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Design and Manipulation in Augmented Reality of Fanuc 200iC Robot

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ABSTRACT: *In this paper, an AR (Augmented reality) system based on a multimodal user interface is proposed and its core techniques are described. The objective of this work is to realize certain task that operators can use the virtual robot to ameliorate the interaction with the real world using AR environment. VC++ and OpenGL are used to create this application. AR applications (ARToolKit) is used to detect the real-time position and orientation of camera and to facilitate the operator's observation and operation. Experiments prove that the system is reliable and efficient. Simulation result is obtained and it is very useful for designers to ameliorate the interaction with the real world.*

Keywords: Augmented Reality (AR), Kinematics model, 200iC Fanuc, OpenGL, User Interface

1. Introduction

Augmented Reality (AR) allows the overlay of virtual images on the real world, there has been much research in the field of AR in last years, AR is used for a wide range of applications in computer vision such as computer-aided surgery, repair of complex machines, establishment modifications, interior or structural design. AR techniques can be used to help bring the right information to the right place at the right time [15]. The principle of AR is to take real images to which one adds additional information for a better perception of reality.

In [6], graphical user interface is proposed to make a task easier and mechanisms for the operator and the robot to exchange information at different levels of detail or abstraction and to verify the robot in Virtual Reality and the wireless remote control.

In the work reported by Rastogi and Milgram [14], an operator is provided with visual feedback of a virtual wireframe robot superimposed over an actual physical robot located at its remote working environment. The virtual robot will execute a task for evaluation by the operator, and if it is satisfactory, the task will be transferred to the real robot.

The other initiative, The ARITI system [13] (Augmented Reality Interface for Teleoperation via Internet), one of the characteristics

of project ARITI is the use of the AR for the teleoperation, which is a system of teleoperation allowing the control of a robot by using the techniques of AR, it constitutes an experimental system of teleoperation via the Internet. As an application using a robot to four degrees of freedom, a new version with a robot FANUC Robotics with six degrees of freedom was designed.

In this research work, we present an idea of AR system based on a multimodal user interface, this interface allow users to interact with system using multiple different modes of communication (keyboard, Cameras and joystick), which integrates the virtual robot directly with the real environment video, without building an environment model. Video images provide rich and highly contrasted information. The ARToolkits marker detection method and OpenGL are used for rendering [7]. The virtual environment is established by VC++ and OpenGL.

2 Design of the AR System

The main goal of the system is to generate a path on virtual workpieces using a virtual robot file (Virtual Reality Modeling Language) and computer generated models in AR environment.

2.1 Relationships between Frames

In order to calculate the position of the end-effector, ie the robot tool, the transition matrix between the camera and the robot tool (T_{ct} , R_{ct}) is determined using the relationships between Frames as see in figure 1. The translation T_{ct} and the rotation R_{ct} are given by:

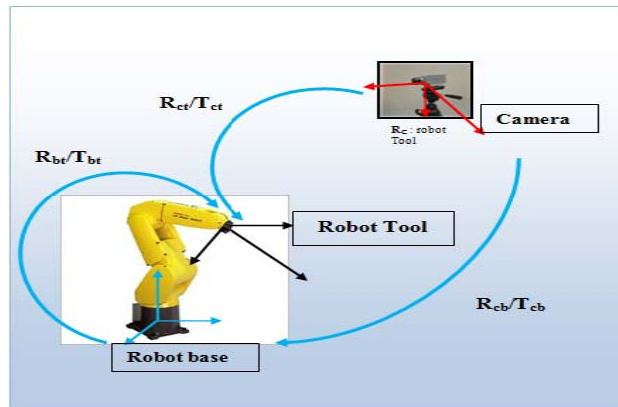


Figure 1. Relationships between Frames

$$T_{ct} = R_{cb} * T_{bt} + T_{cb} \tag{1}$$

$$R_{ct} = R_{cb} * R_{bt} \tag{2}$$

The transition matrix between the camera and the robot base (T_{cb} and R_{cb}) is determined using the most popular algorithm in AR applications, the ARToolKit [8].

