FACTA UNIVERSITATIS
Series: **Automatic Control and Robotics** Vol. 11, N° 1, 2012, pp. 45 - 56

REAL-TIME WEB ACCESS TO THE MECHATRONICS LABORATORY IN THE PROCESS OF E-LEARNING

UDC 004.738.4 159.953 681.5:007.52

Slobodan Aleksandrov[1], Zoran Jovanović[2], Stanimir Čajetinac[3], Milomir Mijatović[3]

[1]Techical School Trstenik, Serbia
[2]University of Niš, Faculty of Electronic Engineering, Department of Control Systems, Niš, Serbia
[3]College of Applied Mechanical Engineering, Trstenik, Serbia

Abstract. *Application of e-learning is getting a new dimension due to the development of fast Internet, which makes it possible to transmit video and audio material in real time through the global Internet network. Nowadays distance learning enables students to access the college and school laboratories in real time wherever they are and whenever they want. The paper presents one of the cheapest solutions to modern WEB-based control laboratories used to educate students in the fields of mechatronics and automatic control of systems. Students can use Internet remote access to the laboratory, controlling the robot from the distant computer or via mobile phones using Android platform.*

Key words: *Ethernet, mechatronics, robot control, TCPIP, Web services*

1. INTRODUCTION

Electronic learning is getting a new dimension due to the fast development of information and Internet technologies. In the late 20th century Learning Management System (LMS) was developed and implemented. These systems enable interactivity in distance learning, monitoring of students' work, as well as database creation. There are many LMS systems which have different capacities and prices. One of the most popular platforms for creating virtual on-line classrooms is Moodle LMS (www.moodle.org). This system provides setting the lessons containing video and audio materials, presentations, knowledge tests, forums, e-mail exchange, chat and other Internet services. The system is used as a supplement to the classical education system (hybrid learning system), but also as a system for creating on-line courses in formal and informal education. This system is

Received April 16, 2012
Corresponding author: Slobodan Aleksandrov
Techical School Trstenik, Vuka Karadžića 11, 37240 Trstenik, Serbia • E-mail: aleksandrovs@yahoo.com

usually applicable in adopting theoretical knowledge. When scientific knowledge is in question the system is not complete due to the lack of training on laboratory equipment, which is a prerogative for adopting practical knowledge and skills [1, 2]. The paper presents the characteristics of up-to-date mechatronics laboratory which is used to train students not only under real conditions but also for remote access by fast Internet and Web browser. The paper aims at implementation of free of charge software in the process of creation of the laboratory for remote access to real didactic mechatronics systems. Apart from education, the system for remote access and control by means of Internet is also applicable to real industrial mechatronics systems. The system is suitable for remote video supervision and system control, monitoring the system parameters, change of parameters, remote detection and error elimination, stopping and starting the automatic systems. When this application is in question a special attention must be paid to the Internet time delay [3] as well as to the increase of protection level when accessing industrial systems.

2. ORGANIZATION OF WEB BASED LABORATORY FOR MECHATRONICS

The control over mechatronics systems involves a wide range of knowledge and skills in the fields of mechanics, hydraulics, pneumatics, electronics, sensors, electromotor drives, programmable logic controllers (PLC), computer science and programming. The general diagram of mechatronics systems is shown in Fig. 1.

