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Web-Based Laboratory Using Multitier Architecture

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1. Introduction

Actuality, Internet provides a convenient way to develop a new communication technology for several applications, for example remote laboratories. The remote access to complex and expensive laboratories offers a cost-effective and flexible means for distance learning, research and remote experimentation. In the literature, some works propose platforms based on the Internet in order to access experimental laboratories; nevertheless it is necessary that the platform provides a good architecture, clear methodology of operation, and it must facilitate the integration between hardware (HW) and software (SW) elements. In this work, we present a platform based on "multitier programming architecture" which allows the easy integration of HW and SW elements and offers several schemes of tele-presence: teleoperation, telecontrol and teleprogramming.

The remote access to complex and expensive laboratory equipment represents an appealing issue and great interest for research, learning education and industrial applications. The range potentially involved is very large, including among others, applications in all fields of engineering (Restivo et al., 2009; Wu et al., 2008).

It is well known that several experimental platforms are distributed in different laboratories in the world, and all of them are on-line accessible through the Internet. Since those laboratories require specific resources to enable a remote access, several solutions for harmonizing the necessary software and hardware have been proposed and described. Furthermore, due to their versatility, these platforms provide user services which allow the transmission of information in a simply way, besides being available to many people, having many multimedia resources.

The potentiality of remote laboratories (Gomez & Garcia, 2007) and the use of the Internet, as a channel of communication to reach the students at their homes, were soon recognized (Basigalup et al., 2006; Davoli et al., 2006; Callangan et al., 2005; Imbre & Spong, 2006; Rapuano & Soino, 2005).

Several works based on remote experimentation, which are used as excellent alternatives to access remote equipment, have been published (Costas et al., 2008).

Then, to solve the problem of testing engineering algorithms in real-time, we apply the advantages of the computer Network, computer communication and teleoperation. Furthermore, developing these new tools give the possibility to use these equipments for remote education.

In remote experimentation there exists several schemes based on the communication channel called **telepresence schemes**, some of them are: i) **teleoperation**, ii) **teleprogramming** and iii) **telecontrol**. In (Wang & James, 2005) some concepts are related with teleoperation. In other works, (Huijun et al., 2008) analyze the time-delay in the telecontrol systems, and (Cloosterman et al., 2009) studies the stability of the feedback systems with With Uncertain Time-Varying Delays. Others authors propose platforms only to move remote equipment, for example robots, (Wang & James, 2005). Finally, few works talking about the remote programming are published; see for instance (Costas et al., 2008).

However, for a remote laboratory to be functional, it must be capable of offering different schemes of telepresence. This can be easily understood from figure 1 which is an extension of the figure given in (Baccigalup et al., 2006). A comparison between different teaching methods, taking into account the teaching effectiveness, time and cost per students, is schematized in figure 1.

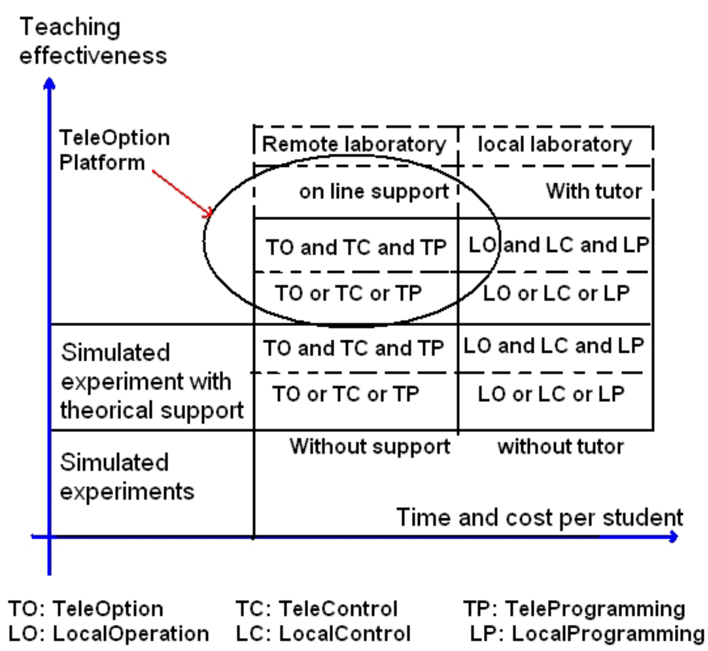

Fig. 1. Comparison between local and remote laboratories.

Contribution

Considering figure 1, the goal of this work is to introduce a platform called *Teleoptions*, which offers an alternative for remote laboratories, using three of the *telepresence schemes*: teleoperation, telecontrol and teleprogramming.

The main feature of this framework is its multitier architecture, which allows a good integration of both hardware (HW) and software (SW) elements.

