WEB-BASED ROBOTICS REMOTE LAB

A. Ikhlef, B. Boukhezzar, N. Mansouri

Laboratory of automatics and Robotics, University Frères Mentouri Constantine (ALGERIA)

Abstract

A robotics remote laboratory is presented in this paper. It is intended to teach undergraduate students the basic principles of robot manipulators. A graphical environment is developed to allow web-based remote control of the arm robot. A camera oriented towards the robot allows to visualize in real time the robots movement. The robot can be controlled remotely in two modes; point-to-point mode or trajectory mode. The Graphical user interface GUI displays, in real time, the values of the joint angles and the corresponding cartesian position of the end-effector. The GUI is designed to help students to fully understand the control technique of robot arms as well as the interest of using the direct and the inverse kinematic model.

Keywords: remote Lab, Robot Arm, Automatic Control, online laboratories.

1 INTRODUCTION

Laboratory works are very important learning tools, particularly in engineering sciences field. These labs allow the students to see in the real world the application of the different theories studied in the class. They allow them also to observe the difference between theoretical and experimental results and identify the sources of these differences. To carry out the labs work properly, the institutions must provide students with equipment, instruments, workspace, etc.

However, a large part of these institutions suffers from the considerable increase of the student number and the logistical problems, which really makes the organization of lab work more difficult. For this, a lot of researches have been launched to provide a rational solution to these problems. Most of the offered solutions have been based on the evolution of information and the communication systems and the spread of the Internet throughout the world. The remote labs could be a practical solution to this problem because they allow sharing the same experiment lab to a larger number of students spread over different geographic areas. They give a remote access to hardware experiments without the necessity of people displacement, which reduce the inactivity days. The students use a graphical interface to control the experiment and visualize in real time the evolution of the various measurements. Many remote labs have been developed around the world in different fields, Control, Robotics, Electronics, microelectronics, computer sciences, …, etc ([1], [2],[3], [4],[5]).

In this work, an automatic control lab for robotics education is mounted and tested. The remote lab deals with physical experiments for the undergraduate level in automatic control. The whole architecture of the remote lab is based on ISA architecture [6]. The main objective of this work is to teach students the basic principles of modeling and control of the robot manipulators [7]. The platform allows the client or the student to access through his account in order to: make reservation, launch the experiment and view experiment storage results. The student manipulates the experiment via a GUI based on LabVIEW environment [8]. This GUI has two control modes for the robot manipulator; point-to-point control and trajectory control. During the experiment, the student can also visualize in real time the robot's movement via an IP camera oriented to the robot. Moreover, the GUI displays in real time the Cartesian coordinates of the end-effector position and the joint angles corresponding to this position. The student can also enter the values of the desired reference points or trajectories on which he wants to control his robot.

The paper is organized as follows: Section 2 describes the design of the remote Lab. The model of the robot arm is reported in section 3. Section 4 presents the experiment results. Finally, conclusions and some perspectives are given.

2 DESIGN OF THE ARM ROBOT LAB

The general architecture of the arm remote lab is shown in figure 1. The basis of this architecture is the ISA platform. It is mainly composed of two parts:

- The service broker that manage authentication, users access and data storage.
- The Lab server that manage the experiments, it is directly connected to the hardware.

The client (student) can access the platform via his access account using a standard Web browser. He must install in his device the plug-in LabVIEW Run Time Engine to be able to control the experiment from the GUI. When he is logged in, he can reserve a time slot for the experiment, launch the experiment, change the experiment parameters, view the results, …etc. A camera is oriented towards the robot to allow the client to supervise the experiment progress in real time.

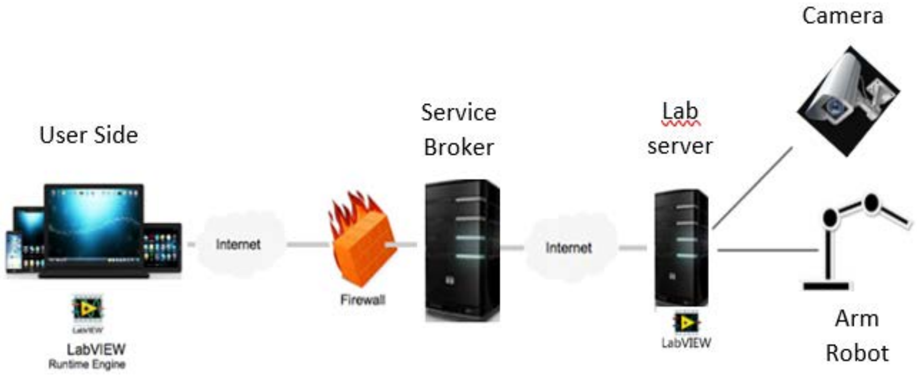

Figure 1. Architecture of Arm Robot Remote Lab.

The home page of the Arm robot remote lab is accessible through the following web site *http://ilab.umc.edu.dz/ilabservicebroker*.

Figure 2. Home page of Arm Robot Remote Lab.

