [-15, 15], and it is smoother than the other two curves. Therefore, the cubic non-uniform rational B-spline programming method based on the shortest stroke can make the performance of dexterous hand more stable and life longer.

3.2. Workspace Analysis of Dexterous Hands (1) Control Principle of Moving Frame and Pushing Slip

The flexible underactuated three-fingered dexterous hand designed in this paper has one fixed finger and two movable fingers. The base finger and the proximal finger are connected by ball screw, and the length of the finger is adjusted according to the size of the object being grasped. Next, we simulate the grasping space of dexterous hands.

According to the degree of bending of normal fingers, the rotation range of the middle finger joint is about 0 ~ 90 degrees, and that of the distal finger joint is about 0 ~ 60 degrees. Using MATLAB for kinematics simulation, the motion trajectory diagram is shown as lows Fig.3. fol

The curve from outside to inside is the trajectory of distal knuckle endpoint, object contact point and middle knuckle endpoint in turn. Thus we know that the dexterous hand designed in this paper is outstanding in simulating human hands.

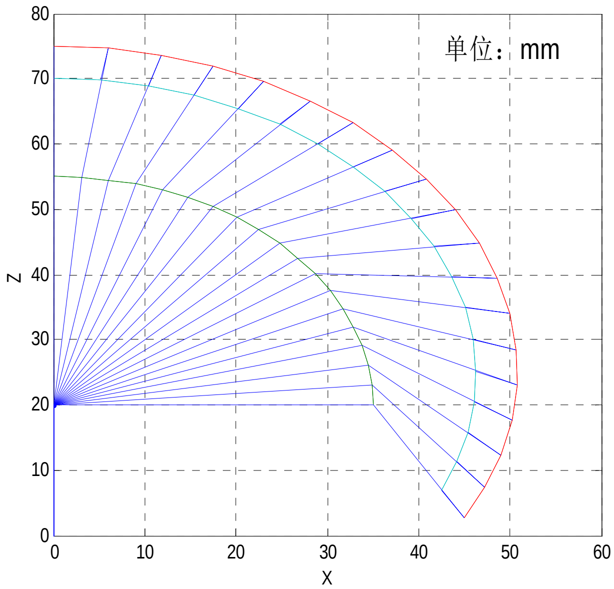


Fig 3. Planar motion trajectory of fixed fingers

4. Conclusion

In this paper, a new structure of multi-fingered underactuated dexterous hand is designed, which is of great significance in industry, extreme environment and bionics. This paper focuses on how to improve the flexibility and adaptability of dexterous hand, carried out in-depth analysis and design, in the process of scientific research results obtained in the following areas:

(1) Firstly, the classical hand bionics is deeply studied and studied, and the appropriate number of fingers, knuckle length, rotation angle and type of motion pairs are selected. Aiming at the incompatible contradiction between grasping ability and dexterity of traditional dexterous hand, a new underactuated dexterous hand is designed, which is simple and adaptive to grasp objects. The 3D model of dexterous hand is established to simulate the configuration of objects grasping different sizes and shapes. A grasping method based on fingertip friction is proposed for a special small size object.

(2) The spatial coordinate system of dexterous hand is established by D-H method, and the forward and backward kinematics of single finger are analyzed, including fixed finger and moving finger. The velocity of dexterous hand in the workspace is analyzed by Jacobian matrix, which provides the basis for the follow-up study of the control and trajectory planning of dexterous hand.

(3) In order to find the best motion path, the trajectories of three-dimensional polynomial, cubic B-spline and cubic non-uniform B-spline programming are compared. The finger workspace of dexterous hand in grasping steel ball and plank is simulated by MATLAB.

(4) the dynamic equation of dexterous hand is established by Lagrange method. A wire rope model was added to the dexterous hand imported into ADAMS, and the joint torque was analyzed when the external force was applied at the fingertip. Finally, based on the joint simulation of ADAMS and MATLAB, the error between the two simulation curves is compared, and within a reasonable range, the correctness of the dynamic analysis is verified.

References

[1] Speeter T H. Control of the Utah/MIT dextrous hand: Hardware and software hierarchy[J]. Journal of Field Robotics, 2010, 7(5):759-790.

[2] Pugh T A M, Mackenzie A R, Langford B, et al. The influence of small-scale variations in isoprene concentrations on atmospheric chemistry over a tropical rainforest[J]. Atmospheric Chemistry & Physics, 2011, 11(9):4121-4134.

[3] Dollar A M. The Highly Adaptive SDM Hand: Design and Performance Evaluation[J]. International Journal of Robotics Research, 2010, 29:585-597.

[4] Grebenstein M, Albu-Schäffer A, Bahls T, et al. The DLR hand arm system[C]. IEEE International Conference on Robotics and Automation. IEEE, 2011:3175-3182.

[5] Hands D, Robot S. Developments in dextrous hands for advanced robotic applications[C]. Automation Congress, 2004. Proceedings. World. IEEE, 2004:123-128.

[6] Jin M H, Wang D J, Fan S W, et al. QNX and Simulink-Based Control Platform for HIT/DLR II Robot Hand[J]. Applied Mechanics & Materials, 2010, 37-38:923-926.

[7] Tetsuya Mouri, Takahiro Endo, Haruhisa Kawasaki. Review of Gifu Hand and Its Application[J]. Mechanics Based Design of Structures & Machines, 2011, 39(2):210-228.

[8] Gazeau J P, Zehloul S, Arsicault M, et al. The LMS hand: force and position controls in the aim of the fine manipulation of objects[C]. IEEE International Conference on Robotics and Automation, 2001. Proceedings. IEEE, 2001:2642-2648 vol.3.

[9] Jiang Z, Xiong H G, BUAA, et al. Test System of Future Avionics High Speed Data Bus based on SCI[J]. Aeronautical Computer Technique, 2002.