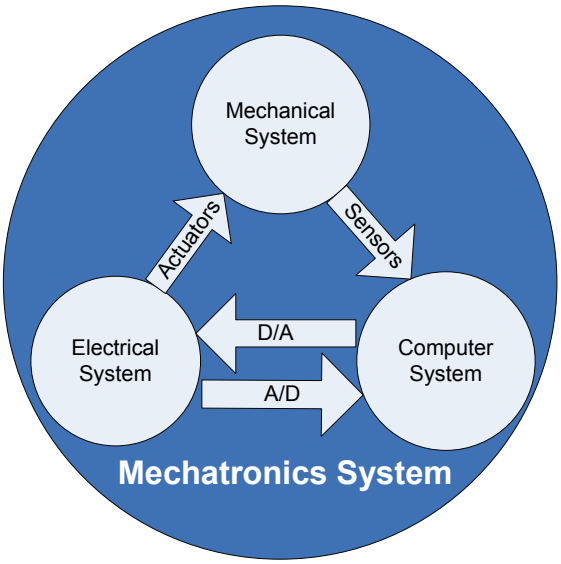

Fig. 1. Block diagram of the mechatronics system

The mechatronics system is a fusion of mechanical, electrical and computer systems into a single functional automation system. Modern didactic systems, which look like real

industrial mechatronics systems and which are realized with industrial components, are needed for successful education in the field of mechatronics. These systems are very expensive so schools and colleges cannot provide various didactic mechatronics systems. Also, not more than two students should be trained simultaneously on one didactic system in order to successfully obtain the skills wanted. The laboratories at the colleges can be used only during working hours. Thus, the Web laboratory for remote access is the best solution if students and teachers want to use the laboratory equipment from any place all over the world [4, 5]. Therefore, several Web laboratories from one or more related universities can be networked into a single virtual centre [6]. It enables students, professors and scientists from various universities to use modern laboratory equipment and didactic systems. This system has great importance not only for education but also for joint research and project realization by the scientists from different national and foreign universities. The paper presents the laboratory for mechatronics in Engineering School in Trstenik, which is used for regular teaching processes. The aim is to form the Web laboratory (Fig. 2) which would be available for the pupils, students and teachers on-line after working hours. The laboratory consists of the following didactic systems:

- Robot station Mitsubishi Melfa RV-2AJ
- Sorting station controlled by PLC Festo FC-640
- Distribution station controlled by PLC Festo FC-640
- Two electro-pneumatic systems controlled by PLC Festo FC-34
- PLC system for controlling the operation of asynchronous motor
- PLC system for controlling the operation of DC motor
- Two PC computers
- Notebook
- IP Web video cameras
- Samsung I5500 Galaxy 5 Android smart phone
- Network equipment - switch and router
- Internet ADSL connection
- Software for PLC programming - Festo Software tools V.4.10.50
- Software for robot programming - RoboExplorer 1.1

The first didactic system Mitsubishi Melfa RV-2AJ is a robotic hand with five degrees of freedom. The joints of the robot are driven by AC servomotors, while the actuator is a pneumatic gripe having photo sensors. The robot is controlled by the controller which has three modes of operation:

- Manual moving of the robot by the module for remote control
- Control of the robot by the computer by means of software package RoboExplorer