The used GUI was developed in the LabVIEW environment. This environment has a pre-implemented web server designed for the remote control of the GUI created in this environment. The GUI communicates with the robot via an acquisition card. This card is used to send controls to the motors mounted on the robot's joints and to receive position measurements from the sensors. The robot control method is based on the kinematic model.

3 ARM ROBOT KINEMATIC MODEL

The arm robot used in this experiment is a serial link arm as represented in the following figure. To control this robot to move from a given point to another, we need first to calculate his kinematic model (forward and inverse kinematic).

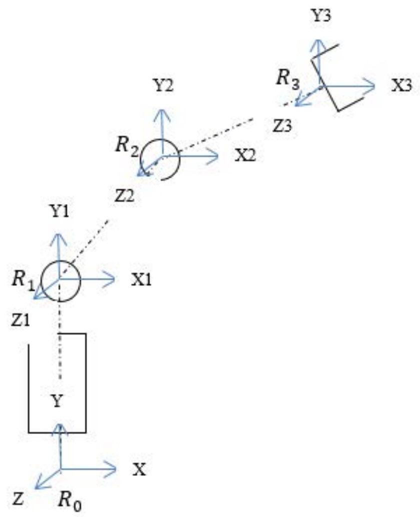

Figure 3. Arm Robot frames assignment.

The presented arm is an articulated robot with three degrees of freedom. All his joints are revolute. For the calculation of forward kinematic model we use the homogeneous transformation matrix. Where the matrix T_1^0represent the position and the orientation of the frame R_1 in the frame R_0. According to the homogeneous transformations we can obtain the following transformations matrix.

$$T_1^0 = \begin{bmatrix} C_1 & 0 & S_1 & 0 \\ 0 & 1 & 0 & a_1 \\ -S_1 & 0 & C_1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}, \quad T_2^1 = \begin{bmatrix} C_2 & -S_2 & 0 & a_2C_2 \\ S_2 & C_2 & 0 & a_2S_2 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}, \quad T_3^2 = \begin{bmatrix} C_3 & -S_3 & 0 & a_3C_3 \\ S_3 & C_3 & 0 & a_3S_3 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

The forward kinematic model represents the position and the orientation of the end effector frame R_3 in the base frame R_0. So, the global transformation T is obtained from the matrix product as follows:

$$T = T_1^0 . T_2^1 T_3^2$$

$$T = \begin{bmatrix} C_1C_{23} & -C_1S_{23} & S_1 & X_p \\ S_{23} & C_{23} & 0 & Y_p \\ -S_1C_{23} & -S_1S_{23} & C_1 & Z_p \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Where $X_p, Y_p \; and \; Z_p$ represent the forward kinematics of the robot arm

$$X_p = a_2C_1C_2 + a_3C_1C_{23}$$

$$Y_p = a_2S_2 + a_3S_{23} + a_1$$

$$Z_p = -a_2S_1S_2 - a_3S_1S_{23}$$

For the inverse kinematics we must express the joint angles $\theta_1, \theta_2, \theta_3$ as a function of the positions $X_p, Y_p \; and \; Z_p$.The implementation of the inverse kinematic model in LabVIEW is presented in figure 4.

4 ARM ROBOT EXPERIMENT AND RESULTS

In order to illustrate the performance of the experimental Arm robot lab described in this paper we present first the developed GUI and the corresponding source code. The GUI presented in figure 5 has three tabs:

- **Manual control mode**: in this mode the client uses the (+) and (-) buttons to change manually the angle value of each joint. he can also open and close the clamp attached to the last link of the robot.

- **Point-to-point control mode**: in this mode the client must enter the Cartesian position of the new desired position. Once the position is validated, the robot automatically moves to this position based on the inverse kinematics model. The client can observe on the interface the movement of the robot as well as the values of the angular variables corresponding to this position. This mode allows him to check the multiple solutions of the inverse model. He can notice that for the same position the robot can have several articular configurations.
- **Trajectory control mode**: the student introduces a set of points in the form of Cartesian coordinates. Once the trajectory is validated, the program calculates for each point the corresponding angular coordinates. These coordinates will be displayed on the interface and transmitted via the acquisition card to move the robot.

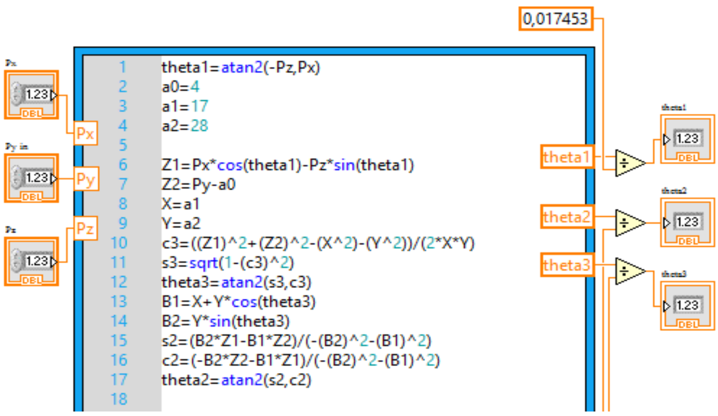

Figure 4. Inverse kinematic model in LabVIEW.