Structure of the work

This work is organized as follows: In Section 2, definitions and concepts used in this work about tele-control, tele-operation and tele-programming are introduced. In Section 3, the proposed scheme based on multitier architecture is presented. The laboratory server description is given in Section 4. In Section 5, two applications of the platform are presented. The first application concerns the remote experimentation of an induction motor located in the IRCCyN laboratories in Nantes; France. The second application consists of the remote experimentation of the manipulator robot located in the CIIDIT-Mechatronic laboratories in Monterrey; Mexico. Finally, in Section 6, conclusions and recommendations are given.

2. Some concepts

Now, we introduce the concepts of teleoperation, telecontrol and teleprogramming, which will be used in the sequel.

Teleoperation is defined as the continuous, remote and direct operation of equipment (see figure 2). From the introduction of teleoperation technology, it made possible the development of interfaces capable of providing a satisfactory interaction between man and experimental equipment. On the order hand, the main aim of **telecontrol** is to extend the distance between controller devices and the equipment to the controller. Thanks to the development of the Internet, the distance between controller devices and the equipment has been increased (see figure 2).

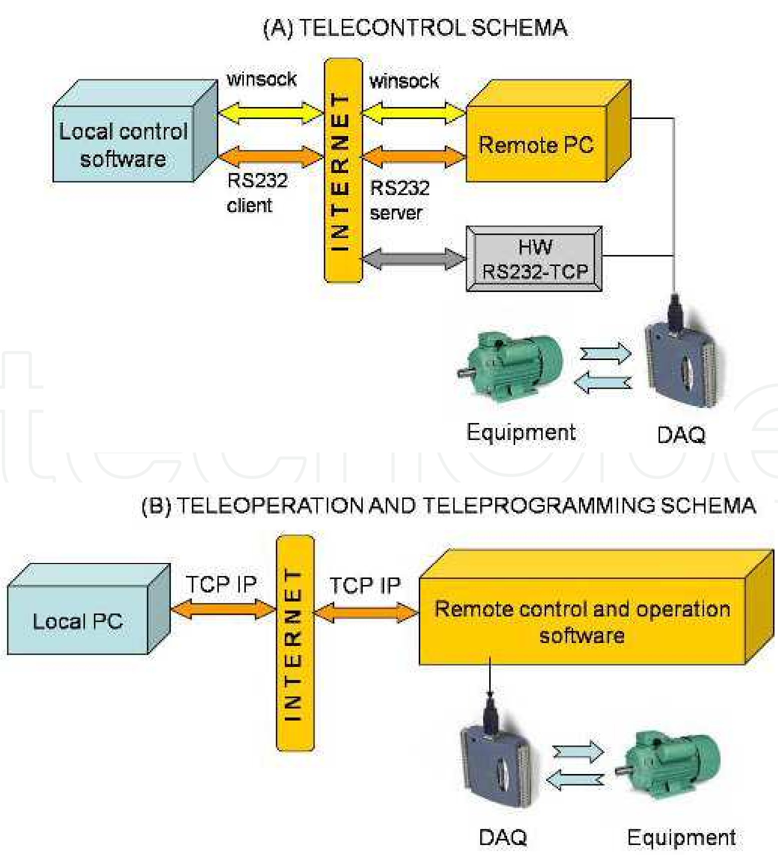

Fig. 2. Telecontrol, teleoperation and teleprogramming schema.

Figure 2.B shows a **teleoperation** scheme through the Internet working with a single channel of communication. This channel is used to change the parameters of the controller devices and/or plant. However, the effects of these changes will depend on the server layer.

Figure 2.A shows a **telecontrol** scheme through the Internet, in which the two channels of communications are required (closed-loop system), i.e. forward path *Ch1* and feedback path *Ch2*. In this case, it is necessary to maintain the stability of the closed-loop system. A solution to stability problem is that the time dalay must be less than the sampling period (Hyrun & Jong, 2005).

Furthermore, there exists a different interpretation about the **teleprogramming**. One of them is extending the distance between software programmer and the microcontroller or control board. On the other hand, it is possible to programming a remote system using two systems, called the master system and slave system, separated by the communication channel. In (Jiang et al., 2006) the teleprogramming method is based on teleoperation.

3. Framework proposed based on multitier programming

Now, we will introduce the software descriptions that are used in the proposed platform.

Figure 3 shows the tiers of the proposed framework called *Teleoption*, which has more performance than a classical telepresence framework application. *Teleoption* allows the interaction between different elements in hardware and software. Furthermore, it is possible to work under the three schemes of telepresence, i.e. teleoperation + telecontrol + teleprogramming.

The top level of the framework is the HTTP server, winsock services, webcam server and RS232 server. The second level of the framework implements the PHP script modules, DLL library and database services. All services can be shared by the VNC Server.

This distribution of software presents great advantages: i) Security in the platform, ii) several ways to transmit information from the hardware.

