Research on Modeling Technology of Virtual Robot Based on LabVIEW

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Abstract. Because of the dangerous working environment, the underwater operation robot for nuclear power station needs manual teleoperation. In the process of operation, it is necessary to guide the position and orientation of the robot in real time. In this paper, the geometric modeling of the virtual robot and the working environment is accomplished by using SolidWorks software, and the accurate modeling and assembly of the robot are realized. Using LabVIEW software to read the model, and established the manipulator forward kinematics and inverse kinematics model, and realized the hierarchical modeling of virtual robot and computer graphics modeling. Experimental results show that the method studied in this paper can be successfully applied to robot control system.

1. Introduction
With the progress and development of science and technology, human activity space is no longer limited to the field of human survival. It has penetrated into the deep sea, outer space, nuclear radiation, toxic and harmful environment, and other dangerous environment. At this point, dangerous operating robots are being used. Instead of human beings, they enter the job site, operate under human control or do their work autonomously, [1]. The robot in this paper is a robot which is used in the underwater environment of nuclear power station to identify and salvage foreign bodies. Due to the particularity of the environment, the operators are not able to work close observation of the robot, with the help of robot carrying a camera, can realize the identification and tracking of foreign body, but because of the camera installation position and angle limit, still unable to observe the full range of the position and pose of the robot, the robot control becomes very difficult. In order to solve this problem, we join the virtual robot model is highly consistent with the real robot, motion driven real-time virtual robot with real robot pose information, through the observation of the movement of virtual robot, obtain the real robot working position. The operation difficulty of the operator is greatly reduced, and the operability of the whole system is improved.

There are many modelling methods for virtual robots, and various modelling software are springing up. Different methods and software have different characteristics:
(1) using OpenGL graphics library combined with VC, VC++ or VB tools.
This method is relatively mature, there have been many successful examples of [2,3], but the procedure is too complicated, need to draw a graphical programming language, when the graphics is complex, or the accuracy is relatively high, the workload alarming, and graphics effect is not realistic, the effect is not very ideal.
(2) using virtual reality commercial software.
There are many mature software, such as VRP in China, Virtools in France, EON Studio in USA, visual simulation driver software, WTK, /VTK, /STK, Quamtum3D, OpenGVS and so on. These software has made great progress in modeling virtual scene. But when it is applied to the virtual simulation of industrial robot, it is not accurate, convenient and quick to construct and modify the geometric characteristics of mechanical products. And it can not exactly reflect the position information of real manipulator. In teleoperation robot, the maximum efficiency of virtual reality can not be realized[4,5].

2. Robot structure and kinematics analysis

2.1. Robot structure analysis

The robots studied in this paper are applied to the underwater environment of nuclear power plants, and the identification and salvage of foreign bodies in the high radiation environment of nuclear power plants are realized. The main body includes the following parts, such as car body, large camera, small camera, waist, big arm, small arm, wrist and gripper, as shown in figure 1.

![Main structure of robot](image1)

**Figure 1. Main structure of robot**

![Robot coordinate system](image2)

**Figure 2. Robot coordinate system**
2.2. Kinematics Analysis of Robot

According to the law of motion of robot, coordinate system is set up, as shown in Figure 2. When a robot does a job, he usually needs to do the following. With the movement of the robot in the working environment, the vehicle mounted large camera visits a round, when the foreign body is found, the recognition and tracking of the vehicle are realized. At the same time, the information transmitted by various sensors on the vehicle body is detected. When the foreign body enters the manipulator's grab range, the crawl mode is started and the virtual robot model is enabled. It is only necessary to analyze the kinematics of the robot in the grasping process. As shown in Figure 2, the waist rotates around the Z_1 axis, the big arm revolves around the Z_2 axis, the small arm revolves around the Z_3 axis, the wrist rotates around the Z_4 axis, and the gripper movement is realized by a special mechanism, and the manipulator end point coordinate system is O_5-X_5Y_5Z_5. The connecting rod size information is shown in Table 1.

