Space Robot Motion Planning Oriented to Autonomous Capture Path

Lu Jiayuan*
Chongqing Vocational College of Transportation, School of Intelligent Manufacturing and Automobile Chongqing, China, 402247
* Corresponding author: hitjylu@163.com; hchk15@zjpedi.com

Abstract. Anthropomorphic robots are an important part of the field of robotics. Controlling the motion of anthropomorphic robots through human movements has important research significance not only for robot control research, but also for robots in national defense, rescue, monitoring, logistics, medical care, elderly care, nursing, and education. There are a wide range of application scenarios in such fields. With the increasing maturity of motion data capture equipment and anthropomorphic robot equipment and the diversity of application environments, traditional anthropomorphic robot control algorithms can no longer meet application requirements. This paper combines Microsoft's Kinect and Aldebaran's Nao robot to propose a set of kinematics equation algorithms that fund the capture path to realize the real-time imitation control of human motion by anthropomorphic robots.

1. Introduction
Robots are an important representative of modern advanced intelligent equipment and high-tech. They play an important role in the development of the world's industry. The development of the robot industry can judge whether a country or region's manufacturing level and core competitiveness are in the advanced ranks[1]. At present, different countries have different definitions of robots. My country has adopted the definition of robots from the International Organization for Standardization: a programmable actuator that has a certain degree of autonomy and can move in its environment to perform expected tasks[2]. Robots have many classifications. According to international standards, my country divides robots into industrial robots and service robots. Industrial robots refer to automatic control, reprogrammable, multi-purpose manipulators that can program three or more axes. Divided into fixed and mobile[3]. Service robots are robots that can complete useful tasks for humans or equipment in addition to industrial automation applications. Service robots can also be subdivided into special robots, public service robots, and household robots. The Japan Institute of Industrial Robotics (JIRA) divides robots into 6 categories, namely, manual robots, fixed sequence robots, variable sequence robots, teaching reproduction robots, numerically controlled robots, and intelligent robots. Robotic Industries Association (Robotic Industries Association) only considers the last four categories of the above classification methods as robots. Because robots can improve productivity, safety, efficiency, and ensure product consistency in most scenarios, and can replace manual work in dangerous environments, they do not need a comfortable environment[4]. They are used in national defense, rescue, monitoring, logistics, medical, etc. There are a wide range of application scenarios in areas such as elderly care, nursing, and education. Human-computer interaction is a hot field of robotics research, and a superior and efficient way of human-computer interaction can greatly increase the practical value of robots[5]. Human-computer interaction is an interdisciplinary field of computer,
ergonomics, engineering psychology, and cognition. The main content of its research is the interaction process between humans and machines. The interaction between humans and machines is usually achieved through a set of effective input and output devices. Traditional human-computer interaction methods mainly obtain user input through keyboard, mouse, microphone, touch, sensor, etc., and convert the input signal into computer instructions through computer processing, thereby realizing human-computer interaction. This kind of human-computer interaction is not consistent with human habits in the use of equipment and is also restricted by hardware equipment[6-7].

Controlling the movement of robots through human movements not only has important research significance for the control of robots, but also greatly promotes the application and development of robots in all walks of life. Nowadays, there is still a big gap between the intelligence and usability of robots and people's expectations. Among them, the inability to effectively capture human behavior is one of the important reasons. Therefore, with the development of science and technology, humans hope to be able to control robots to complete tasks that people want to accomplish through a voice or an action. At present, some smart devices have added the function of gesture recognition, but due to the low accuracy of recognition and positioning, the difficulty of target detection and recognition, and the limitation of small amount of information, it is not widely used at present. By using some high-precision motion capture devices to capture human behavior movements, the robot can repeat human movements well and complete certain specific tasks. For example, in special dangerous environments such as national defense, rescue and counter-terrorism, there are some complex three-dimensional scenes that require robots to independently judge[8].