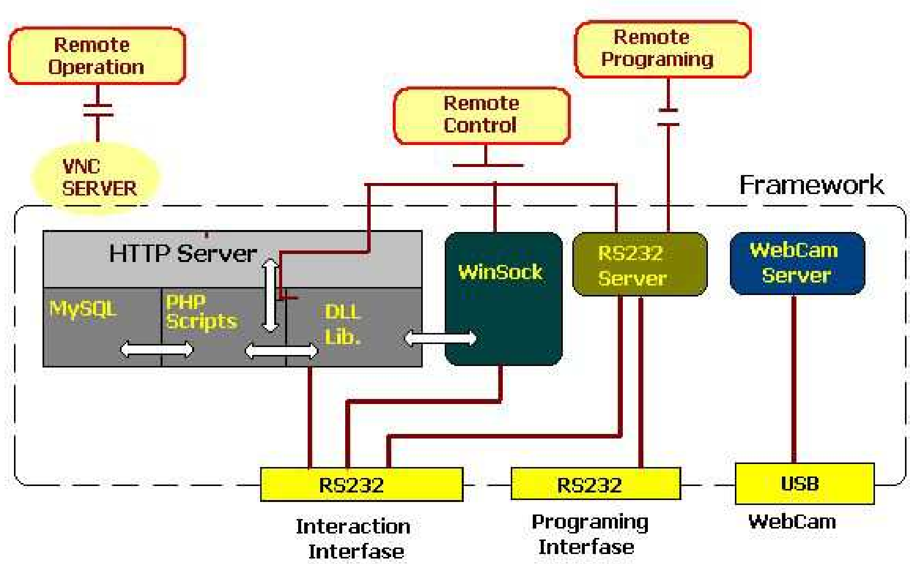

Fig. 3. Multitier architecture proposed.

Presentation tier. The HTTP Server is the presentation tier. This tier contains several Web pages with information of the platform services.

Furthermore it includes the instructions and regulation of the platform

Logic tier. In this tier, we have the programming layer. Three programming languages are used in the platform: PHP, Visual Basic and SQL. In the logic tier interacts the blocks: *i)* "PHP scripts" (which contain several programs in PHP) , *ii)* the block of the data base MySql and, *iii)* the block of the DLL libraries (designed in VBasic).

Database tier. The database tier contains information about of the platform, i.e. the users list, logbook. In fact, logic tier and database tier provide security to platform, since it is possible to use restrictions proportioned by a PHP script. This script allows the use of the platform only if the user has the permission.

Communication tier. The platform allow establish several ways of communication with the hardware: i) using *Serial Server Component* (RS232 Server), ii) using Windows sockets (Winsock) or DLL's library, and iii) using the PHP script services (see figure 4).

Serial Server Component is a software based RS232 to TCP/IP converter. RS232 Server allows any of the RS232 serial ports on the PC laboratory to interface directly to a TCP/IP network.

On the order hand, also is possible the remote access using the sockets of Windows or DLL's library. The remote user uses its own programs to send instructions to program modules of the platform.

Finally, the platform has modules designed in PHP, here, the remote user can to access to hardware using a Web page of the platform.