### Table 1. Every connecting rod size of robot

| connecting rod i | twist angle α_\[i\] | Length of connecting rod a_\[i\]| Twist angle θ_\[i\] | distance d_\[i\] |
|------------------|----------------------|-----------------------------|-------------------|--------------|
| 1                | 0°                   | 0                           | θ_1               | d_1=0.065m   |
| 2                | -90°                 | 0                           | θ_2               | 0            |
| 3                | 0°                   | a_2=0.300m                  | θ_3               | 0            |
| 4                | 90°                  | 0                           | θ_4               | d_4=0.270m   |
| 5                | 0°                   | 0                           | 0                 | d_5=0.141m   |

Because,

\[
i^{-1}T = R_x(\alpha_{i-1})D_x(a_{i-1})R_z(\theta_i)D_z(d_i) = \begin{bmatrix} c\theta_i & -s\theta_i & 0 & a_{i-1} \\ s\theta_i c\alpha_{i-1} & c\theta_i c\alpha_{i-1} & -s\alpha_{i-1} & -s\alpha_{i-1}d_i \\ s\theta_i c\alpha_{i-1} & c\theta_i c\alpha_{i-1} & c\alpha_{i-1} & c\alpha_{i-1}d_i \\ 0 & 0 & 0 & 1 \end{bmatrix}
\]

And

\[
0_5T = 0_5T(\theta_5)j_5T(\theta_3)j_5T(\theta_2)j_5T(\theta_1)j_5T(\theta_0)
\]

Because,

\[
0_5T = \begin{bmatrix} c_2c_3c_4s_2s_3 & -s_2c_3c_4 & c_3s_2 & c_2s_2s_3(d_4 + d_5) + a_2c_2 \\ -s_2c_3c_4 & c_3s_2 & c_2s_2s_3(d_4 + d_5) + a_2c_2 \\ -s_2s_3c_4 & c_2s_3 & c_2s_3(d_4 + d_5) - s_2a_2 + d_4 \\ 0 & 0 & 0 & 1 \end{bmatrix}
\]

3. The Establishment of Virtual Model

3.1. Model Building

In LabVIEW, there are two ways to build model. (1) draw the model (2) by using the geometric VI of LabVIEW, and import the model built by external CAD software. The first method is used to model simple geometry and complex assembly relations. Second methods, you can import geometry model format, ASE, STL, VRML, three kinds. ASE format used in 3D Max more, VRML and STL format is more common, in SolidWorks, Pro-E, AutoCAD and other software can be used[6].

The VRML (Virtual Reality Modeling Language) is a platform independent operation, based on 3DWeb, describing interactive 3D world and object language, it by creating a virtual scene to achieve real effects. Virtual reality scene created by VRML is a realistic simulation of the 3D product modeling, hierarchical, multi sensory object oriented characteristics of the virtual world, interactive,
real-time and support web browsing, and because the VRML file as HTML document upload / download, and start the VRML browser to watch the 3D model of the document described, a good solution to the problem of information exchange and sharing [7,8].

The shape and assembly relationship of robot in this research are complex, and second methods are adopted. Draw the model using SolidWorks, export VRML format file.

3.1.1. **SolidWorks rendering model**

A comprehensive analysis of the robot body during the crawling process not only exercise the waist, big arm, small arm, hand motion, simple procedures, the robot is divided into five parts, body, waist, big arm, small arm, hand, in the "clear outline structure" under the condition of more simple drawing better. The model, to fully consider the position and direction in the process of kinematics analysis of coordinate system, the coordinate system of each model is consistent with the real robot kinematics coordinate system. In the establishment of industrial robot 3D model with SolidWorks2011, using SolidWorks VRML conversion program will output VRML file: File - Save: save type VRML (3. WRL) - option.. - File Format: VRML version: VRML97, you can output VRML file. The use of SolidWorks VRML modeling, greatly reducing the modeling workload, improve work efficiency, more important is to realize the precise modeling of virtual industrial robot model accuracy is directly related to the effect of process control[9,10].

3.1.2. **Virtual robot in LabVIEW**

So far, the part model of the virtual robot has been constructed. It is necessary to display the assembly in the LabVIEW and simulate the motion of the real robot.

