Remote Lab for Robotics Applications

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Abstract—This article describes the development of a remote lab environment used to test and training sessions for robotics tasks. This environment is made up of the components and devices based on two robotic arms, a network link, Arduino card and Arduino shield for Ethernet, as well as an IP camera. The remote laboratory is implemented to perform remote control of the robotic arms with visual feedback by camera, of the robots actions, where, with a group of test users, it was possible to obtain performance ranges in tasks of telecontrol of up to 92%.

Keywords—remote environment, remote lab, robotic arm, robotics training

1 Introduction

With the increasing boom of robotics in all human activities, being familiar with the control of a robotic agent is not unusual. Robotic toys today are very common, it is possible to find from assistive robots to support feeding to people with limitations [1] to assistant robots of physical activity for adolescents [2], which are part of the great variety of developments found in the state of the art. The presentations of the robotic agents are very varied, until reaching critical support points, as intermediaries in teleoperations [3]. This type of applications allows to see the incidence of the robots in the activities of the man and his improvement of the quality of life.

Due to this, to develop platforms of training in the control of robots, versatile for any age range, becomes important for its assertive use and development. Nowadays, with the possibility of remote control of different systems, such as air conditioning [4], control of robots [5] and similar, coupled with the advantages of virtual laboratories [6], remote laboratories for telecontrol robots offer solutions for needs such as training in various areas [7], for example in the case of teleoperation.

Remote laboratory environments already carry several developments reported in the state of the art [8][9], and have shown several advantages, such as low cost implementation [10][11] and skill development in robot control and programming algorithms [12][13]. In this article, it is presented a remote laboratory environment for telecontrol of two robotic arm type agents, capable of interacting with each other, using visual feedback from the user through an IP camera, looking for a simple environment of easy assimilation, for learning and training in robot telecontrol.

Then the article is divided into 4 sections, section two describes the design of the remote laboratory, section three presents the analysis of results and finally section four gives the conclusions reached.

2   Application environment

The proposed remote laboratory consists of the manipulation of two robotic arms to tele-command, a monitoring camera for visual feedback and an Arduino card with expander card for Ethernet connectivity, network access routers are used to connect the remote site with the laboratory. In the remote site there is a web interface for manipulation of each degree of freedom by robotic agent and setting of the connection. This scheme, which proposes a bidirectional communication, is shown in figure 1.
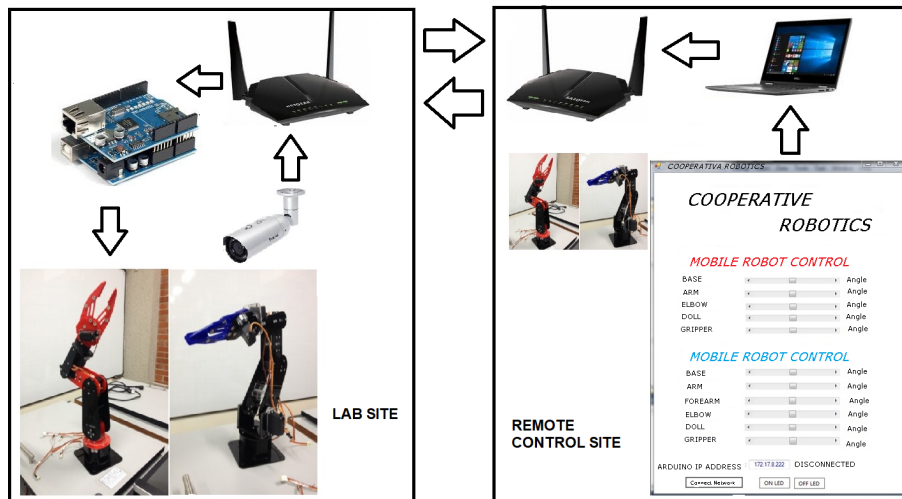

Fig. 1. Application environment.

The first aspect required is to do the kinematic analysis of the robot with respect to a reference system, which allows to determine the position and orientation of the end effector of the robot, known the values of the joints and the geometric parameters of the elements of the robot. For this analysis the Denavit-Hartenberg (D-H) algorithm is used, which is based on the assignment of axes coordinated by degrees of freedom as shown in Figure 1, both robotic arms used have the same architecture.

The kinematic analysis, as shown in figure 2, is derived to determine the D-H matrix, which allows to relate the spatial variations of each degree of freedom and to concatenate them. The virtual environment will allow manipulating each degree of freedom, for the rotational case, using the D-H matrix shown in Table 1.
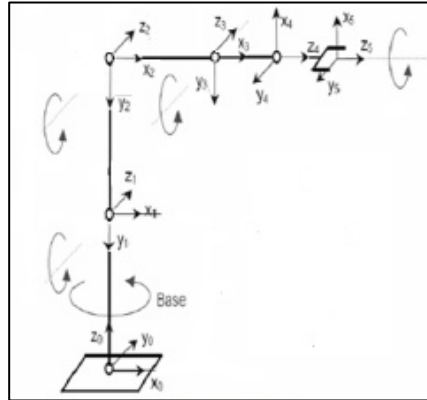
Fig. 2. Inverse Kinematics.