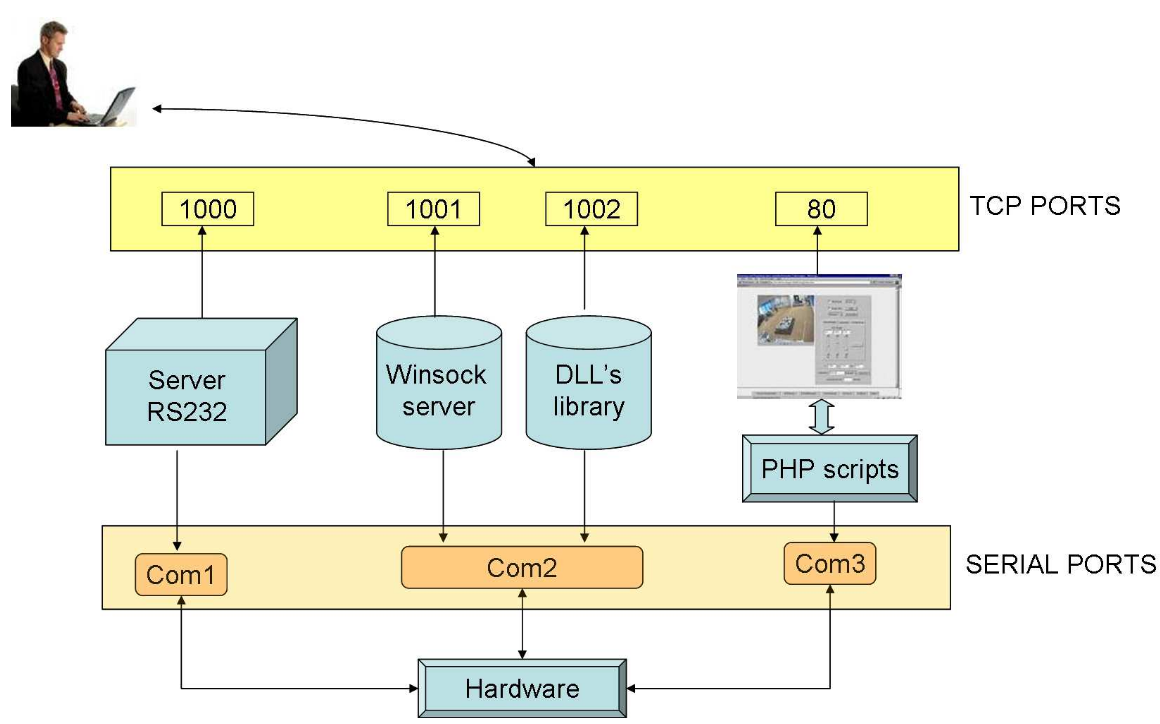

Fig. 4. Communication tier.

3.1 Operational method of the platform

When the services of **remote programming** are used, then the framework opens a communication's channel in order to share the serial services (RS232), and allows the remote programming.

If the services of **remote control** are used, then the framework opens more communication options. The first option is similar to the remote programming method, but in this case the control board and the equipment are separated, a remote communication is established by means of Internet using the services of the RS232 Server/Client.

The second alternative of remote control is the winsock option, which is similar to the last method, but the interchange of information is given by the winsock module. In this case, it is necessary to know the operation commands of the controller in order to send the information through that Internet to Winsock module, and then Winsock module will send the information to hardware.

The third option of remote control, the framework allows the access to control of the hardware using a Webpage, where the user does the work of controller. Here, the framework receives the commands of the user and sends this information to some PHP script, which sends the information to the operational layer of the multitier programming.

Finally, in the ***remote operation***, all framework are shared using the services of some VNC (Virtual Network Computer) which is a communication protocol based on RFB protocol which allows the remote access of the desktop of other computers located on the web. VNC protocol transmits the keyboard and mouse events from one computer to another, relaying the graphical screen updates back in the other direction, over a network.

4. Laboratory Server (LS) implementation

Besides the proposed framework, an architecture based on *Computers of Distributive Tasks (CDT)* is proposed. This architecture is shown in figure 5.

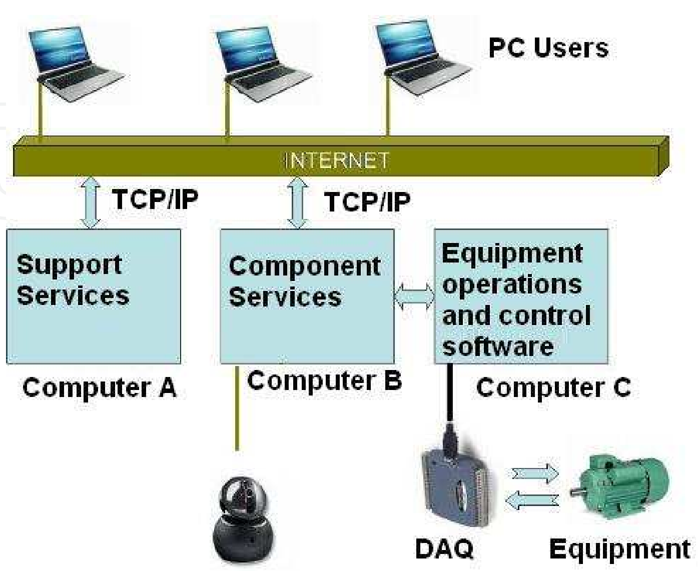

Fig. 5. Computers of Distributive Task.

Computer A allows establishing a communication both textual and oral between the local and remote user, in such way, this computer provides help on line and uses the following freeware software:

- Messenger: Textual communication and webcam.
- Skype: Oral communication, IP Telephony and videoconference.

Computer B has the task of sharing several resources through the Internet. The architecture proposed is installed in this computer. This computer uses the following software:

- Matlab/Simulink. This Software is used typically in control systems.
- ControlDesk. It is a graphical tool for controlling in real-time the equipment.
- UltraVNC server. It is software belonging to the VNC family
- LogmeIN. It is ESS software.
- TCPComm server. It is a RS232 server, which allows sharing the serial ports (COMM) of the computer. Serial port is used commonly as communication channel between PC and equipments.
- WebcamXP. Allow sharing the images from the webcams, these webcams can show the equipment details.

Computer C has an interface with the data acquisition board (DAQ), and does not share any resources on the Web. This computer is only used to share information with Computer B throughout the remote control. Furthermore, this computer protects the access to the plant (experimental equipment) in order to avoid damages caused by unauthorized users.