If the path is broken, and the operator needs to maintain a certain safe distance from the specific task location to be completed, then this remote control method will have a huge application prospect; in the medical field, the robot is more stable, the surgical field of view is wider, and the rotating knife position The advantages of being able to reach parts that cannot be manipulated by humans are greatly developed. However, due to the problem of imitation accuracy, the current scientific research field is developing slowly, and there are still many areas that need to be improved. Nowadays, there have been some research results in robot interactive control, but many of them are implemented offline through designed actions or through wearable devices. These implementation methods do not have an advantage in the human-computer interaction experience. In order to improve the robot's imitation of the human body For the interactive experience of actions, this paper proposes a system based on automatic path capturing for robots to imitate human actions in real time[9].

2. Principle of robot motion path

Motion capture is the process of capturing or sampling target posture and position information over time. It is usually used to analyze the extraction and visualization of bones in the process of human motion. It has a wide range of fields in military, entertainment, sports, medical, computer vision, and robotics verification. application. Motion capture systems are usually divided into optical systems and non-optical systems.

Optical systems usually use two or more image sensors to provide overlapping projections to capture and calibrate the 3D position of the target. Devices that use optical systems for motion capture are divided into marked and unmarked devices. In the unmarked system, the tracked object does not need to wear any special equipment for motion tracking. The marking system uses marking points coated with retroreflective materials to reflect the light generated near the camera lens, or to light one or more LED lights very quickly at a time to identify their relative positions to the camera lens.

Forward kinematics is to calculate the pose of the robot end when all the link lengths and joint angles of the robot are known. For forward kinematics, it is necessary to derive a set of equations related to the specific configuration of the robot, so that the known joint and link variables can be substituted into these equations to calculate the pose of the robot, and these equations can also be used to derive the reverse motion Learn equations. The pose of a rigid body in space can be represented by a matrix, where the coordinate origin and the three vectors of the rigid body's own coordinate system pose relative to the reference coordinate system can be represented by the following matrix formula.
Among them, a, o and n respectively represent the attitude of the roll angle, pitch angle and yaw angle in the coordinate system, and p represents the position information in space. The specific steps of model establishment are:

Step1: You only need to specify the z-axis and x-axis. The z-axis in the rotary joint represents the direction of rotation according to the right-hand rule, and the sliding joint points to the direction of the joint linear motion. The standard DH fixes the coordinate system of the link at the output end of the link, so the z-axis at the joint i is represented by z_{i-1}. There is always a common perpendicular with the shortest distance between two adjacent z-axes, which is orthogonal to the two adjacent z-axes, and usually defines the x-axis of the local reference coordinate system in the direction of the common perpendicular. For the common perpendicular ai of zi-1 and zi, the direction of x is defined as along the ai direction. If the z-axes of two joints are parallel, you can select a common vertical line that is collinear with the common vertical line of the previous joint to simplify the model; if the z-axes of two adjacent joints intersect, it will be perpendicular to the two straight lines. The straight line of the plane is designated as the x-axis.

Step2: Transform a reference coordinate system to the next coordinate system after necessary movement. For the coordinate system z_{i-1}x_{i-1} conversion to the next local coordinate system z_{i+1}x_{i+1}, the following four steps can be done: rotate around the z_{i-1} axis +1 to make x_{i-1} and x_{i+1} parallel to each other; translate d_{i+1} along the z_{i-1} axis The distance of 1, makes x_{i-1} and x_{i+1} collinear; translate the distance of a_{i+1} along the x_{i-1} axis that has been rotated, so that the origins of x_{i-1} and x_{i+1} coincide, at this time the origins of the two reference coordinate systems coincide; The z_{i-1} axis rotates around the x_{i+1} axis to align the z_{i-1} axis with the z_{i+1} axis. At this time, the coordinate system i and i+1 are exactly the same, and we have successfully converted from one coordinate system to the next.

Step3: Use four right-multiplied motion transformation matrices to represent the transformation between two coordinate systems.