ARToolKit includes several models of two-dimensional markers. It allows to find markers, to recognize and identify them. However, its performance in markers detection should be improved. In fact, often, it happens that markers are confused with each other or they are detected by error in foreground. ARToolKit marker is black border square surrounding a model which is compared to other pre-recorded models in ARToolKit matching template database (figure 2) [11]. ARToolKit gives the position of the marker in the camera coordinate system, and uses OpenGL matrix system for the position of the virtual object. ARToolKit defines different coordinate systems mainly used by the computer vision algorithm and the rendering.

Whereas The transition matrix between the robot base and the end-effector (T_{bt} and R_{bt}) is calculated by using the Geometric model of the FANUC 200iC robot .

2.2 The Direct kinematic Model

In this work we use LRMate 200iC Robot model, an industrial 6 DOF robot from Fanuc Robotics [12]. The direct geometric model (DGM) is the set of relations which express the position of the end-effector, i.e. operational coordinates of the robot, according

to its joint coordinates. In the case of a simple open-chain, Forward kinematics model of the robot is represented by

$$X_i = f(\theta_i) \quad (3)$$



Table 1. Modified geometric parameters D-H of the FANUC robot

i	σ_i	α_i	d_i	θ_i	r_i
1	0	0	0	θ	0
2	0	90	75	$P + \theta_2$	0
3	0	0	400	θ_3	0
4	0	90	75	θ_4	410
5	0	-90	0	θ_5	0
6	0	90	0	θ_6	0

Table 1. Modified geometric parameters D-H of the FANUC robot

Where σ_i , α_{i-1} , d_i , θ_i and r_i are the Denavit-Hartenberg parameters [4]. The link transformation matrix are given by the Denavit-Hartenberg and Table 1 [9]. The transition matrix of the LRMate 200iC Robot is calculated in [2], it can be represented by the transformation matrix T_k^0 .

$$T_k^0 = k_{i=1} T_i^{i-1} q(i) \quad (4)$$

Realizing the composition of transformations of equation (3) we obtain:

$$T_6^0 = T_1^0 \cdot T_2^1 \cdot T_3^2 \cdot T_4^3 \cdot T_5^4 \cdot T_6^5 \quad (5)$$

$$T_E^f = T_0^6 \quad (6)$$

and

$$T_E^f = \begin{bmatrix} S_x & N_x & A_x & P_x \\ S_y & N_y & A_y & P_y \\ S_z & N_z & A_z & P_z \end{bmatrix} \quad (7)$$

The transformation matrix of tool frame in the end-effector frame is given by :

$$E = T_E^0 \quad (8)$$

2.3 Robot Fanuc Modeling

The virtual environment includes the geometrical model of robot. the virtual geometric model is created using the real dimensions of the robot. The robot is designed by the use of the CAD environment SolidWorks [16]. The SolidWorks source file is used to generate the geometrical model of robot. After the file converted into VRML file format, it can be read directly by the OpenGL Library. Then the robot model can be displayed in simulation scene. The virtual model of the FANUC 200iC robot is shown in figure 3.

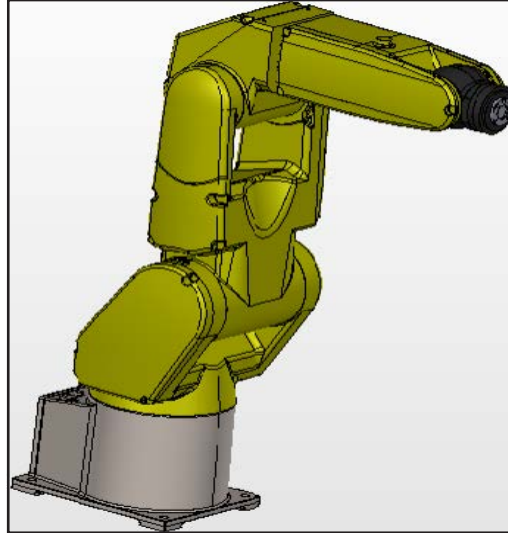


Figure 3. Fanuc 200iC robot modeling in virtual environment

3. Results and Analysis

In this work ,we use a camera Logitech Webcam C 905, The camera specifications are:

- Resolution: 16001200.
- Up to 8-megapixel photos(enhanced from Native 2-MPHD sensor.)
- FPS at full resolution: 30
- Hi-Speed USB 2.0 certified.

