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# Development of Easy Teaching Interface for a Dual Arm Robot Manipulator

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***Abstract*— it is very complicating for the operator to teach a dual arm robot manipulator. A dual arm robot manipulator has two arms, a left arm and a right arm. For a dual arm robot manipulator the cooperation of the two arms is important for many jobs. The operator has to teach the relative motion between the left arm and the right arm. But it is very difficult to teach the relative motion between the left arm and the right arm using the traditional teaching pendants. Because with the traditional teaching pendant system, the operator has to consider the relative kinematic relationship to achieve the cooperative motion of the left and the right arms. For this reason, the easy teaching interface for the dual arm robot manipulator has been developed in this research. It gives very intuitive way to teach a dual arm robot manipulator. The research result will be introduced.***

*Index Terms*—**Dual arm robot manipulator, User Interface, Easy Teaching.**

## I. INTRODUCTION

These days, more researchers and companies are interested in the dual arm robot system because two-arm robot system has more advantageous than the traditional single arm robot system. Single arm robot has just one arm and it is impossible to behave like human who manipulates some object with the cooperation of the left and the right arms. These days, in many cases, human-like cooperative motion of the left and right arms is important. That is why many commercialized dual arm robot systems have been introduced in the market. It is not easy to make the manipulator understand the operator's intention. Generally speaking, teaching pendants would be one of the easiest ways to teach the manipulator arm. But it is not easy to use a teaching pendant for the naive operators. So, the intuitive teaching methods for a general purpose have been introduced by many researchers. [1-6]. It is very complicating for the operator to teach a dual arm robot manipulator. Because it is very difficult to teach the relative motion between the left arm and the right arm, using the traditional teaching pendants. With the traditional teaching pendant system, the operator has to consider the relative kinematic relationship between the two arms to achieve the cooperative motion of the left and the right arms. In this reason, the easy teaching interface for the dual arm robot manipulator has been developed in this research. It gives very intuitive way to teach a dual arm robot manipulator. The research result will be introduced in this paper. The developed interface is very simple but very powerful for teaching the relative motion of a dual arm robot manipulator.

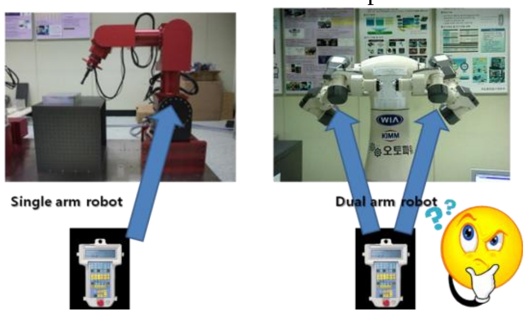


**Fig. 1 The need for the development of an easy teaching interface for a dual arm robot manipulator**

## II. RELATIVE MOTION KINEMATICS

There are two ways to define the motion of a dual arm robot manipulator. The first thing is the absolute motion and the next is the relative motion as introduced by the authors [3].The absolute motion means that the motion of a dual arm robot manipulator is defined with respect to the base coordinates as shown Fig 2. In this method, the left arm's motion and the right arms motion are defined separately. But for the cooperative jobs, it is more convenient to use the relative motion definition which means that the left arm's motion is defined with respect to the coordinates on the end-effector of the right arm as shown Fig. 3 [4].

The transformation matrix for Arm 1 and Arm 2 is defined as the follows.

$$U1_i = \begin{bmatrix} n1_i & o1_i & a1_i & p1_i \\ 0 & 0 & 0 & 1 \end{bmatrix},\ U2_i = \begin{bmatrix} n2_i & o2_i & a2_i & p2_i \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (1)$$

Subscription i means the joint number of a robot manipulator. U1 means the transformation matrix from the end effecter of Arm 1 to Joint i of Arm 1, and U2 means the transformation matrix from the end effecter of Arm 1 to Joint i of Arm 2. Now, Jacobian matrix can be calculated by the following equation [4].

$$ {}^1J_{12} = \left[ \begin{array}{ccc|ccc} -a1_1 \times (P2_7 - P1_1) & \cdots & -a1_6 \times (P2_7 - P1_6) & a2_1 \times (P2_7 - P2_1) & \cdots & a2_6 \times (P2_7 - P2_6) \\ -a1_1 & \cdots & -a1_6 & a2_1 & \cdots & a2_6 \end{array} \right] \quad (2)$$

The superscript 1 means the end-effect or coordinates of the arm 1 is used for the reference coordinates for the expression of the Jacobian.

