

Controlling Two Remote Robot Arms with Direct Instruction using HapticMaster and Vision System

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Abstract

This paper proposes a system that helps an operator control a manipulator using a direct Tele-guidance method that allows him to grasp with a data glove and teach the real manipulator to assemble/disassemble mechanical parts. The direct Tele-guidance is realized by calculating joint angles from the position and orientation of the end effector, which are specified with his data glove. Task environment are captured from two pan tilt TV cameras which are controlled according to his head movement, and he can see the stereoscopic image of it through an HMD. When deciding the end effector has approached to an object to be grasped, or a part grasped has come up to a target object, he has only to use a haptic device to continue his operation. The device transmits to him the force and torque values added to the force torque sensor attached to the end effector. This information allows him to intuitively recognize the state of the effector together with the visual information and makes it possible to precisely control it

Key words: Robot Arm , Haptic Master , Data Glove

1. Introduction

The use of robot arm increases in various fields late years. And much research is done about the use of robot arms. As a method to control robot arms, joint instruction method is general which gives information such as a coordinate or each joint angle of a robot arm. When we want to give instruction to several robots in order to have them collaborate, we must give a sequence of instruction to them while considering the position relation between their arms. It is not easy for a beginner to give correct instruction to the robot arms.

On the other hand there is a direct instruction method as a simpler instruction method. This is a method to give robot arms their movement with a man grasping the arms. It is not an appropriate instruction method when there are more than one robot in the environment, or they are in the remote place or the environment is dangerous for a man.

We propose a system in a virtual reality environment that helps us to give several robot arms instructions using a simple instruction method and realizes collaboration with several robot arms which are located at a distant

place. In the task of machine part assembly, as it is difficult for robot arms to decide with any computer vision system whether the parts to be assembled have been exactly mated, they may be not able to finish the operation. This system successfully gives an operator a feeling of fitting between parts to be assembled by using a force feedback device together with the direct instruction method.

2 . GENERAL BASIC IDEA

2.1 Instruction

There are two ways that we use to give instruction to a robot. One is an indirect instruction method that gives the joint angle with a teaching box or robot language, and another is a direct instruction method that gives direct movement to a robot by grasping it with a hand. As for the indirect instruction, we can instruct correct movement to a robot arm by giving numerical value directly, but on the other hand, it is difficult to give complicated instruction,

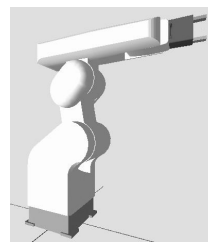


Figure 1. 6 DOF model.

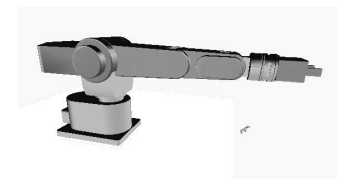


Figure 2. 5 DOF model

and it will take a long time to finish the instruction process. The direct instruction method can let the instruction finish in short time as it helps us operate a robot by hand directly. On the other hand, there is the problem that instruction of minute movement is difficult with the direct instruction method, but there is an advantage that it permits us to intuitively operate a robot by devising scale conversion in the movement speed of an arm.

2.2 World Tool Kit

The World Tool Kit of SENSE8 Company is used to make it easy to construct the virtual reality environment. World Tool Kit is a library of the C language function and

offers several means for producing a complicated application which requires various objects in a virtual environment to works as well as in the real world .

2.3 Force feedback

It is considered that we rely on not only vision system but also the haptic sensation returned to our hand when we want to insert a peg in a hole. From this point of view, it is considered that haptic information should be given to an instructor of the virtual robot arm. In this study a force torque sensor is installed at the end effector of the robot arm and the force to be added to the effector is transmitted to the HAPTICMASTER, which is one of haptic feedback devices, by way of PC. When the part which the robot arm grasps touches other parts, the instructor can get the sense of touch from the HAPTIC MASTER and it helps him attain precise instruction.

3. Modeling

3.1 Modeling of robot arm

A robot arm with 5 degrees of freedom and the one with 6 the degrees of freedom are modeled in the virtual environment. The robot arm is decomposed into several joint parts in order to make it easy to construct the models. The model s of the robot arms shown in Figure 1 and Figure 2 are constructed by combining the individual part into hierarchical structure.