The camera is calibrated with ARToolKit method “Two Step. Calibration” [1], and the intrinsic parameters are:

- Distortion factor (mm): (288,5 356,5 53,3 1,3456)
- Matrix intrinsic :

$$\begin{pmatrix} 655,0883 & 0.00000 & 438.50000 & 0.00000 \\ 0.00000 & 759.23013 & 316.60000 & 0.00000 \\ 0.00000 & 0:00000 & 1:00000 & 0.00000 \end{pmatrix}$$

3.1 The User Interface

For the users, Graphic Interface is developed to interact with AR application allowing the visualization and localization of virtual objects. This interface contains 2 parts: The first one used for the application controls using the forward kinematics model by giving the robot necessary articulation to attain a desired position, The second part is to integrate the vision module to display real-time video stream from camera. It is used to show the simulation display of the virtual robot and the virtual environment.

3.1.1 The Interface Control

This interface provides all the necessary tools to ensure the control of the robot and to follow the position of the end-effector relative to the camera. The robot can operate according to Joint angles where it moves following its 6 rotations $(\theta_1, \theta_2, \theta_3, \theta_4, \theta_5, \theta_6)$ Figure 4. The end-effector of robot can be shown in this view. The control panel is used to control the motion of the virtual robot by pressing the button on it.

3.1.2 The Vision System

The solidWorks software is used to generate the 3D model of the robot Fanuc 200iC, in this module the tracking process in

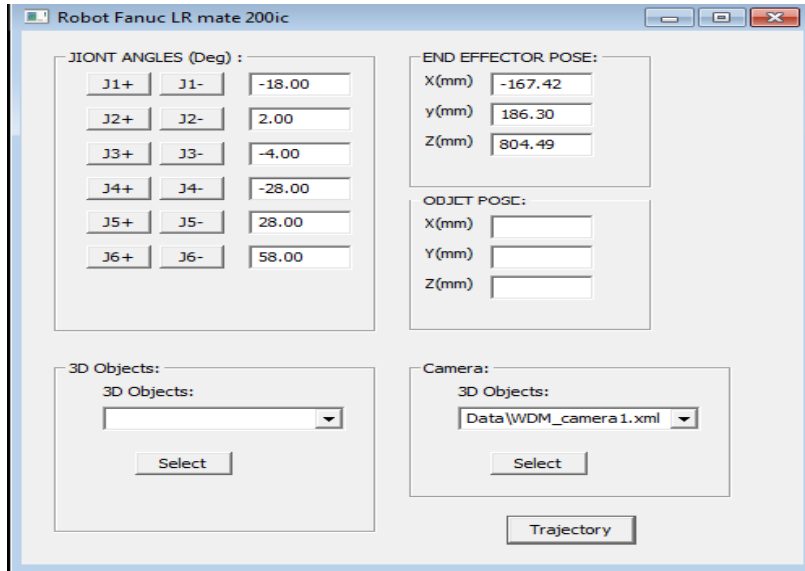


Figure 4. Fanuc 200iC robot interface control



Figure 5. Display real-time video stream from camera

is used with ARToolKit and OpenGL, it is composed of two steps: object recognition and pose estimation. The positions and orientations of the markers relatively to the camera are calculated, and the virtual objects are rendered in video frame as seen in Figure 5.

3.2 Example

A simple miniature work cell was constructed using virtual objects as shown in Figure 6. The task is to move the robot using the interface control to the virtual objects. As the user moves the end-effector, its tip coordinates relative to the camera's coordinate system are displayed in the interface control user for guidance.

We carried out the experiment with 20 robot positions of T_x , T_y and T_z , we computed at the same time the transformation relating

the robot tool to the camera.

