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Tele-Operation of Dual Arm Robot Using 3-D vision

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ABSTRACT

A master-slave system is proposed as a teaching device for a dual arm robot. The slave robots are remotely controlled by two delta-type master arms. In order to help the operator to observe the target object from the desired position and desired direction, cameras are mounted on a specialized manipulator. Movements of two slave arms are coordinated with that of the cameras. Due to this coordinated movements, the operator needs not to care the geometrical relation between the cameras and the slave robots.

Keywords:Tele-operation, Robot, Delta Arm,Vision

1.Introduction

Recently coordinated movements of dual arm robot are becoming more and more popular, since they realize complex tactful manipulations like human hands. Typically in the fields of arc welding coordinated movements of the welding torch and the welding target enable the ideal welding even under the effects of the gravity. Usually the coordinated movements are realized with two manipulators in the factories. One problem of such a dual arm robot with coordinated movements is how to specify the complex movements of both manipulators. Usually an operator specify the movements of both manipulators using a teaching pendant. In order to cope with this problem, one technique is to employ sensors like vision sensors. By employing a vision sensor, arc welding tasks along the complex welding path can be easily performed Another technique is to employ a master-slave control method. Using dual master arms, the operator can specify complex movements of dual arm robot. Master-slave systems are developed mainly in hazardous and critical fields such as nuclear power plants, space and underwater. In such fields, the cost is not important factor. However, if we intend to use a master-slave system as a teaching device in the conventional factories, the master-slave system should be simple and cost effective.

In this paper, we propose a master-slave system as a teaching device for the coordinated dual arm robot. One feature of our system is that the slave arms are remotely controlled by the operator considering the case where the. slave robots are settled in the factory and the operator is in a remote office. The operator observes the slave arms and the environment by two TV cameras.

Another feature is that two TV camera are mounted on a robot. The posture and the position of the cameras are controlled by the head movement of the operator Therefore, the operator can observe the target objects by adjusting the position and the orientation of the cameras.

The third feature of the system is that the movements of the dual arms are coordinated with the movements of the CCD cameras. Due to these coordinated movements,the operator needs not to care the geometrical relation between the slave arms and the cameras. Therefore, according to the head movements of the operator, the slave arms and the cameras move automatically.

One more feature is that two master arms are composed of a parallel link mechanism called delta arm. Due to the simple structure of the delta arm, two master arms are readily realized.

As an experiment, teaching tasks using dual arms were tested. It was concluded that teaching task could be simplified by our system.

2. Configuration of Robot System

The system configuration is shown in Fig.1. The operator observes the target environment through a 3-D vision system using two TV cameras, those are mounted on a camera manipulator. The movements of the camera manipulator are specified by the movements of the operator's head. Two master arms are manipulated by the operator. According to the movements of the master arms, two slave arms move. At the end of the slave arms two fingers with touch sensors are mounted. Therefore, the operator can obtain the 3-D images at various position and various orientation and also touch sensor output.

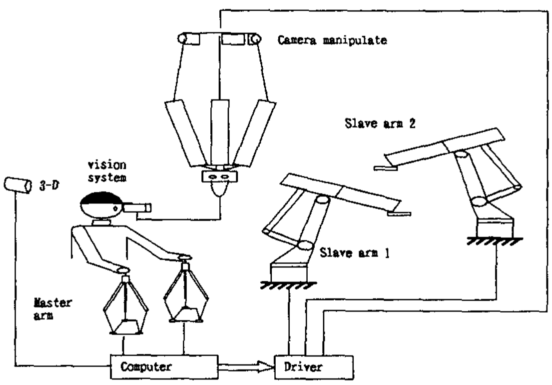

Fig. 1 System configuration

2.1 Slave system

The slave system, here we consider, is composed of two six-axis arms as shown in Fig.2 and one camera manipulator on which two cameras are mounted as shown in Fig.3. The camera manipulator is employed to offer images from various viewing points with various orientations. The position and the posture of the camera manipulator is controlled by the movement of the operator's head. Movements of the operator's head can be readily measured by an image processing technique to detect four marks attached on the operator's head.