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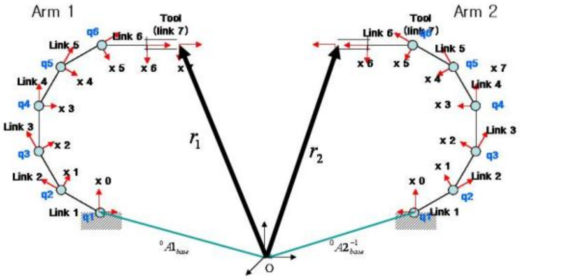


**Fig. 2 The absolute motion definition of the position of the arm 1 and arm 2**

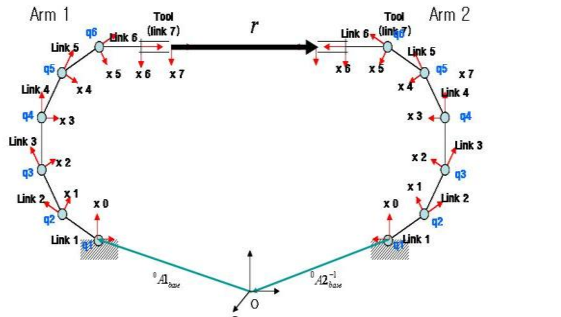


**Fig. 3 The relative motion definition of the position of the arm 2 with respect to arm 1**

## III. EASY TEACHING INTERFACE FOR A DUAL ARM ROBOT MANIPULATOR

The developed teaching interface is very simple and useful to teach a cooperative motion of the two arms because the operator can easily teach a dual arm robot manipulator not only with the absolute motion reference but also with the relative motion reference with respect to the each other arm. In this chapter, the developed easy teaching interface for a dual arm robot manipulator is introduced. In the next chapter, the usefulness of the proposed easy teaching interface for a dual arm robot manipulator will be verified through some teaching experiments using the developed easy teaching interface. In this chapter, the developed easy teaching interface for a dual arm robot manipulator is introduced. As mentioned above, the Jacobian relationship between the two arms (left and right arms) has been developed by the author [4]. In this research, a new easy interface for the dual arm robot manipulator has been developed. It is developed to use the retrieve kinematic relationship to make it easy to teach the relative motion between the left arm and the right arm. As a result, the operator can easily teach the cooperative motion of the left arm and the right arm using the developed easy teaching interface. Figure 4 shows the developed user interface to teach a dual arm robot manipulator. It has a Graphic User Interface which the operator meets when he/she wants to teach a dual arm robot manipulator. It is composed of two parts, the left part, #1, and the right part, #2~#7. The left part is used to teach the joint motion of a left and a right arm separately. This part is not different from existing teaching pendant systems.

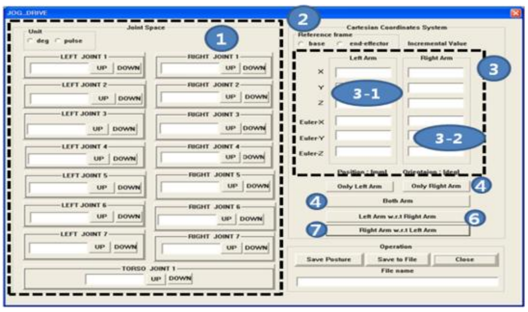

**Fig. 4 The developed easy teaching interface to teach a dual arm robot manipulator**

The right part consists of 6 areas, #2~#7, of the figure 4 and it is very different from existing teaching interface for a robot manipulator. The right part is used to teach the manipulator in a Cartesian coordinate system. The area #2 shows a radio button to define the reference coordinates for the Cartesian space. The area #3 shows the text edit box to write down the position and the orientation command in a Cartesian space. When the operator types some command position and orientation in the area #3, the meaning of the written values of the area #3 are different according to the buttons in the area #4~#7. If the button, “Only Left Arm” or “Only Right Arm” in the area #4 is selected, the meaning of the values in the text boxes of the area #3 is the absolute position and orientation of the end effectors of the left and right arms. In the teaching process, the manipulator will be taught to go to the reference position and orientation. For example, if “Only Left Arm” is pressed in the area #4, the end-effector of the left arm goes to the position and orientation written in the text box in the area #3. If “Both Arm” is pressed in the area #4, both of a left arm and a right arm are controlled to go to the target position and orientation written in the area #3. In these cases, the operator can teach the manipulator with the absolute position and orientation command. If one of the buttons in the area #6 and #7 is pressed, the values in the text box in the area #3 means the relative position and orientation command. If the button “Left arm with respect to Right arm” in the area #6 is pressed, the values in the area #3-1 mean the relative target position and orientation of the end-effector of the left arm with respect to the end-effector of the right arm. In this case, the values in the area #3-2 mean the absolute target position and orientation of the end-effector of the right arm. Thus, if the button in the area #6 is pressed, the right arm goes to the absolute target position and orientation written in the area #3-2, and the left arm is controlled to go to the relative position and orientation with respect to the right arm. As a result, the left arm and the right arm are controlled to do work cooperative job.