5. Experimental setup: Study cases

5.1 Remote experimentation of an electrical machine

The methodology described in the above section is applied to show remote access to the set-up of electrical motor located in the IRCCyN laboratory in Nantes France (figure 6), from the CIIDIT-Mechatronic laboratory in Monterrey, Mexico.

The set-up located at IRCCyN is composed of an induction motor, a synchronous motor, inverters, a real time controller board of dSPACE DS1103 and interfaces which allow to measure the position, the angular speed, the currents, the voltages and the torque between the tested machine and the synchronous motor. The motor used in the experiments has the following values: 1.5 kW normal rate power; 1430 rpm nominal angular speed; 220V nominal voltage; 7.5A nominal current; np = 2 number of pole pairs, with the motor nominal parameters: Rs = 1.633 Ohms stator resistance; Rr = 0.93 Ohms rotor resistance; Ls = 0.142H stator self-inductance; Lr = 0.076H rotor self-inductance; Msr = 0.099H mutual inductance; J = 0.0111/rad/s2 inertia (motor and load); fv = 0.0018Nm/rad/s viscous damping coefficient. The experimental sampling time T is equal to 200 s.

Furthermore, this laboratory is equipped with the remote technology described above, and can present several time delays that can appear during any real time experiments and are necessary to analyze:

- Transmission delay thought Internet (TI).
- Control algorithm computation (TC).
- Sampled time of the Data Acquisition (TS).

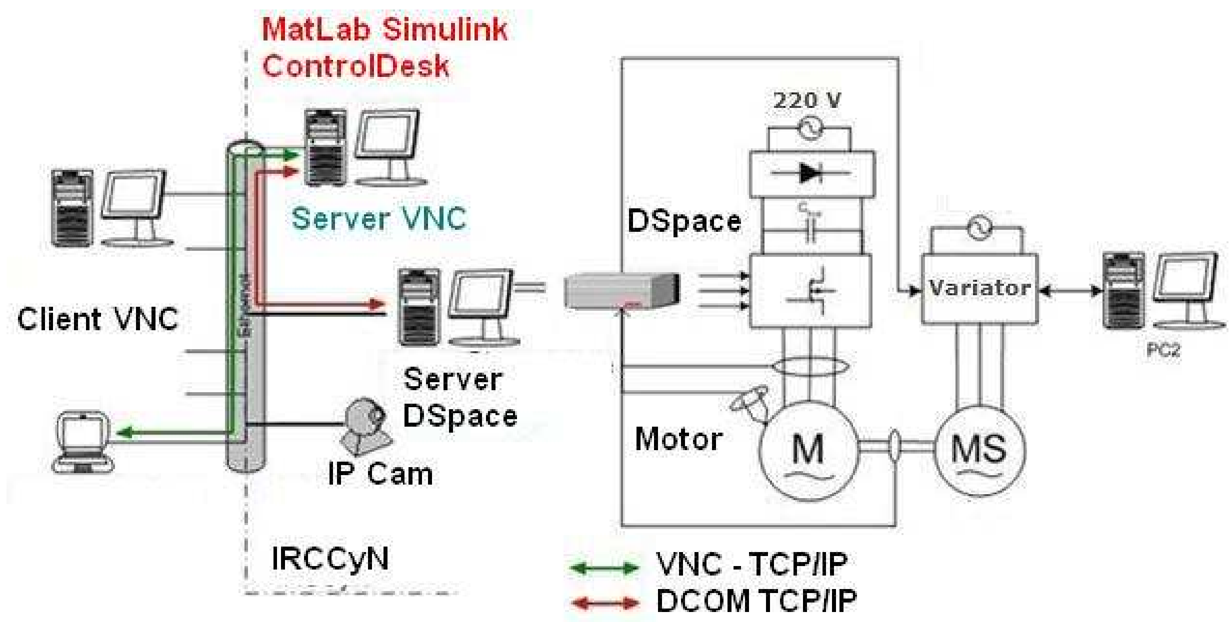

Fig. 6. IRCCyN laboratory schema.

These time delays depend on the tele-presence scheme selected. In a telecontrol scheme, the total time T = TI + TC + TS could be high and could affect the stability of the system. Nevertheless, if T = TC + TS is small, then a teleoperation scheme offers an excellent solution in remote experimentation, due to the time delay TI is not considered by the aforementioned reasons (see section 2).

Therefore, the scheme used for remote experimentation is based on teleoperation where the effects of the time delay and uncertain property is not considered in the stability of the system, because the controller and the plant are in the same layer, as shown in figure 2.

In this experiment, the time delays registered are: TI (ping) = 400 mseg. avg., TI (camera) = 3 seg. avg., TI (screen feedback, VNC) = 2 seg. avg., TC < 70 mseg.; TS = 120 seg. (DS1104).

