Research on Artificial Intelligence Robots and Simulation Software in Virtual Training Pendant

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Abstract. Under the background of artificial intelligence education, the application of RobotArt industrial robot simulation software in university teaching can make teaching "low carbon", which not only saves training equipment, effectively reduces teaching costs, and greatly improves the learning efficiency of industrial robot programming. The thesis combines virtual simulation technology and practical operation in the training workshop to quickly improve the teaching effect, reduce the hidden safety hazards in the training process, and enable students to quickly grasp the key points of teaching, and at the same time, it can also reduce the teaching difficulty and work of the training teachers.

Keywords: Artificial intelligence, intelligent robots, college education, industrial robot simulation.

1. Introduction
High-end CNC machine tools and robots are one of the "ten key areas of manufacturing" in the "Made in China 2025" plan. At present, the demand for intelligent equipment such as industrial robots in the production line continues to expand. Experimental teaching courses for industrial robots are very important in the training of relevant professional courses. The industrial robot system is complex, expensive, and the cost of experiment and maintenance is high. The application of virtual simulation technology in the experimental teaching of industrial robots is an efficient and economical solution. In the RobotArt software, you can operate and program the robot with the virtual teach pendant just like using the actual teach pendant to operate and program the robot; you can simulate the actual industrial robot workstation for the design and verification of the scheme [1]. The robot program can be directly downloaded to the actual robot system without any conversion; the model built by the third-party mainstream modelling software can be imported, so that users can develop or maintain the robot program offline in the Windows environment, significantly shortening the programming time and improving the program structure.
2. Virtual simulation modelling of industrial robots

2.1. Robot structure analysis
In this paper, industrial robots for assembly operations are used as virtual simulation objects. This type of robot is an articulated six-axis robot, which has the advantages of large working range, long reach and compact structure [2]. It has been widely used in arc welding, material handling and process applications, and has a typical experimental teaching value. The structure of the six-axis industrial robot is shown in Figure 1, and the specific parameters of each joint axis are shown in Table 1.

![Figure 1. The structure of a six-axis industrial robot.](image)

| Shaft type                  | Axis name   | Axis action description | Axis movement range |
|----------------------------|-------------|-------------------------|---------------------|
| Spindle (basic axis)       | Axis 1 (J1) | Body rotation           | From $+170^\circ$ to $-170^\circ$ |
|                            | Axis 2 (J2) | Arm exercise            | From $+150^\circ$ to $-90^\circ$ |
|                            | Axis 3 (J3) | Forearm movement        | From $+80^\circ$ to $-100^\circ$ |
| Secondary axis (wrist movement) | Axis 4 (J4) | Wrist rotation          | From $+155^\circ$ to $-155^\circ$ |
|                            | Axis 5 (J5) | Wrist flexion           | From $+135^\circ$ to $-135^\circ$ |
|                            | Axis 6 (J6) | Circular wrist movement | From $+200^\circ$ to $-200^\circ$ |

Among them, axis 1-axis 3 respectively control the rotation of the base of the robotic arm, and the rotation of the lower arm and upper arm; axis 4-axis 6 control the rotation of the spherical wrist joint at the end of the upper arm in 3 degrees of freedom in space. Among them, cylinder clamps, welding guns, spray tools, etc. can be installed on the flange at the end of shaft 6 to realize robot operations.

2.2. The establishment of the robot 3D model
The basic work of virtual simulation is to establish a three-dimensional model of the corresponding entity. A robot is a comprehensive system composed of a variety of parts assembly, and its component structure and assembly relationship are complex. Virtual simulation not only requires the design of the robot's model to be close to the actual equipment, but also requires the cooperation of the model's material, scene, lighting and other simulation elements in order to well restore the robot's real physical motion effect [3]. On the premise of ensuring the structure and dimensions of the model, perform operations such as rendering the appearance of the model to make it beautiful and realistic.
2.3. Realization of simulated motion of industrial robot

Establishing the logical relationship of the simulation movement According to the classification of robot components and the movement relationship between the components, the logical affiliation of each component model of the robot can be established. For six-axis rotary joint robots, the movement of axis \( i \) is based on the movement of axis \( i-1 \). According to the knowledge of robot kinematics, the transformation relationship between the coordinate systems of each axis of the robot can be described by a homogeneous transformation matrix. Define \( T_{i-1}^{i} \) as the coordinate transformation matrix of the axis \( i \) coordinate system \( ii i iOXYZ \) relative to the axis \( i-1 \) coordinate system \( i-1 i i-1 OXYZ \), and the point \( P \) in the space is represented as \( P_i \) and \( P_{i-1} \) under the coordinate systems \( ii i iOXYZ \) and \( i-1 i i-1 OXYZ \), respectively, then:

\[
P_{i-1} = T_{i-1}^{i} P_i
\]

The coordinate transformation of a six-axis industrial robot can be expressed as:

\[
T_0^n = T_n^6 \ldots T_2^1 T_1^0
\]