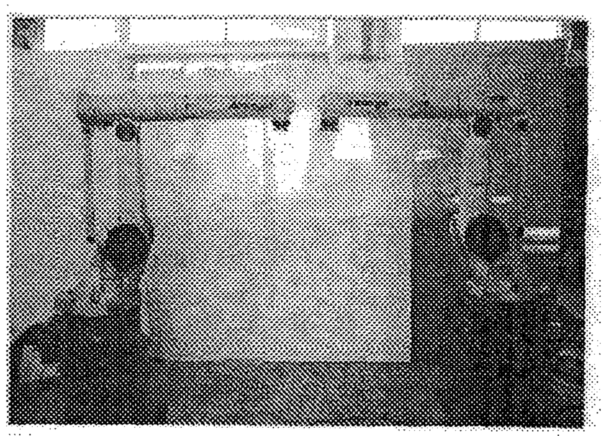

Fig.2 Slave arms

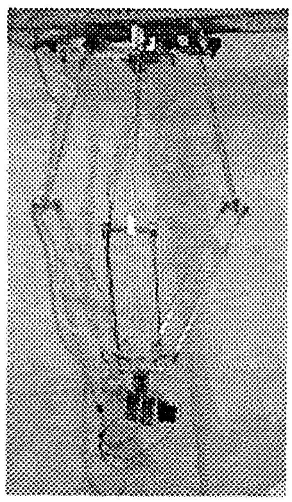

Fig.3 Camera manipulator

2.2 Master system

The master system has a different configuration from that of the slave system, and is composed of two delta arms as shown in Fig.3. A feature of delta arms is that rotary encoders are mounted at every base joint of three links. Based on the geometry of the delta arm, three-dimensional position of the end of the delta arms can be determined by the data from the rotary encoders. At the end of every delta arm, a joy stick with three-dimensional rotating freedom is mounted. The joy sticks are designed so that the operator can specify the posture of the delta arm using the joy stick easily.

In order to teach the movement of the slave arms, two delta arms are used to specify the positions of the slave arms and a joy sticks mounted at every mater is used to specify the posture of the slave arms.

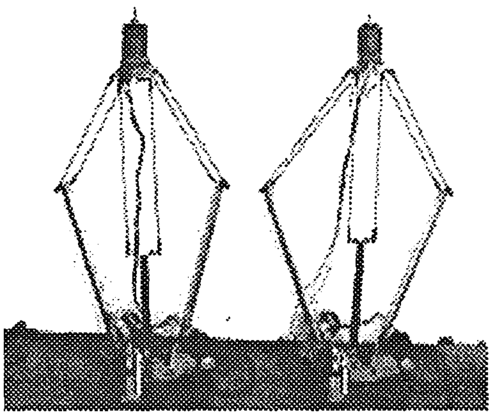

Fig.3 Delta arms with joy sticks

3. Coordination of Camera System and Slave Arms

The camera manipulator is employed since images from various view points are indispensable to know the target object and the environment in detail. The operator can move the camera manipulator by moving his head.

The movement of the camera causes the changes of the geometrical relation between the camera and the slave arms. This changes of the geometrical relation makes the manipulation of the slave arms confusing. Therefore, the coordinated movements between the camera and the slave arms are introduced. This coordinated movements enables the operator to manipulate the slave arms as if the slave arms are settled on the camera coordinate system and moves together with the cameras.

3.1 Definition of coordinate systems

We introduce coordinate systems as shown in Fig.4 where T(A,B) denotes homogeneous transformation matrix from coordinate system A to coordinate system B. Based on the camera coordinate system settled on the center of both cameras, the position and the orientation of the slave robot i (i=1,2) is represented by the homogeneous transformation matrix T(C,Ri) calculated by