Table 1. Kinematic matrix

Joint	θ	d	a	α
1	q1	d1	0	-90
2	q2	0	d2	0
3	q3	0	d3	0
4	q4-90	0	d4	-90
5	q5	d5	0	0

The energization of all degree of freedom, controlled by servomotor, requires a regulated source of 12 volts at a current of 5 amperes, for the adequate manipulation of both arms, in total 12 servomotors, the power supply provides 12 volts and a maximum current of 5 amps. A voltage regulator L78S05 is used for supplying the Arduino board which regulates the pulse modulation signal of each servomotor and the Ethernet connectivity card used, Figure 3 illustrates the connection circuit designed for the integration of the source to the Arduino control board and servomotors connections of each arm.
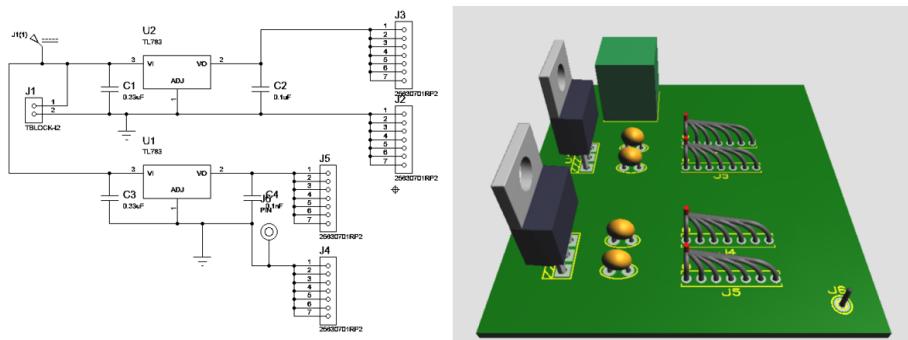

Fig. 3. Control circuit.

Figure 4 illustrates the implementation of the circuit and Arduino cards used, in the area of the physical laboratory.

Figure 5 shows the robotic command interface of each of the degrees of freedom per arm, which is located on the remote computer. For visual association of the user two colors are used, red for arm one and blue for arm two. Shift bars are used for greater agility in the variation of movement of the robotic arm, towards the left side the angle decreases and towards the right it increases. The interface includes the field of assignment of the IP address of the Arduino card in the remote area to be reached by the Ethernet network. On the left side the visual feedback part is visible to the user via the IP camera, the interface allows the IP address to be entered. The environment of this application was implemented in C language under the Visual Studio software.
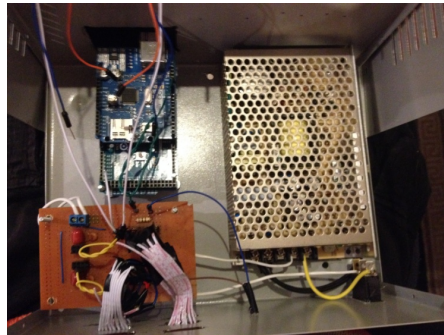

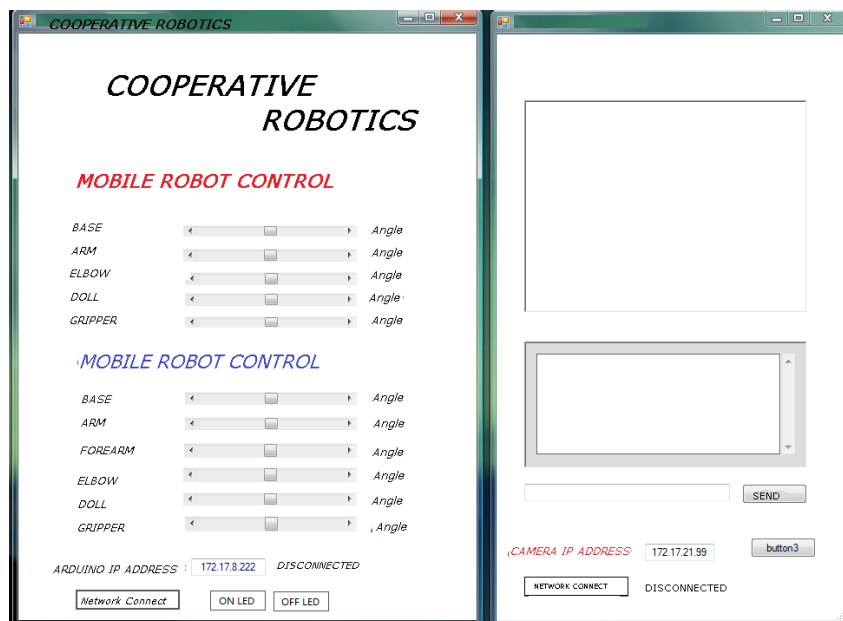**Fig. 4.** Integration of circuits for robotic control.