Automatic mode

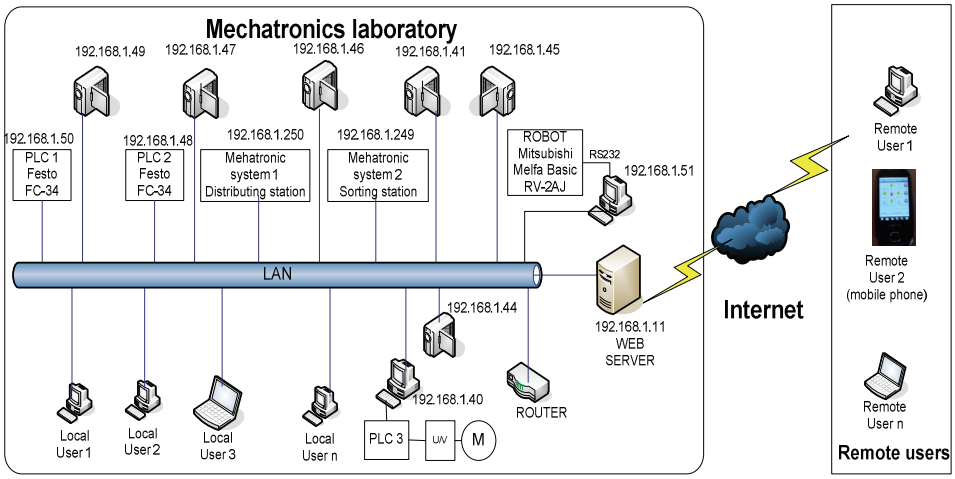

Fig. 2. Web based mechatronics laboratory

The PC computer is connected with the robot controller by a series of connection RS232. Robot positions are set and robot programming is done in the program package RoboExplorer. The setting of the robot coordinates and program writing are shown in Fig. 3. Thanks to this didactic system the students should be able to master hardware structure of the system, the interaction, control and programming of real industrial robots. For on-line use of this system it is necessary to set the option of remote control of the computer which is connected with the robot and on which the appropriate software is installed. If there is no such option, it is advisable to apply some of the software packages such as Team Viewer, Remote Desktop and the like. The first experiment which was conducted in the laboratory of Mechatronics in the Engineering School in Trstenik was to use the software package TeamViewer for remote access to PLC. Testing this remote access to PLC over the Internet was realized between many locations – the automatic control laboratories at the Faculty of Electronics in Niš and in the laboratory of Mechatronics in Engineering School in Trstenik. This system, configuration parameters, and the particular way of accessing the work were presented in a paper [7, 8]. In this paper, this model was used for remote access and control of Mitsubishi Robot Melfa RV-2AJ, by using Internet network. The system for remote robot control is equipped with a video camera and it enables constant monitoring of the robot arm movements in the real time. Controlling the robot using TeamViewer from the remote computer is done in exactly the same way as in the real system in the laboratory (Fig. 4). From a local or remote location students can:

- move the robot
- teach points
- download teach points to the controller
- download robot programs to the controller
- monitor the programs running in the controller
- monitor the status of inputs/outputs
- start/stop programs

- reset errors
- turn the servos on/off
- monitor the position of the robot
- drag and drop files into the robot controller

In addition to controlling the robot from the distant computer, remote control was realized via mobile phones using Android platform. Implementation of such a remote control is also possible with a mobile platform iPod and iPhone. Besides the direct application of this remote control system in education, remote access to Web based laboratory, it is convenient for monitoring and controlling distributed automatic controlled systems. Mobile wireless technology today presents new alternative teaching and learning tools.

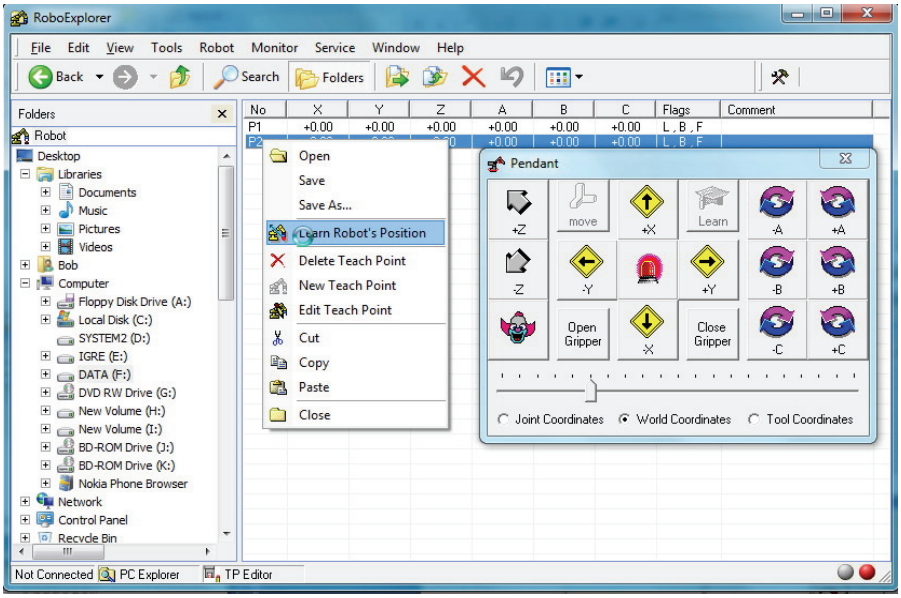

Fig. 3. Setting the robot tool coordinates

Besides all here mentioned advantages of the system, controlling the robot via mobile phone over the Internet, we have noticed the following limitation and disadvantages:

- For easy access you need fast Internet network.
- For easy and quick video transfer in the real time, you need three video cameras of high resolution placed in the position to monitor the whole working space of the robot.
- Placing the robot in the desired position is not easy
- In the process of programming the robot, it is advisable to define coordinates where the robot hand will move in advance.
- For easier control and work, it is advisable to have a mobile phone with a larger diagonal and larger monitor resolution.

This system gives possibilities for further development of the controlling software which will eliminate the here mentioned disadvantages and enable a total control of the robotic system, with special reference to define access rights, time limitation and collision detection.

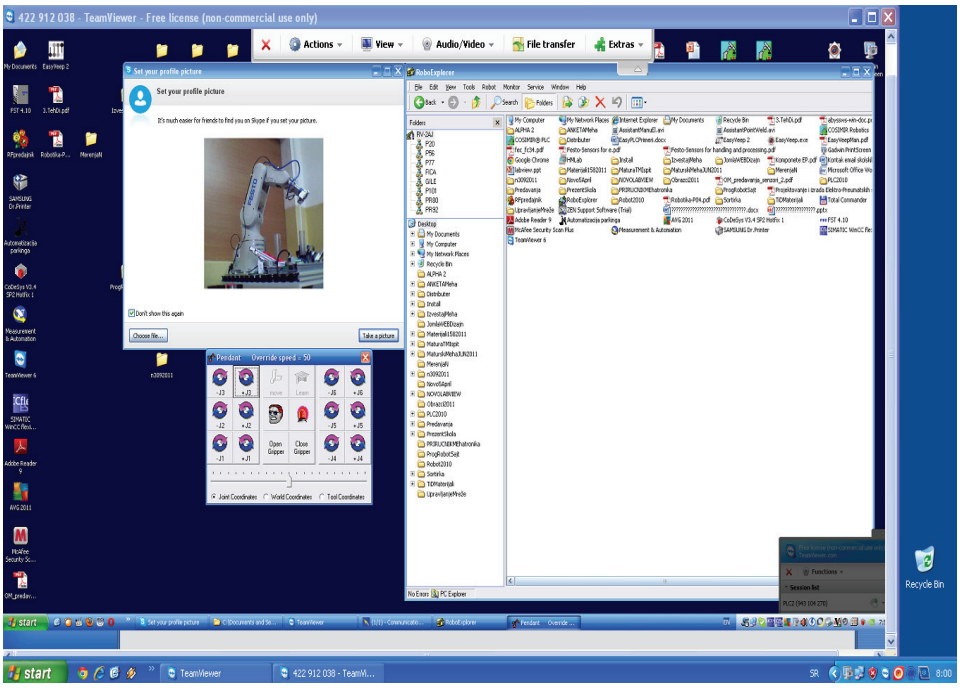

Fig. 4. Robot control from remote location

Didactic systems for distribution and sorting, which are controlled by PLC, are used to test and diagnose real mechatronic systems. These systems are controlled by Festo PLCs FC640 which have network module, support for TCP/IP and which are directly connected to the local switch device by Ethernet cable. Each PLC has a unique IP address thus enabling a direct access through the computer network.