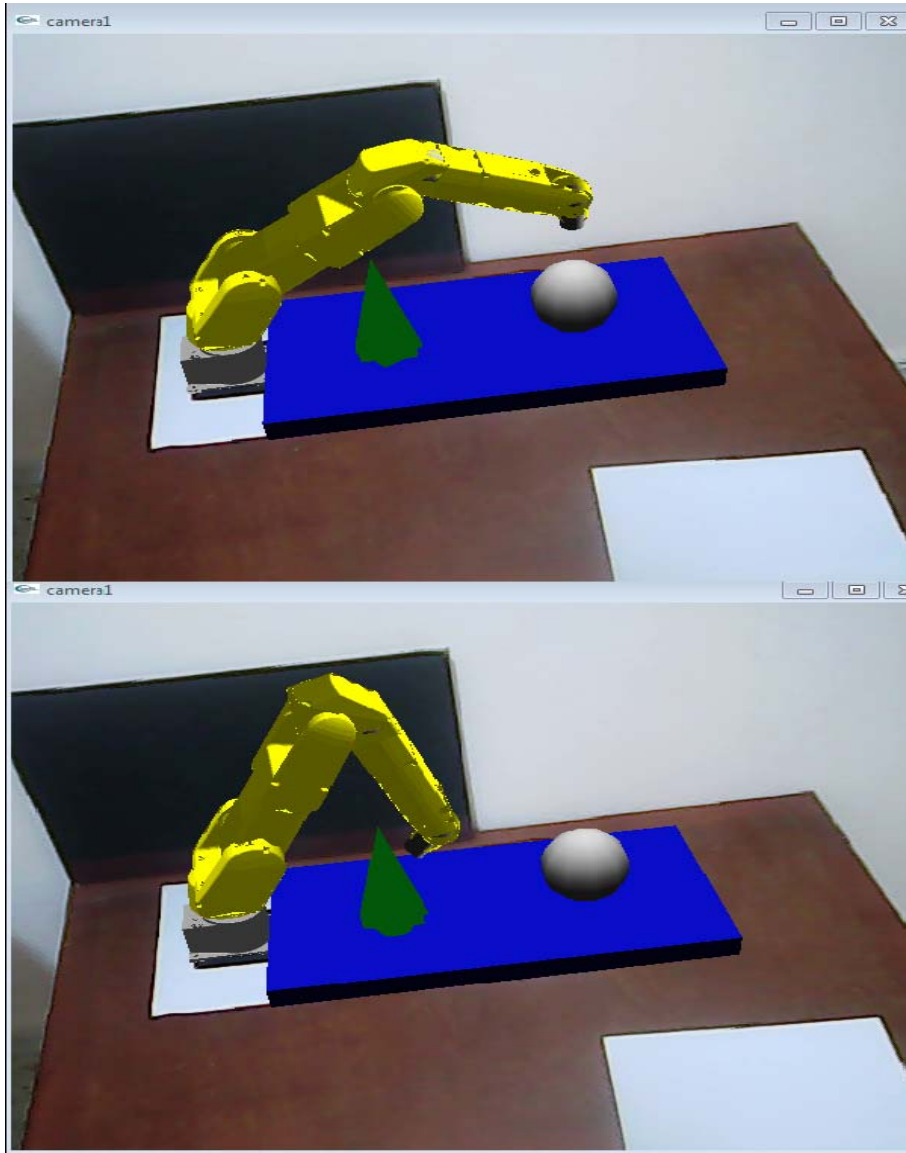


Figure 6. Example of the fanuc robot task

	Average value	Variance	Standard deviation
Tx (mm)	181.1198	1.9960	1.4128
Ty (mm)	181.8311	11.0411	3.3228
Tz (mm)	816.0435	4.3297	2.0808

Table 2. The numerical results of the calibration (Tct)

From the figure 7, we can see that the measured values are fairly constant. It is the goal for the pose estimation between the camera and the end- effector robot.

Table 2 shows that the calibration presents the best performance in term of generalization error, the numerical results proved the effectiveness of this calibration to extend overlaying on other scene elements using a single target pose computation.