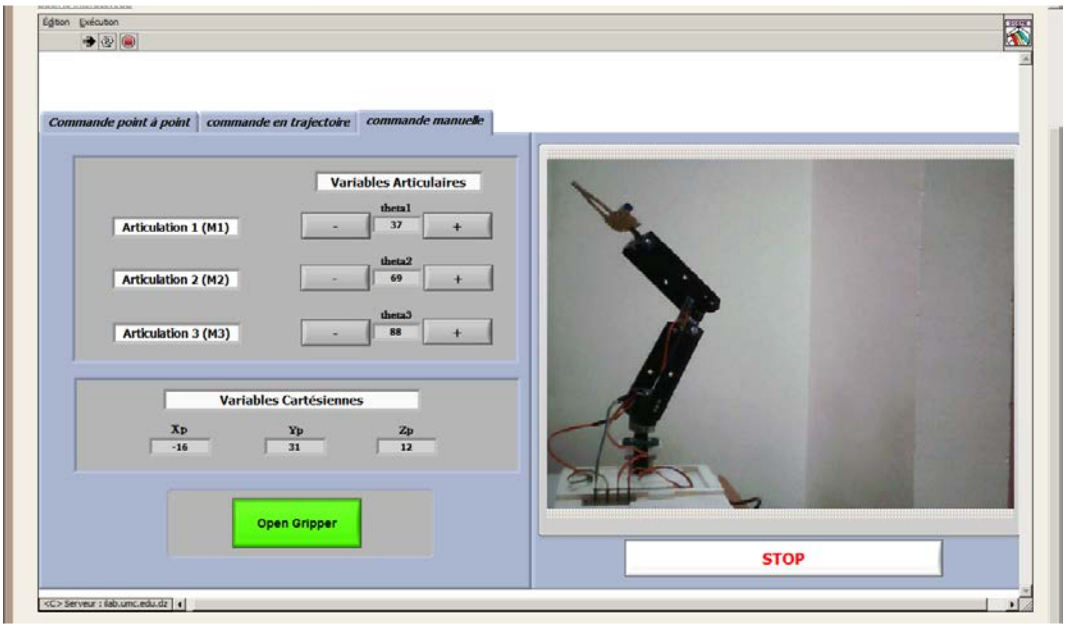

Figure 5. GUI of the remote Arm Robot.

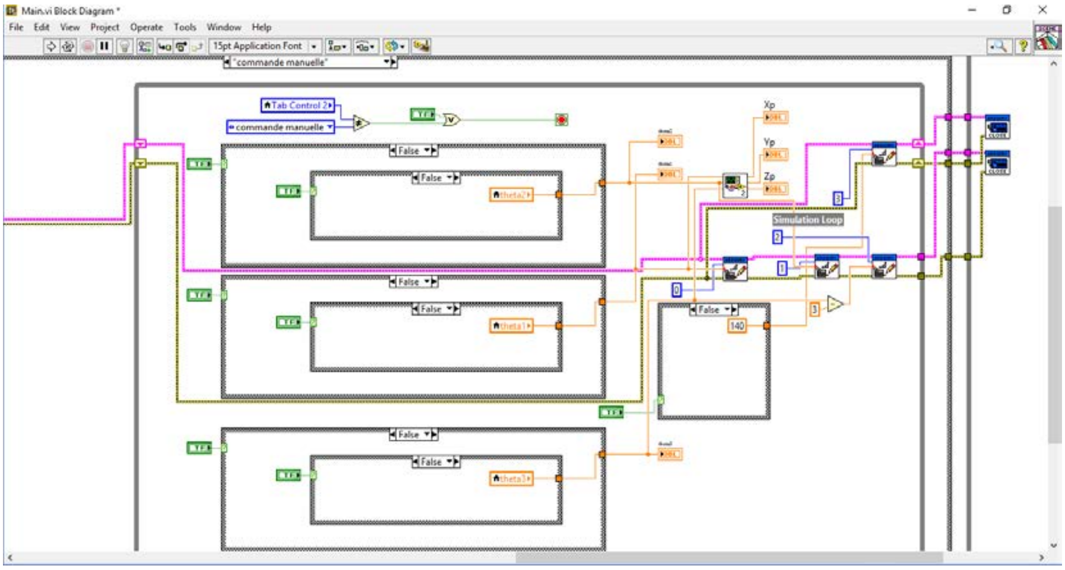

Figure 6. Part of the source code in LabVIEW.

5 CONCLUSION

This lab remains available to students 24 hours a day and 7 days a week to help them understand the basics of modeling and controlling manipulator robots. They can take up the experience several times, unlike hands on lab where the lab session is limited in time. As a future work, we would like to add some features to the GUI like the Jacobian and the dynamic model.

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