Figure 7 shows a Mexican user, which applies a control algorithm, in order to access the remote laboratory, located in Nantes; France. From the figure 7, we can see *the computer A* showing the images sent by the webcam and the response obtained when the control algorithm is applied to the induction motor, which is transmitted by computer B using Controldesk and Matlab.

Figure 8 and 9 shows the screenshots obtained from this experiment. The first image shows the images given by webcam of the machine (with the sound), the second figure shows the Remote software ControlDesk throughout LogmeIn services.

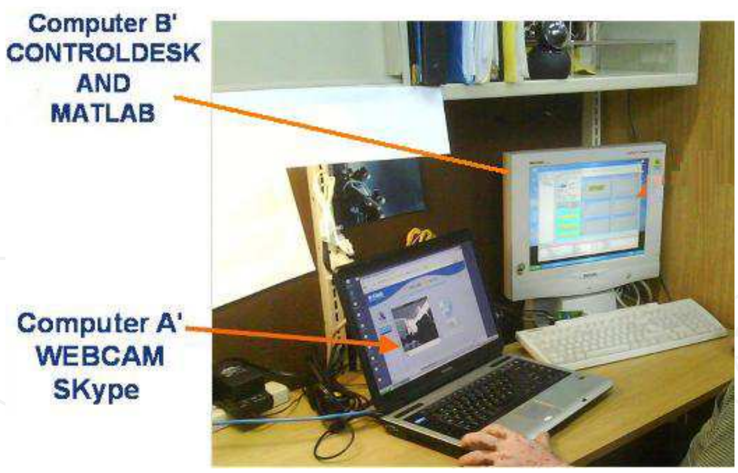

Fig. 7. Remote access by Mexican user.

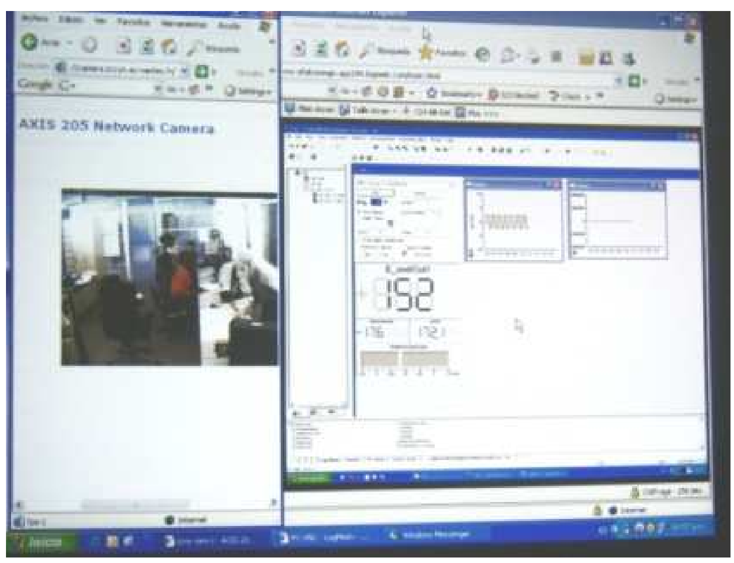

Fig. 8. Remote experimentation using LogmeIn services.

Fig. 9. Remote images of the induction motor.

5.2 Platform-setup in robotic education

It is undisputed that remote laboratories are not able to replace traditional face-to-face laboratory lessons, but they present some benefits of remote accessible experimentation:

- Flexible schedule vs. restricted schedule.
- Individual experimentation vs. group experimentation.
- Access from any computer vs. access only in the laboratory.
- Student self-learning is promoted.
- Student can use other educative means as Internet documentation, simulations, software, etc.
- The student is motivated when he is seeing his experiments and results.

This section presents another application of the architecture proposed. We emphasize that this architecture allows a remote user to access the services of control, programming and operation of robots located in the CIIDIT-Mechatronic laboratories in Monterrey; Mexico.

Teleprogramming. The objective of the teleprogramming is that the students use the BASIC microcontroller language in order to program the PICAXE microcontroller. In this platform, the student can use the basic instructions in order to program the robot: servo*, goto, serin, serout, pause, if, for*.

The student can program the PICAXE microcontroller using the flowchart method programming. Flowchart is an excellent means of pedagogy; the software shows a panoramic and graphical view of the programming sequence.

Telecontrol. The platform allows sharing the DLL resources so that the student can design programs in Visual basic, C, Matlab, or other languages. In the telecontrol option, the student can design and prove algorithms, using simulation software in local mode, subsequently if the capacity of the network is not large and it does not affect the stability of the systems, then it can be proven on-line on the robot.