3.2 The model of a hand

To directly instruct robot arm in virtual space, a virtual hand equivalent to the real hand becomes necessary. So the model is defined, which is consisted of 19 parts. Movement of this model is decided by referring to the position data obtained from data glove with three-dimensional position sensors.

4. Superimposing Two Virtual Spaces

In this system a TD-300 of Intergraph company is used to build virtual environment. Further two video cameras and an HMD are used in order to get a virtual task environment from a real environment including real robot arms and objects (Figure 3).

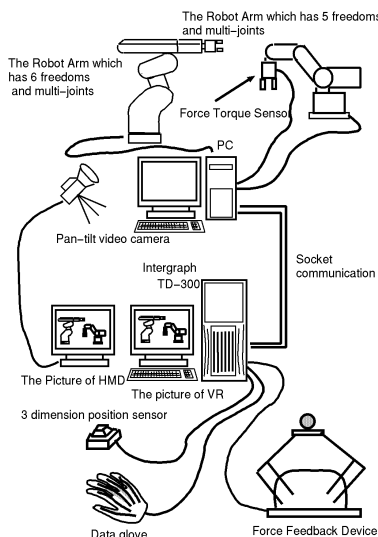
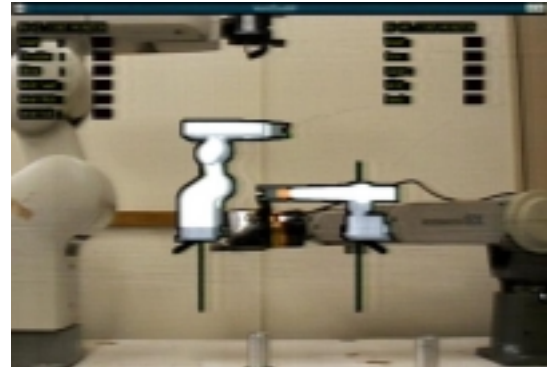
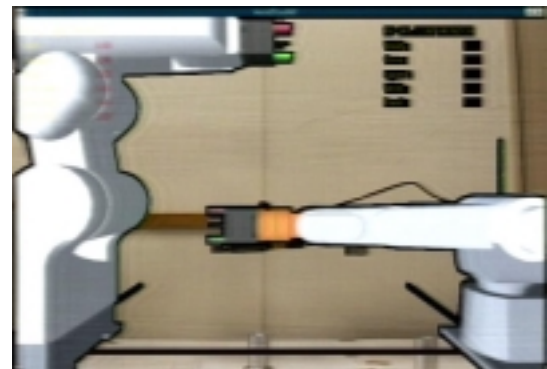


Figure 3. System organization

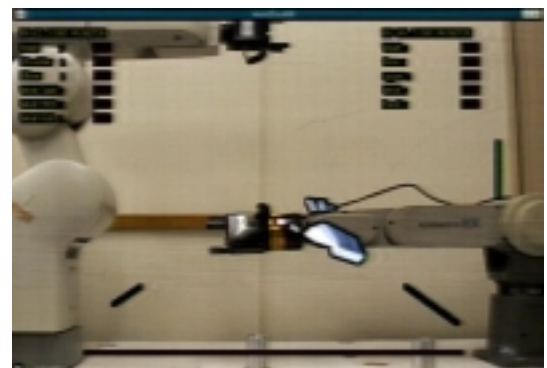
application simply, and offers means for producing an There are two virtual spaces; the first is the space including the virtual hand, and the second is the space constructed with stereoscopic images. In order to manipulate the virtual arm with the virtual hand, the two spaces must be coincided. The flow of work is shown in the following (see Figure 4).



(1)



(2)



(3)

Figure 4. superimposition of virtual space onto realspace

First, it makes the posture of the virtual robot arm and the posture of the fruit robot arm agree. After that, using the scan converter, it piles up the picture of the virtual robot onto the video camera picture. (Figure 4-1) It judges the RGB value of the computer image in the threshold value and the scan converter displays a pixel with high RGB value on the video footage. In other words, only the robot model can be piled up onto the video footage in making a background in the virtual space black.

However, only in this, there is a big difference in the display of the robot model and the display of the actual robot. In to adjust both of the virtual camera, the video camera positions, it becomes an approximately similar display (Figure 4-2).

Lastly, the robot model, too, changes to the black by the keyboard operation. With this operation, the robot model, too, becomes not displayed and only the model of the operator's hand is displayed (Figure 4-3). 4-3 of the figure is the picture that the hand of the operator is sinking into the actual robot arm.