Electro-pneumatic systems are controlled by Festo PLC FC34 and they are used to program the PLC and test current programs (Fig. 6). Software package Festo Software Tools V4.10.50 is used to program the PLC. Like the previous system, each PLC has its local IP address and is connected with the local switch device by network cable. The connection between these systems within LAN is shown in Fig. 2. Applied Festo PLCs have the support for TCP/IP and Web server [9-14]. These PLCs and network cameras have unique local IP addresses, which enables them to have a direct access to any system either by local computer network or Internet browser from any place in the world. The system controlling the operation of asynchronous motor is used for testing the current programs and for writing new ones which control the motor operation. The control is done by Festo PLC FC-34 which have network module, support for TCP/IP and which are directly connected to the local switch device by an Ethernet cable.

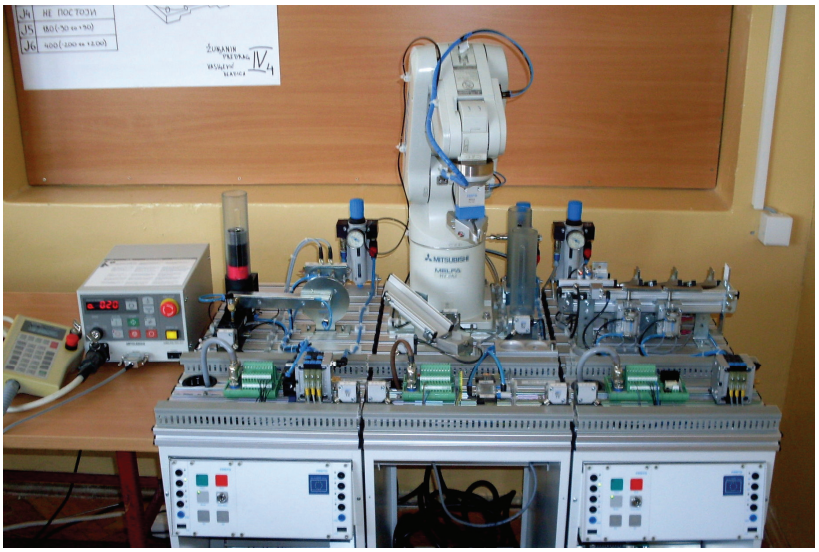

Fig. 5. Industrial robot Mitsubishi RV-2AJ, sorting and distribution station

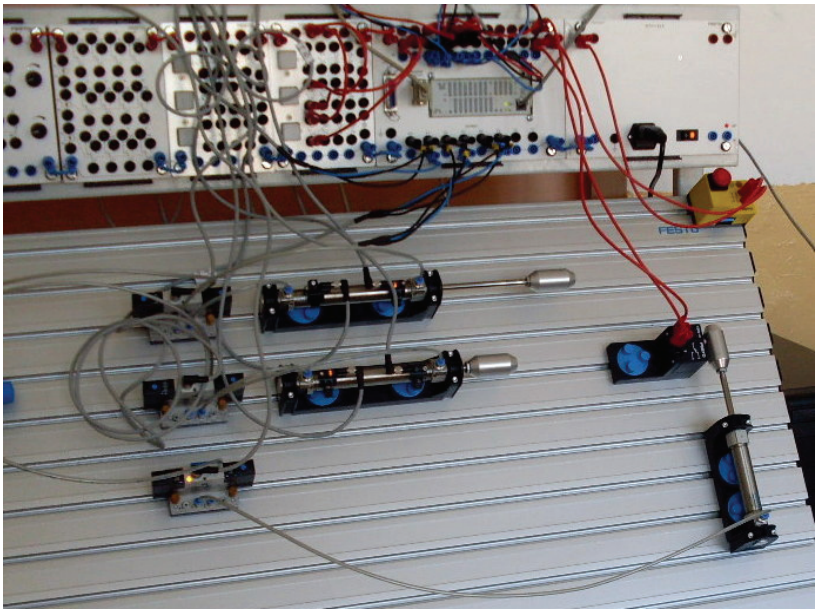

Fig. 6. Electro-pneumatic systems controlled by PLC

The PLC controls frequency regulator which controls the speed and direction of the asynchronous motor (Fig. 7). The system controlling the operation of DC motor is used for testing the current programs and for writing new ones which control the motor operation. The control is done by Omron ZEN PLC which is connected with the computer by a series of connection RS232.