To drive the robot to the desired pose, the value of each joint needs to be determined. Through the D-H model established above, we can use inverse kinematics to solve these joint values. Solving the robot inverse kinematics equations can obtain the joint angles directly used to drive the robot to the desired position, but in the actual solution, the inverse solutions must be calculated and these equations must be derived, and then they can be used to drive the robot to the desired position. In the actual operation of the robot, the computer calculates the inverse of the forward kinematics equation or brings the value into the forward kinematics, and uses the Gaussian elimination method to solve the unknown joint vector will take a lot of time. In order to make the robot move according to a predetermined trajectory, such as moving in a straight line segment, the computer must calculate the joint angle multiple times within one second, because when the robot only knows two points, the trajectory between these two points is unknown. Yes, it depends on the rate of change of the robot joints. In order to make the robot move according to the desired path, the path must be divided into multiple small segments so that the robot can move between two points.

Follow the divided small and short paths to move in sequence. This also means that a new inverse kinematics solution needs to be calculated for each short path. The shorter the time to calculate the new solution, the more accurate the robot's motion. There are many methods to solve inverse kinematics, which can be roughly divided into two categories: analytical method and numerical method.

The analytical methods mainly include geometric methods and algebraic methods. The geometric method is to perform geometric operations through the obtained human limb vectors to obtain the corresponding joint angles. The advantage of this method is that the calculation is fast, the new inverse kinematics solution can be quickly solved when the bone data is acquired by the capture device with
high frame rate, and the high-angle similarity simulation can be performed. The disadvantage is that the end trajectory similarity is not high. Formula (2) is the main formula to obtain the joint angle of the robot by the geometric method.

\[ \theta = \arccos \left( \frac{\mathbf{a} \cdot \mathbf{b}}{||\mathbf{a}|| ||\mathbf{b}||} \right) \]

(2)

The algebraic method uses the conversion equation established by the D-H model to perform related matrix operations to obtain the solution formula of the joint angle, which is also a general method of inverse kinematics analysis. The algebraic method is to do all the mathematical processing in advance, and the inverse kinematics solution can be obtained faster when the actual computer controls the robot. Establish the D-H model of the left arm of the Nao robot, as shown in Figure 1.

![Figure 1 Robot arm](image)

3. In conclusion

The robot industry in today’s society is developing very rapidly. This is mainly because the robot industry is the joint supporting equipment for the development of advanced manufacturing, and an important entry point to transform the production and lifestyle of human society. The R&D and industrialization of the robot field is also a measure of a country’s science and technology. Innovation, one of the important signs of the development level of high-end manufacturing. In the field of robotics-related research, anthropomorphic robots simulating human motion is an important part of it. In some dangerous or inaccessible areas, robots can be used to imitate human movements instead of humans to complete some high-risk tasks, so how to ensure robots. It is of great research significance to be able to imitate human movements in real time. This paper combines somatosensory devices and anthropomorphic robots, using Microsoft Kinect sensors and Nao robots to realize the related research of simulating human actions. By analyzing the similarity of the angle configuration of the action simulation and the similarity of the end trajectory, the simulation effect of the experimental results is evaluated.

References

[1] Guo Wei. Research on motion control of humanoid robot based on depth sensor [D]. Nanjing University of Posts and Telecommunications, 2020.
[2] Chen Yu. Research on Robot Intelligent Grabbing Method Based on Meta-learning [D]. Nanjing University of Posts and Telecommunications, 2020.
[3] Xie Dongfu. Research on the structure and motion performance of a composable hexapod robot adapted to mountain orchards [D]. Nanchang University, 2020.
[4] Wang Chundong. Research on Modeling, Motion Planning and Control of Jumping Self-balancing Robot[D]. Dalian Maritime University, 2020.

[5] Zheng Xiaoxuan. Research on path planning and control system of mountain citrus picking robot[D]. Hubei University of Technology, 2020.

[6] Zhang Bo. Research on robot interaction method based on multi-space unification [D]. South China University of Technology, 2020.

[7] Xu Cong. Research on rotating and climbing soft robot based on vibration drive [D]. Zhejiang University of Technology, 2020.

[8] Yu Jiayuan. Research on the imitation learning method of humanoid robot motion based on HMM[D]. Beijing University of Architecture and Architecture, 2020.

[9] Zhang Huayan. Research on the Visual Localization and Motion Planning Methods of Humanoid Robots in Dynamic Environment [D]. Beijing University of Architecture and Architecture, 2020.