$$T(C,Ri)=T(Bc,C)^{-1}\,T(B,Bc)^{-1}T(B,Bi)T(Bi,Ri).$$

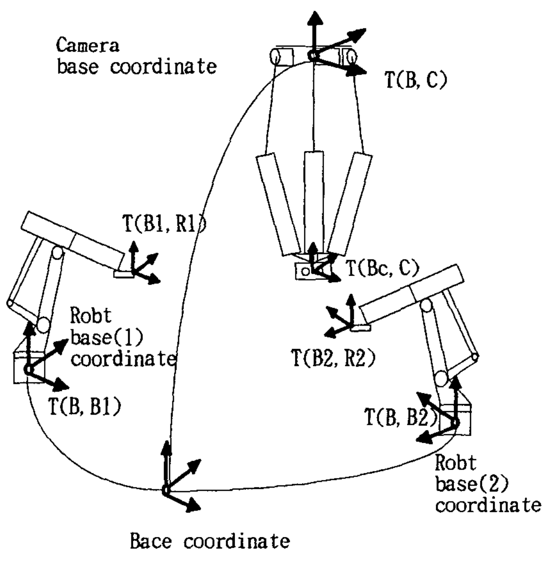

Fig.4 Coordinate System

3.2 Coordinated Movement

Coordinated movements enable the operator to manipulate the slave arms as if the slave arms are settled on the camera body. Movements of the operator's head determines the matrix T(Bc,C) and this matrix control the movement of the camera arm. Manipulation of the master arms determines the matrices T(C,Ri) (i=1,2). In order to realize the coordinated movements, movements of the slave arms are specified by

$$T(Bi,Ri)= T(B,Bi)^{-1}\, T(B,Bc)\, T(Bc,C)\, T(C,Ri).$$

Due to the above algorithm,. the operator can control the slave arms without any considerations about the change of geometrical relation between the camera and the slave arms

4. Teach and Playback Task

When the operator moves the master arms, the dual slave arms moves similarly. Also the camera arm moves according to the movements of the operator. When the operator requests the control system to record the j-th position and the orientation for the robots, the control system calculates the homogeneous transformation matrix T(Bc,C), T(B1,R1) and T(R1,R2), where T(R1,R2) is determined by

$$T(R1,R2)=T(B1,R1)^{-1}\, T(B,B1)^{-1}T(B,B2)T(B2,R2).$$

After that, these three matrices are stored in the memory as teaching data. It should be noticed that matrices T(R1,R2) is stored instead of T(B2,R2), since the relative position and the orientation between the both slave arms are major concerns in the coordinated motions.

Once all teaching data are obtained, we can playback all movements considering the relative speed between the both arms. It is needed to interpolate points linearly between every teaching point. The interpolation enables the slave arms to move smoothly.

5. Experimental result

We had two experiments using our system. In order test the operational ability, an experiment was executed under the condition that the operator observes the target object and the target environment directly with his eyes The desired task was to pick up a bottle and pour water into a cup. The bottle was grasped by a slave arm and the cup was grasped by the other slave arm as shown in Fig.5.

The test was executed by three operators after training for five minutes. Every operator admitted that the operation of the master arm was easy and didn't need any skill.

The second experiment was to execute the same task using 3-D vision system. While the operator was awkward slightly, he succeeded to execute the task without any trouble.

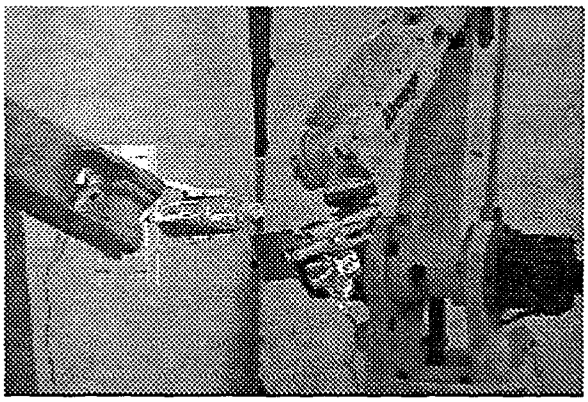

Fig.5 Task by dual arms

6. Conclusion

In this paper, we proposed a master-slave system as a teaching device for a dual arm robot.

We conclude as follows:

(1) The delta arm was effective as a master arm since its compact and light mechanism makes the arm relatively free from the gravity effect.

(2) The coordinated movement between the camera and the slave arms was helpful for the operator to manipulate the slave arms from various viewing orientation.

(3) 3-D vision system was effective for the tele-operation. Introduction of a camera manipulator improved the operation ability. However, there still remains some difficulty when the operator uses 3-D vision system. The reason might be the resolution of the TV camera. Some assists using some sensors may be necessary.

(4) The teaching device proposed here is practical since it has a simple configuration and is easy to manipulate. Using internet device, our system is applicable in many fields.

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