5. Direct Instruction Method

We will describe a method to instruct a virtual robot arm with data glove directly. By referring to both information from 3 dimensional position sensors and that from the data glove, a virtual model of operator's hand is moved freely in the virtual space.

When grasping the virtual arm, which is the image of the real robot arm, and the operator successfully moves his hand to the point he intends, the system can lead the real arm to the corresponding point by transferring to the arm the value of each joint angle of the virtual arm. It is a fundamental problem in the direct instruction of robot arms that the system can correctly judge whether an instructor is going to move an arm or not. In this system, it does the interference judgment of the box which surrounds the whole model of the hand of the operator and the box which surrounds the fingertip (the black part) of the robot arm. Then, when bent above above the angle of box fellow's contacting and moreover finger's there being which is constant, an operator is judged to try to move a robot arm about the system.

At the same time, does the system compute a distance between the model of the hand of the operator and two each of the robot fingertips, too, and which robot fingertip does the operator try to move or the judgment, too, goes.

And, it prepared the mode to do the collision detection of the robot and the robot to avoid the crash of two robots when two robot arms are intersecting work, too (Figure 5).

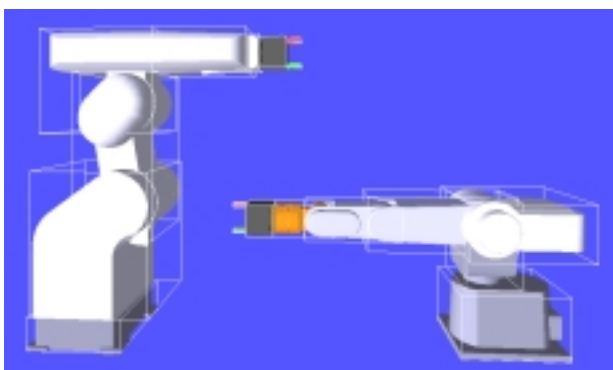


Figure 5. Bounding box of robot

5.1 Determining the posture of the arm

Each joint angle and the position of the robot are needed to compute the next posture of robot when an instructor leads the arm to the next position. In case of 5 DOF robots, the system can decide the posture from both the coordinate and the orientation of the arm end point and the constraint on the arm posture.

In case of the 6 DOF robot which was used by this research, on the structure, more than one answer exists. The candidacy of four answers is computed when the 6 DOF robot which was used by this research fixes the position and the posture of the fingertip in the relation of the design.

- 1: The value with positive θ_4 and moreover the value with positive θ_5
- 2: The value and moreover θ_5 with positive θ_4 have a negative value.
- 3: The negative value and moreover the value with positive θ_5 by θ_4
- 4: The negative value and moreover θ_5 have a negative value in θ_4 .

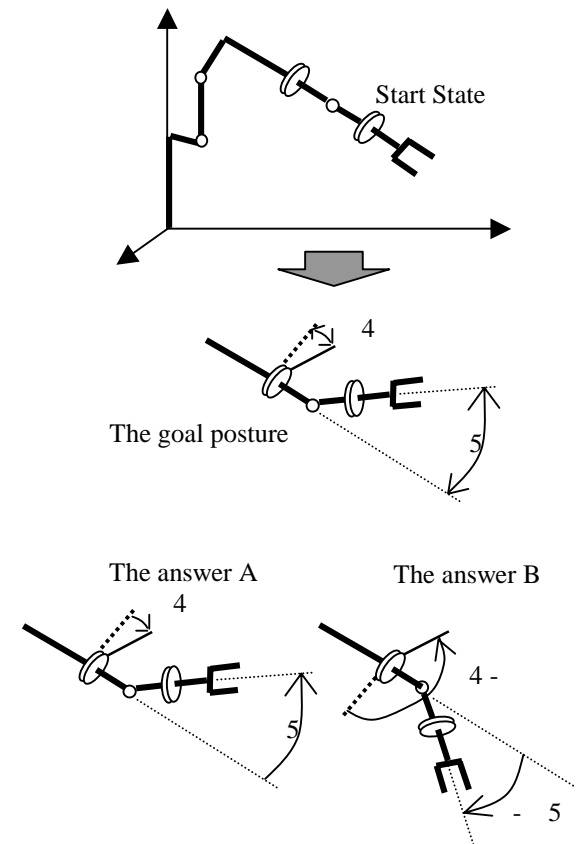


Figure 6. The choice of the operation of the 6 freedom degree arm

Both the direction of the positive and the direction of the negative are designed with 160 degrees by the operation range of θ_4 of this robot arm.