Analyze the relationships among the components, as shown in figure3

![Figure 3. Component relation diagram](image)

The whole scene is independent of an object, and the independent ground is a sub object. The robot, each degree of freedom requires the establishment of a relationship between two objects, an object is the relationship between father and son, son with the parent object object motion, shown in Figure 4 hierarchy, the next level is a component part of sub objects. The whole robot has four degrees of freedom relative to the scene. From the waist, each child object has only one degree of freedom relative to the parent object. Establish a hierarchical relationship between components in a program. As shown in figure 5.
According to the assembly relation of the real robot, the LabVIEW model is used to set up the spatial relation of each model in the program VI, and the virtual robot is assembled, as shown in figure 4.

![Virtual robot assembly model](image)

**Figure 4. Virtual robot assembly model**

3.2. Virtual robot data interface

So far, the virtual robot has been built. In order to realize the movement of the virtual model, it is necessary to set up the data interface. The motion of each joint has been analyzed in the 2.1 section. Figure 4 shows the initial position of the robot, and the interface data of the virtual model is the absolute position of each joint. No matter what data is passed, it needs to be transformed into the absolute position of each joint to realize the correct display of the virtual model.

Each joint rotation during the crawling process, using the LabVIEW VI "set rotation, rotation axis and angle of each joint position information set, will pass over the data transmitted to each joint, realize the model movement.

4. Virtual model motion control

Introduced in the 1.2 section, the system has two major functions (1) real-time simulation movement (2) simulation movement. Each module is equipped with real-time data display window, with the movement of the virtual model, real-time display of the rotation angle of each joint, and the manipulator end position matrix, to provide detailed data support for the operator.

4.1. Real-time simulation motion model

The operator operates the real robot motion and collects the rotation angle of the motor at each joint. The collected data is directly communicated to the virtual model interface, and the virtual model is driven to follow the real robot motion.

4.2. Simulation movement model

When the operator is in real operation, the simulation operation can be carried out on the virtual system, and several exercises can be carried out to improve the operation proficiency. You need to start the simulation motion model. The robot can also solve the kinematics forward kinematics and inverse kinematics solutions, and realize a variety of control methods.

4.2.1. Real time manipulation simulation

Operators on the system simulation operation, training operation ability. The real robot uses speed control in the course of movement, and the operator sends a speed command to the robot through a desktop control system or a joystick. The operator uses the same method in the simulation operation. A speed interface is needed for the virtual model to capture the speed information that the operator
passes over. As shown in figure 5 provides an interface for virtual velocity model, at the same time as
the virtual mode of the movement, the real-time display of each joint and the turning angle of the
manipulator end effector matrix, provides detailed data for the operator.

**Figure 5.** Interface for virtual velocity model

### 4.2.2. The positive and inverse solutions

Before the actual operation, the operator often on the robot kinematics analysis and trajectory planning,
grasp the inverse kinematics analysis and so on a series of theoretical analysis, through the virtual
model simulation, prediction model of real motion please condition, to plan the path with better
attitude. This virtual system provides rich operation mode and powerful data support for it.

**Figure 6.** Positive and inverse solutions simulation
As shown in figure 6, the kinematics analysis interface for the robot is positive. The operator inputs each joint to the program, and sets the movement time, chooses the movement pattern: each joint moves step by step or the synchronized movement. The virtual robot moves according to the set data. By simulating the motion of virtual robot, the operator visually obtained position information of the robot, the robot can adjust the position of each joint, movement speed, movement mode, to plan the best path and attitude. At this point, the data are used to operate a real robot, to improve operational efficiency, and to reduce real robot casualties.

5. Conclusions
This study proposes the use of LabVIEW development of teleoperation virtual reality system, using SolidWorks model, modeling greatly simplifies the workload, using LabVIEW powerful programming functions and excellent interactivity and portability, developed a virtual reality system, provide various modes of operation and powerful data support for the operating personnel. Compact program, high portability. The system has been verified by experiments. The results show that the system is stable and reliable, and the real-time meets the requirements. It provides an important reference for future research.

In the next stage, this research will further improve the system, add robot scene and achieve accurate collision detection. Through many experiments, improve the performance of various aspects of the system.

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