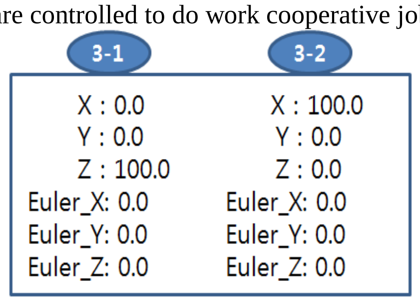


**Fig. 5 An example of target position and orientation in the area #3**

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For easy understanding, a simple example is introduced. Figure 5 show a simple input values in the area #3-1 and #3-2.

First, we suppose that the operator pushes the button "Left arm w.r.t Right arm" in the area # 6. In this case, the meaning of the values in the #3-1 is the relative position and orientation of the left arm with respect to the right arm. The left arm of the dual arm manipulator will be controlled to keep these relative position and orientation with respect to the right arm wherever the right arm goes or whatever jobs the right arm does. In this case, the meaning of the values in the area #3-2 is the absolute target position and orientation the right arm has to go to. As a result, the right arm is controlled to go to the final target position and orientation and the left arm is controlled to keep the commanded relative relationship with the right arm. All the numbers of Fig. 5 and 6 mean the incremental values.

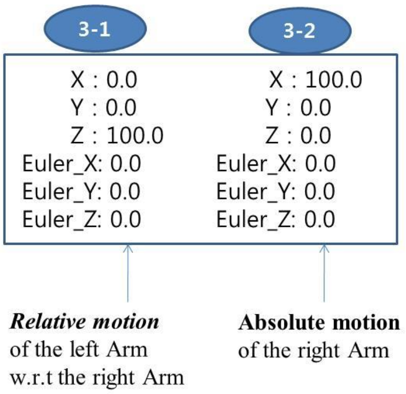


**Fig. 6 The meaning of the values in the area #3 when the operator presses the button "Left arm w.r.t Right arm" in the area #6**

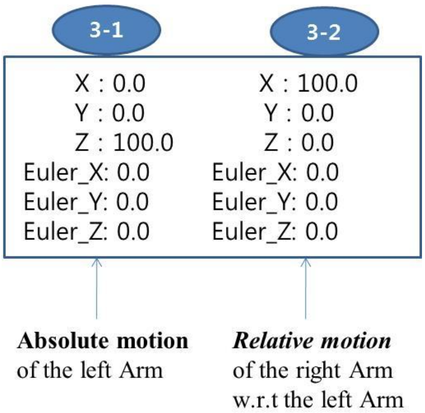


**Fig. 7 The meaning of the values in the area #3, when the operator presses the button "Right arm w.r.t Left arm" in the area #7**

Next, we suppose that the operator pushes the button "Right arm w.r.t Left arm" in the area #7. In this case, the meaning of the values in the area #3-1 is the absolute target position and orientation where the left arm has to reach, as shown in Fig 7. In this case, the meaning of the values of the area #3-2 mean the relative position and orientation of the right arm with respect to the left arm. The right arm will be controlled to keep these position and orientation with respect to the left arm wherever the left arm goes or whatever jobs the left arm does. As a result, the left arm is controlled to go to the final target position and orientation and the right arm is controlled to keep the commanded relative relationship with the left arm. All the values of Fig. 7 mean the incremental values.

## IV. APPLICATION: DIRECT TEACHING USING THE DEVELOPED EASY TEACHING INTERFACE

The developed user interface can be used for the direct teaching of the dual arm robot system. In direct teaching method, the operator pushes or pulls the end-effector of a robot manipulator, and the manipulator is controlled to meet the operator's intention, as shown in Figure 8 [4].