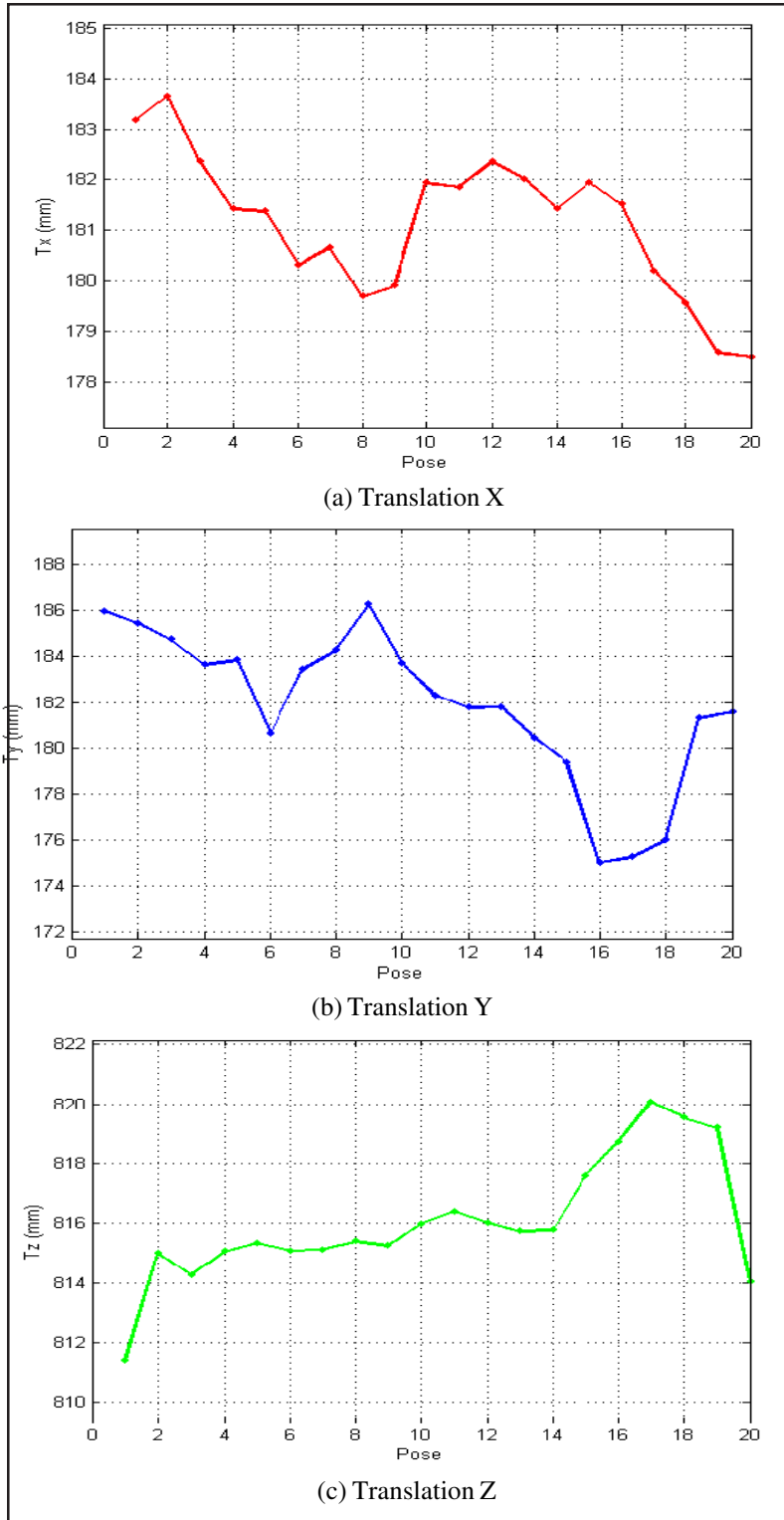


Figure 7. The calibration of the end-effector position (Tct)

Compared to the manipulation application in a virtual reality environment based on VRML (Virtual Reality Modeling Language) in [4], The results from our AR system reveal that our new interface was successful in improving task efficiency, the AR system is added to perform a certain task using the ARToolkits algorithm

4. Conclusion

In this paper, we presented an AR system intended to ameliorate the interaction with the real world. For this purpose, the system vision has been developed using ARToolkits marker detection method and OpenGL library. The manipulation of 200iC FANUC Robot manipulator is solved using the kinematic model of the robot. For the use we created a Graphic User Interface to follow the evolution of virtual robot in the real environment. The analysis of results shows the performance of the system in term of accuracy for camera localization using AR targets. To evaluate the performances of localization, we can added different pose estimation methods (Dhome et al [5], EKF [3], Hybrid EKF [10]).

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