It depends and the candidacy which is two that the absolute value of θ_4 is within 160 degrees from four pieces of candidacy can squeeze(The answer A of figure 6 and the answer B of figure 6).

To choose the more suitable answer from these two answers, it considers that it is moving a robot by the direct instruction.

It is desirable to choose the answer as the movement of the robot arm can be continuously seen more smoothly.

Therefore, it thinks of updating a end effeter position every minute time and in the case, it thinks that it is basic

and that the change quantity with robot arm joint angle should be small.

Therefore, in this system, it computes a difference from the posture of the robot before operation to each of the candidacy of two pieces of posture.

Then, it makes posture with the smaller operation quantity an answer(The answer A of figure 6).

This became able to do that the operator made to twist a robot fingertip move freely.

6. Detection of Force and Force Feedback

In the mechanical assembly, the fitting operation is frequently carried out. In the assembly operation, even if there are a few differences in position or orientation between two parts to be mated it is difficult to finish the operation.

To realize such operations with the robot arm, in addition to visual information introduction of haptic feedback one is needed which informs an operator of the time when they come in contact. If he could sense through the robot arm the information when two parts come in contact, as he will be able to control much delicately the robot arm using both visual information and haptic feedback one in the same way as in the real environment, the part assembly operation with robot arm will be successfully attained.

The system is needed which allows an operator to receive the haptic feedback information by using a force torque sensor and haptic feedback device.

The force torque sensor is installed at the end point of the arm and conveys the force acting on the arm end point to the computer. The force feedback device makes it easier for the operator to attain the fitting operation by informing him of the force acting on the arm.

6.1 Arm control using haptic feedback device

In all processes of instruction the force feedback device should be used, but it is difficult for us to control the robot arm freely with the device because the range of movement is restricted to the narrow range. In the work such as grasping or moving an object with a robot arm, which does not obviously need any haptic sensation, the direct instruction can be conducted with only a data glove and three dimensional position sensors.

The arm control with the haptic feedback device is necessary when the delicate control is demanded, except for the case when he confirms that an object grasped never collides with other objects. Right before the device is used to control the arm, the initial location of the haptic device is set to the location corresponding to the arm current position, afterwards the movement of the arm is controlled with the force feedback device (see Figure 7).

7. Experiment

7.1 The method of Experiment.

At first, both the virtual arm and the real robot arm are established in the home positions respectively. A goal is to assemble a part A and a part B shown in Figure 7. A remote direct teaching with a data glove is used in the first half part of the teaching process where the part A and part B are grasped, and they are come close each

other. They are then put together while checking collision between them. A 5 DOF robot arm is controlled using a Haptic Master in the latter half of the teaching process.