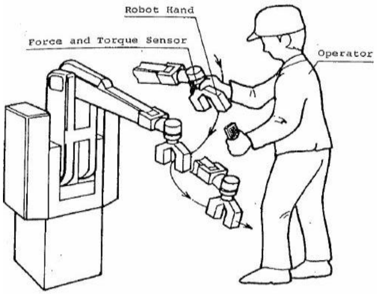


**Fig. 8 The concept of direct teaching [4]**

The developed easy teaching interface can be applied to the direct teaching of a dual arm robot manipulator. In this case, the operator can teach one arm (left arm or right arm) directly by pushing or pulling the end-effector, and the other arm is controlled to keep the relative relationship which is predefined as shown in Figure 6 and 7. Figure 8 ~ 11 show the experimental results. Generally speaking, it is difficult to teach the left and right arm at the same time with the traditional type of teaching pedant system. Even though a direct teaching method can be applied to teach a dual arm robot manipulator, it is not easy to teach the left arm and the right arm at the same time. But with the developed user interface, a dual arm robot manipulator can be taught easily. It is very convenient to teach one arm and the other arm is controlled to follow the predefined relative motion as shown in Figure 6 or Figure 7. In figure 9, the teaching tools on the end-effector of the two arms are shown (red color). This figure shows the operator is pushing and pulling the left arm and the right arm is controlled to follow the predefined relative motion. In this procedure, the left arm is controlled to comply with the teaching force and moment during the direct teaching process.

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**Fig 9 Direct teaching of a dual arm robot manipulator using the developed easy teaching interface**

During teaching process, the manipulator memorizes the trajectory taught by the operator, and it can playback the memorized trajectory after the teaching process is finished. Figure 10 shows the dual arm robot manipulator is doing playback with the reference trajectory taught by the operator after the teaching process is finished. Without the direct teaching method using the developed easy teaching interface for a dual arm robot manipulator, it would be very difficult to teach the cooperation task of the left arm and the right arm.

**Fig. 10 Playback of the reference trajectory**

Figure 11 shows another experimental result. In this experiment, the left arm and the right arm are taught separately. Figure 11 shows "a teaching process of a left arm". In this case, the button "Both arm" in the area #4 is pressed before the operator starts the teaching operation. The teaching processes are done separately for each arm. During the playback process, the left and the right arm are controlled to synchronize the motion of the two arms at the same time. Figure 11 shows the teaching process for the left arm only. The right arm can be taught with similar process.

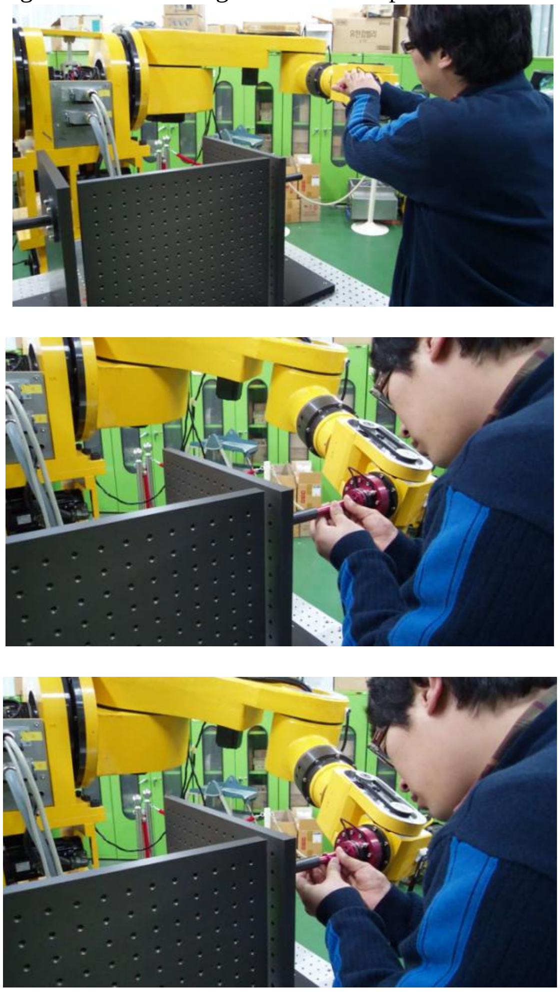

**Fig. 11 Direct teaching of the right and the left arm separately**

## V. CONCLUSION

In this research, an easy teaching interface for a dual arm robot manipulator has been developed and it is introduced in this paper. It is simple teaching interface and it is very useful to teach a cooperative motion of the two arms because the operator can easily teach a dual arm robot manipulator not only with the absolute motion reference but also with the relative motion reference with respect to the each other arm. The usefulness of the proposed easy teaching interface for a dual arm robot manipulator has been verified through some teaching experiments using the developed easy teaching interface.

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