Teleoperation. This platform offers the teleoperation services, so that the student can use all the services of the platform in remote mode. In this case, the platform shared the services of teleoperation using the Skype and logmeIn services.

Figure 10 showing the laboratory scheme located in CIIDIT laboratory in Mexico. The hexapod robot is acceded from the *PC Controller* Computer using two communication channels, RS232 and video. In the *PC Controller* Computer one is located the *Controller Module Server (CMS)*. The end user uses the services of the CMS in remote mode in order to control the hexapod robot.

Figure 11 showing the *screenshot* of a computed located in the IRCCyN Laboratory accessing to CIDDIT laboratory using the *LogmeIn* services.

- Figure 11.A shows the surroundings of the hexapod robot from a internal camera (eye hexapod).
- Figure 11.B presents the hexapod robot from a external camera (auxiliary camera).
- Figure 11 C shows the computers of the remote laboratory.
- Figure 11 D. showing Controller Module Client (CMC).

In the experiment, such a move-and-wait strategy is implemented of initiating control move then waiting to see the response of distant robot: then initiating a corrective move and waiting again to realize the delayed response of the distant system and the cycle repeats until the task is accomplished.

Let us define N(I) to be the number of individual moves initiated by the operator according to the move-and-wait strategy. The number N(I) depends only on the task difficulty and is independent of the delay value according to experiments (Hocayen & Spong, 2006). Consequently, the completion time, t(I), of the certain task can be calculated based on the value N(I) as follows:

$$t(I) = t_r + \sum_{i=1}^{N(I)} (t_{mi} + t_{wi}) + (t_r + t_d)N(I) + t_g + t_d \quad (1)$$

Where $t_r, t_{mi}, t_{wi}, t_g, t_d$ are human`s reaction time, movement times, waiting times after each move, grasping time and delay time introduced into communication channel, respectively.

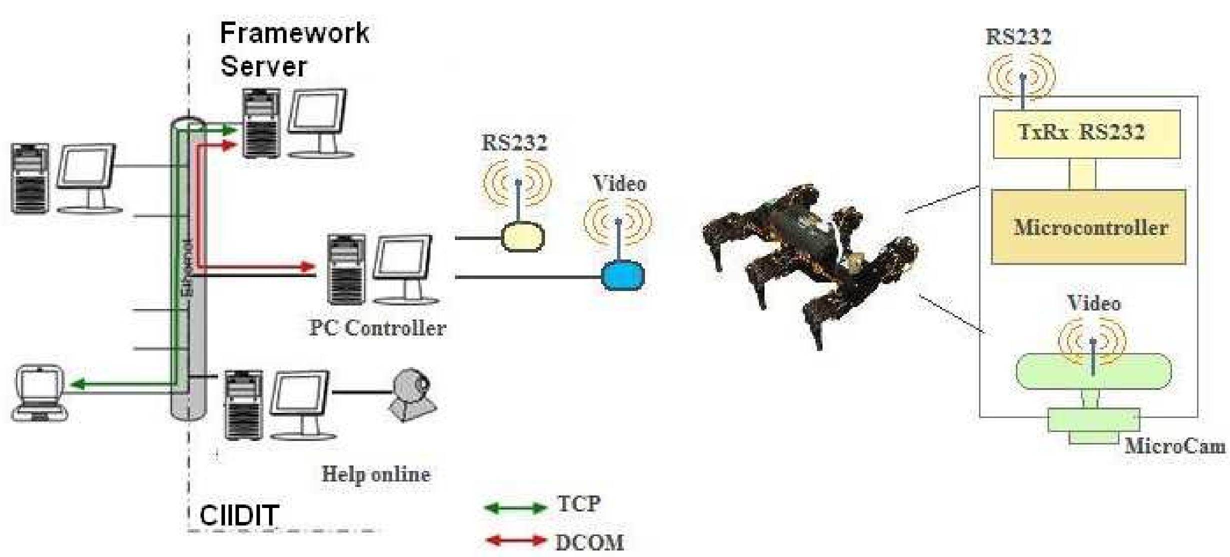

Fig. 10. CIIDIT Laboratory schema.