Fig. 5. Remote monitoring and control tool

Figure 6 shows a flow diagram that guides the start-up logic of the remote application. It must be initialized by doing the network connection, once done, it will initiate the transfer of information from the remote application to the Arduino in the lab and from the IP camera in the lab to the remote interface.
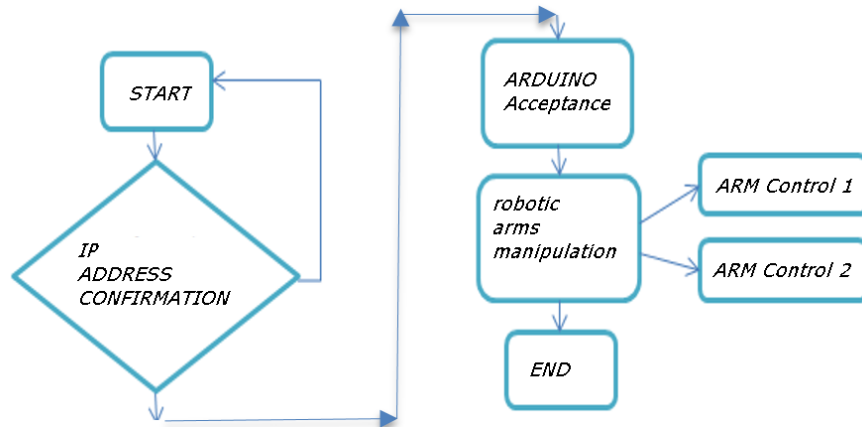

Fig. 6. Flow diagram of operation.

3 Results

To evaluate the remote working environment, a sequence of manipulation of the robotic arms is done to perform a joint object grab task, this sequence consists in manipulating the red robotic arm to pick up a didactic ball, take it to the end effector of the blue robotic arm and it must grab it and move it to another location. Figure 7 illustrates the set sequence, for the case by 5 different users.
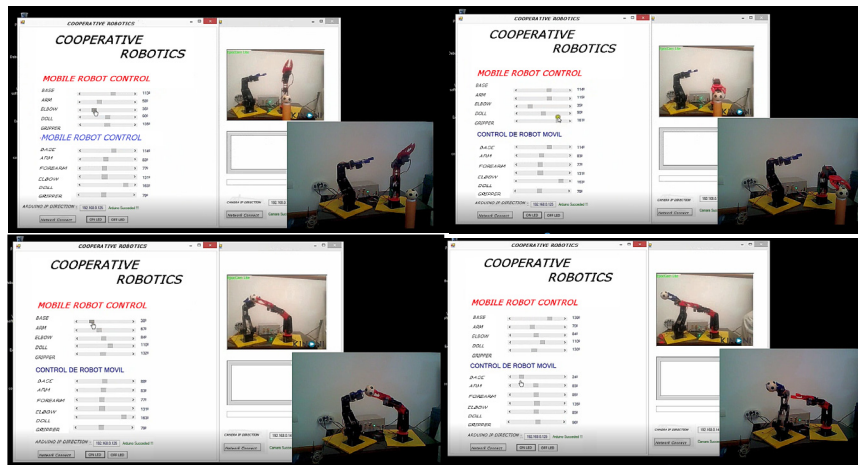

Fig. 7. Test sequence.

Table 2 lists the results obtained when performing the sequence to the test users, who were previously trained in the manipulation of the different degrees of freedom, so that they had a certain level of familiarity with the remote environment and the control of the robot. Accuracy is determined by tolerance values established as metrics in the execution of movements, for example, taking the ball properly and delivering it, without falling during the process, without exceeding the end position of the desired end point, i.e. having to return to reposition some degree of freedom, etc.

Table 2. User Validations

Test	1	2	3	4	5
Accuracy (%)	92	88	82	78	89
Time (min)	3,57	4,12	4,46	4,51	4,38

From the results it can be observed that the task is performed by all users and, according to the expertise of each one, it requires more or less execution time. Subjective factors such as caution are introduced, which at the time characterized the user 5 that with a precision of 89% handled the controls of each robot more carefully to avoid passing a visual reference of displacement, according to the feedback of the camera, which is why it took much longer, compared with user 2, who operated the robots with almost the same precision.

There are some variations of latency in the communication with the IP camera, due to the amount of information to be transmitted, proper to the video signal. These were controlled by an iterative adjustment of the image capture resolution so that it would not be unnecessarily reduced beyond the value according to a time delay noticeable by sight.

4 Conclusions

A remote environment was designed for telecontrol of robotic agents, allowing the proper manipulation of two robotic arms distant through network links. Because of the design features, the remote platform is generic to the kind of user that can operate it, given its simplicity. This design makes the platform functional to students of secondary or professional education.

With this virtual environment it can be developed and verified pre-program routines to the offline mode manipulator, facilitating the user the learning process in telecontrol practices. Although kinematics is involved in the development of the control algorithm for each degree of freedom, including the spatial reference of the effector point to an object of interest would allow better metrics to be performed in precision tasks.

This type of environment allows a simple and inexpensive robotic telecontrol learning interface, usable from anywhere with network connection, easily adaptable to any type of robotic action sequence, such as telesurgery.

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