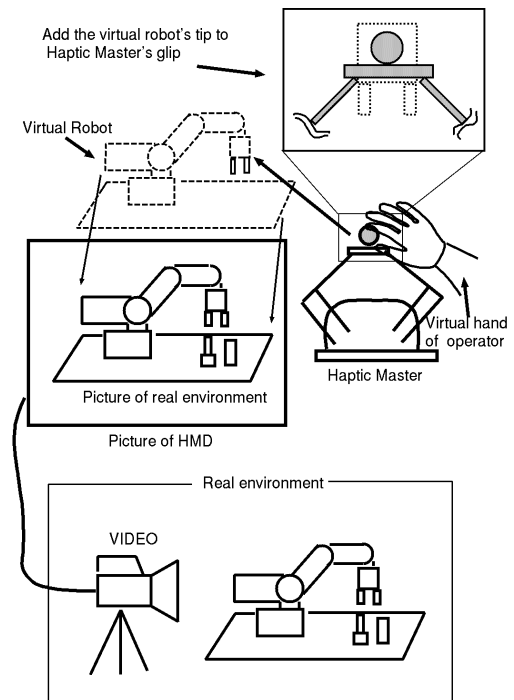


Figure 7. The initial position of a force feedback device

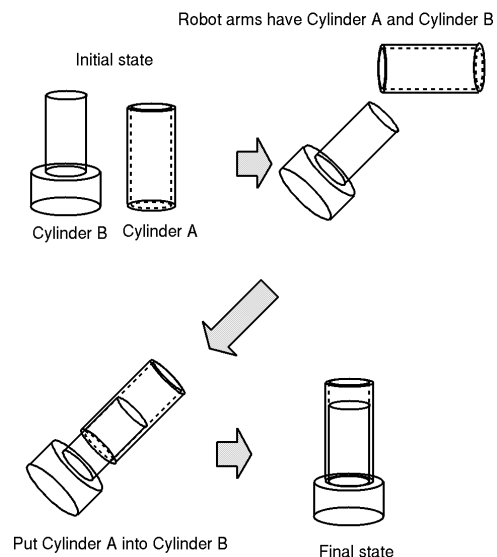


Figure 8 A goal assembly

7.2 Direct Teaching with Data Glove

First, an end of a 5 DOF robot arm is grasped with a data glove and it is moved above the part A. While maintaining the arm end in the vertical direction if circumstances allow, after the middle part of the arm end is moved to the just above the part A, it is closed by keyboard input (Figure 9-4).

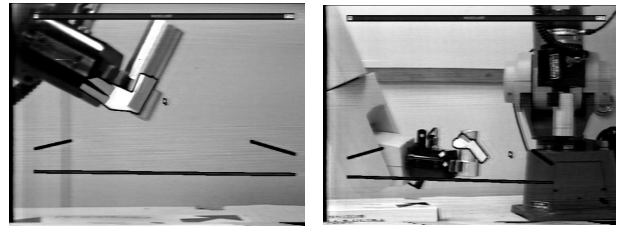
The 5 DOF robot arm end is grasped again, and the part A is lifted (Figure 9-5). Next, the 6 DOF robot arm end is grasped using a data glove. It is moved near the

part B (Figure 9-6). Because the part A must be inserted into the part B, the 6 DOF robot arm is moved so that the head part of the part B can be grasped.

After the middle part of the end point is moved to just the side of the top of the part B, it is closed with keyboard operation (Figure 9-8). Next the part B is lifted with the 6 DOF arm (Figure 9-9).

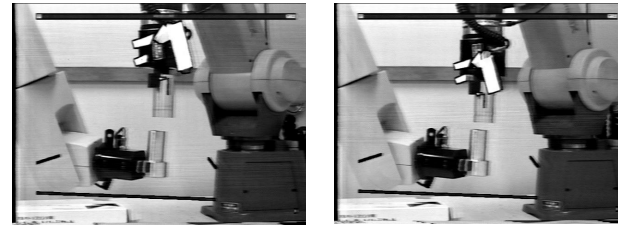
Next in order to insert the part B into the part A, the head part of the part B must be turned aloft. So the 6 DOF arm end is spun 180 degrees using a data glove (Figure 9-10).

In the sequel, the 6 DOF point is moved within the work range of the 5 DOF robot arm, and is stopped there (Figure 9-12). Next the 5 DOF robot arm holding the part A is got hold of with a data glove and moved above the part B (Figure 9-13,Figure 9-14)



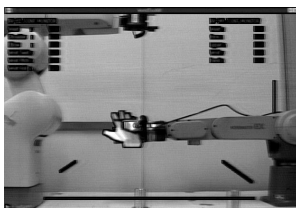
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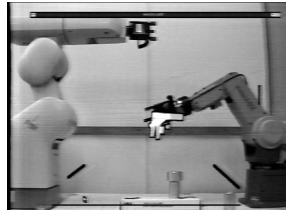


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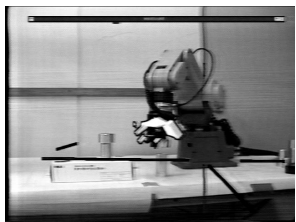
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(1)



(2)



(3)



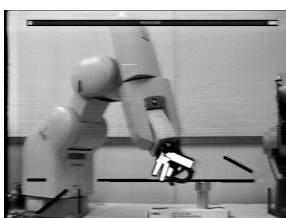
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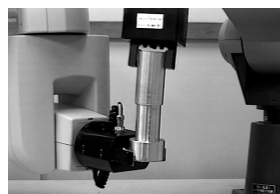
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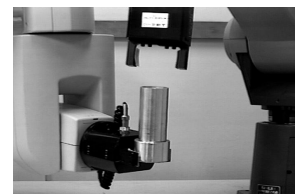
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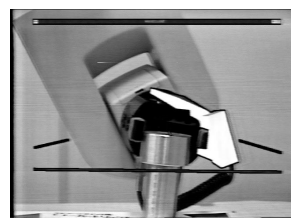
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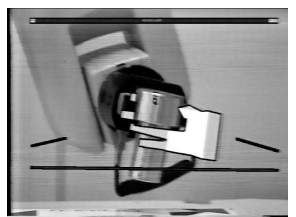
(17)