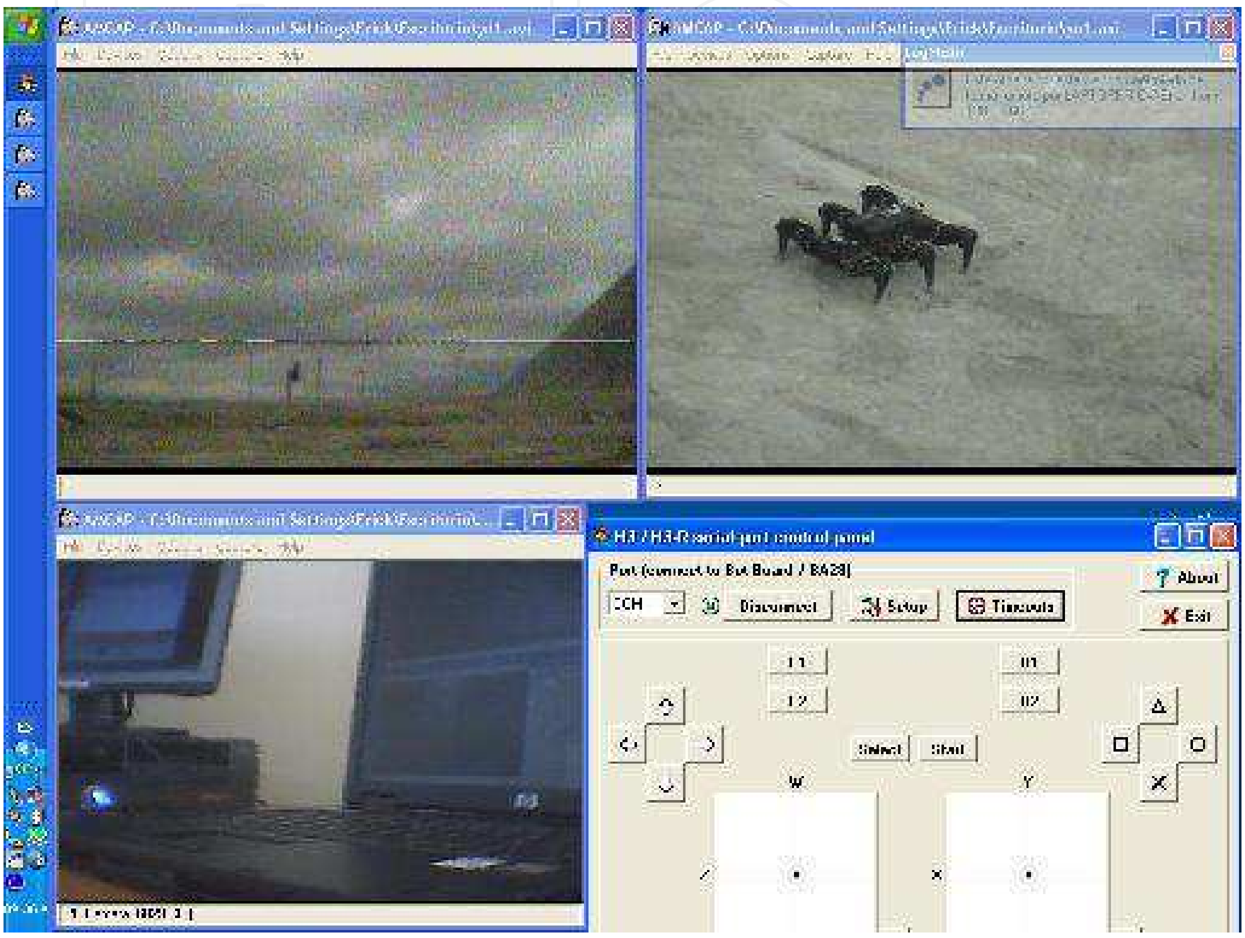

Fig. 11. Experimentation from IRCCyN, Nantes France.

6. Conclusions

In this work the capability of interfacing a large set of options with remote experimentation through the Internet has been demonstrated by the architecture based on multitier architecture.

This architecture allows the easy integration of both hardware and software, offering an excellent tool for remote experimentation, which allows the experimentation using the teleoperation, the telecontrol and teleprogramming schemes.

The main characteristic of the proposed platform has been outlined in this paper by means of a description of experiments.

7. Acknowledment

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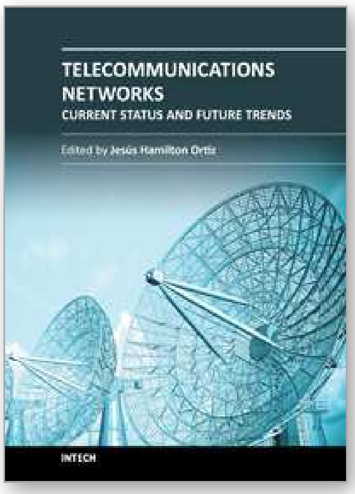

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This book guides readers through the basics of rapidly emerging networks to more advanced concepts and future expectations of Telecommunications Networks. It identifies and examines the most pressing research issues in Telecommunications and it contains chapters written by leading researchers, academics and industry professionals. Telecommunications Networks - Current Status and Future Trends covers surveys of recent publications that investigate key areas of interest such as: IMS, eTOM, 3G/4G, optimization problems, modeling, simulation, quality of service, etc. This book, that is suitable for both PhD and master students, is organized into six sections: New Generation Networks, Quality of Services, Sensor Networks, Telecommunications, Traffic Engineering and Routing.