Among them, \( O_{i-1}iX_iY_iZ_i \) is the base standard system. From equations (1) and (2), \( P_0 = T_0^n P_n \), that is, the motion coordinates of the robot end effector relative to the base frame can be obtained by the transformation of the six-axis motion parameters. In RobotArt environment, the continuous transformation between each axis can be defined by the subordination relationship between the three-dimensional model of each axis component [4]. The hierarchical structure association method is used to express the subordination relationship of each part model of the robot (see Figure 2), and the robot model can be divided into the motion relationship tree, the axis motion part relationship tree and the axis subordinate part tree. Among them, each shaft movement relationship drives the corresponding shaft component to rotate, and the rotation of the shaft component drives the movement of other components subordinate to the shaft component.

![Figure 2. The affiliation of the robot component model.](image)

3. System design of simulation teaching platform in colleges and universities

3.1. Virtual simulation teaching practice process

In the actual simulation teaching practice, the simulation teaching can be divided into five stages (taking the robot to move along the specified rectangular path as an example). The first stage is to
import scenarios and assign tasks. In this part, first import the welding gun as a tool, then set the TCP coordinates and import the rectangular workpiece. In the second stage, the teacher uses the software to explain and demonstrate the instruction functions needed for this task. The rectangular path movement uses the offs function to accurately determine the exact value of the movement path. The movement path of the robot starts from the starting point P1, passes through the points P2, P3, and P4, and returns to the starting point P1.

At this stage, the students will learn programming independently and communicate with each other, and teachers will help them answer questions. The third stage is for students to program and debug offline on RobotArt simulation software [5]. The fourth stage is to import the post code to the body teach pendant of robots such as ABB or KUKA for operation and debugging. The generation of the post-code is shown in Figure 3. At this stage, considering the safety issues and the limited number of equipment, the team leader or representative of each group can complete the operation of the robot body. Teachers should pay close attention to the operation of each machine throughout the process to avoid student collisions and other safety accidents. The fifth stage is task acceptance. That is, the teacher will give the students' final grades of the project based on the offline programming, online debugging and completion time of each group of robots, which will serve as the basis for the course evaluation.

Figure 3. Generate post code.

3.2. Simulation effect
The layout of the industrial robot arc welding simulation training project workstation is shown in Figure 4. The selected industrial robot model is IRB2600, and the positioner model is IRBPA. With the cooperation of the positioner, the industrial robot performs arc welding operations on the parts mounted on the positioner [6]. The specific work steps are: the positioner rotates 90° in one axis, and the round holes on the parts are levelled. The robot arc welding is large. On one side of the hole, the positioner rotates 180° on the two axes, and the other side of the small hole is arc welded. According to the progress of the training, continue to complete the arc welding of the remaining sides of the large and small holes.
The main contents of the training project are: (1) Building a welding robot working environment; (2) Building a model; (3) Importing and activating the positioner; (4) Installing workpieces on the positioner; (5) Multi-path Adding and adjustment of execution order, etc. In the training of this simulation project, in addition to the simulation of the industrial robot body, the simulation processing method of peripheral equipment is added.

4. Teaching evaluation of industrial robots in universities
The prerequisite for implementing the virtual simulation training teaching program of the industrial robot course is to establish a network training room equipped with Robotstudio software, and the number of computers matches the number of training students. If the teacher’s computer is equipped with multimedia network software, the teacher can conveniently use the network teaching platform to complete various teaching activities based on multimedia technology. For example, the teacher tells the development process of the virtual workstation on the teacher’s computer and broadcasts it to each student computer. View the process and results of each student's development of the simulation project on the teacher's computer.

The industrial robot training teaching program has been applied in the 3rd student training teaching of Mechatronics major in the School of Mechanical Engineering of our school, and has received very good training results, which greatly improved students' interest and sense of accomplishment in participating in the training. It stimulates students' enthusiasm for learning and innovative thinking, is conducive to students' innovative practice activities, and also stimulates teachers' enthusiasm for virtual simulation training and teaching. Practice has shown that virtual simulation programming and virtual simulation training of the debugging workstation can give students plenty of room for error correction, and students can repeatedly practice key technical points in the software, thereby greatly reducing beginners’ unskilled operation of industrial robots. The damage to the equipment also solves the problem of insufficient training equipment and funds, reduces the cost of training, and improves the efficiency of practical training.

5. Conclusion
This paper takes the six-axis industrial robot as the research object, analyses its mechanical structure, component composition and kinematic relationship, and integrates a full-scale robot three-dimensional simulation model in the RobotArt virtual simulation environment. On this basis, a six-axis industrial robot virtual simulation teaching system was designed and developed. The application of RobotArt industrial robot simulation software in teaching can make teaching "low-carbon", which not only saves training equipment, effectively reduces teaching costs, but also frees students from the training room, so that students can use computers no matter where they are. Learning with the Internet has greatly improved the learning efficiency of industrial robot programming.
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