(7)



(8)



(9)



(10)

Figure 9. Process of assembling task

7.3 Control Using a Haptic Master

At first, when E of a keyboard is pushed, the coordinate of the arm end point at that time is set to the grip position of the Haptic Master. At the same time, a command that compels the sensor to output the force currently added to the force torque sensor. In this way the downward force caused

by the weight of the part grasped can be canceled. Afterwards, by giving 1/5 of movement of a Haptic Master to the robot arm end, it is control with the Haptic Master. Whenever the robot arm is operated, a value of the force torque sensor is read and given to the Haptic Master. This method allows an operator to sense the force acting on

the arm end point through a Haptic Master when the grasped part comes in contact with other parts. The state of the Haptic Master immediately after the control with a Haptic Master starts is shown in Figure 9-15. An operator grasps the grip of a Haptic Master, and inserts the part B in the part A. He gives a command to open the 5 DOF arm end point from a keyboard, and separates the part B from the arm. (Figure 9-17).

When a robot arm is moved, the coordinate system of a force torque sensor installed in the arm end point also changes. Therefore, the state of the force torque sensor coordinate system is acquired from the posture of the arm, an output value adjusted to the coordinate system of the Haptic Master must be calculated. The technique is as follows.

First, a posture of the arm is acquired using where command. Next using OR command, force acting on the force torque sensor is detected. Using relation shown in Figure 10, a force component to be transmitted to the Haptic Master is computed by applying the following expression. (see Figure 11)

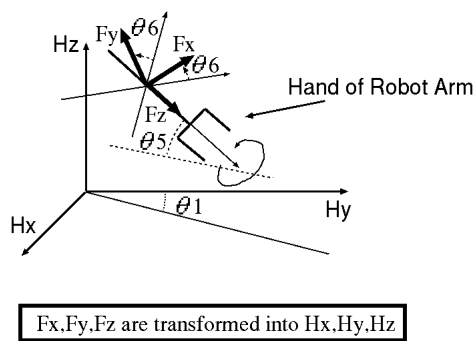
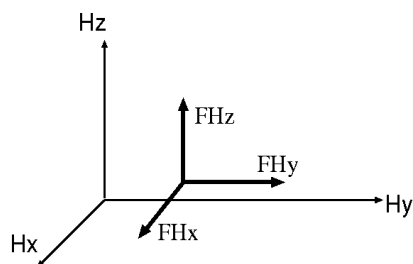


Figure 10 Coordinate of a robot hand

$$FHx = \{ (Fy \cos \theta_6 + Fx \sin \theta_6) \sin \theta_5 + Fz \cos \theta_5 \} \sin \theta_1 - \{ (Fx \cos \theta_6 - Fy \sin \theta_6) \cos \theta_1 \}$$

$$FHy = \{ (Fy \cos \theta_6 + Fx \sin \theta_6) \sin \theta_5 + Fz \cos \theta_5 \} \sin \theta_1 + \{ (Fx \cos \theta_6 - Fy \sin \theta_6) \sin \theta_1 \}$$

$$FHz = (Fy \cos \theta_6 + Fx \sin \theta_6) \cos \theta_5 - Fz \sin \theta_5$$



Fx, Fy, Fz are output of Force Torque Sensor
Hx, Hy, Hz are coordinate system of Haptic Master
FHx, FHy, FHz are input for Haptic Master

Figure 11 Coordinate of HapticMaster

7.4 Results

The experiment is conducted in two ways; the first is controlling it only with a data glove, and the second is the one using the data glove and the force feedback device. Even if parts delicately touched each other when they come close to some extent without the force feedback device, no operator can notice the fact and in most cases the operation failed. On the other hand it was clearly easy to instruct the arm because he can detect the contact between parts in case the force feedback device is available, and he was able to have robot arms attain the movement such as rubbing them together.

8. Conclusion

We proposed a system that helps an operator telemanipulate two robot arms with a direct instruction method. And as a result cooperation with two robot arms was successfully implemented. At present, just one data glove and one Haptic Master are available, no concurrent manipulation of two arms is realized.

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