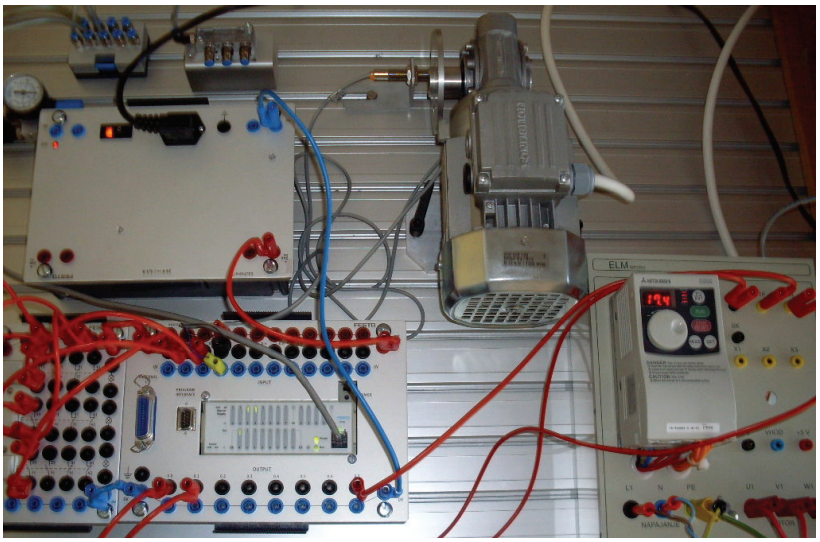

Fig. 7. AC motor speed and direction control with PLC

IP video camera monitors the operation of each didactic system. The camera has its own IP address so the systems can be accessed through the Web browser at any time.

3. SYSTEM FOR REMOTE ACCESS

To realize the system for remote access to the Web laboratory there must be a Web domain with static IP address, server, network equipment and software. The price of such systems is rather high so the schools, colleges and universities nearby cannot afford them. The paper presents a solution for remote access to Web-based laboratory for mechatronics based on free software packages and services. Most Internet providers assign dynamic IP addresses to their users and these addresses change according to some rules. This type of IP addressing is called dynamic addressing. One must be familiar with the new IP address to access a computer. It is done by special Internet service which automatically updates the IP address of defined host or domain after registration and domain activation (Fig.8). Dynamic DNS service enables Internet users to host their own domain name, even if they have dynamic IP address or are behind a router. These services enable the computers to access LAN network by registered domain with no change of IP address. The services are presented on the following sites http://www.dyndns.com, http://www.dns2go.com, http://www.dynu.com and http://www.no-ip.com. DynDNS service (http://www.dyndns.com) is used to realize remote access to the laboratory. The first thing to do is the registration of the unique domain, for instance mechatronikats.dyndns.org, which enables students to access the Web laboratory. When the client's DynDNS is installed, the IP address of the host computer is updated automatically so the changed IP address complies with the registered laboratory domain. Thus the users can access the Web laboratory through a known Web address regardless of the current IP address. This service defines the application of video cameras, e-mail servers, FTP servers, Remote Access and open source Apache

Web server. The access to the Web laboratory is controlled by the server in which WAMP (Windows Apache MySQL and PHP) is installed and access Web site is set. Wamp Server is a Windows web development environment. It allows the creation of web application with Apache, PHP and MySQL database. This server is an open code system having great possibilities. The address of local Web server is 192.168.1.11. The system defines the IP address of gateway, appropriate ports at the router and the range of IP addresses which allow the remote access (Table 1).

Table 1. Network/Port forwarding

Network/NAT/Port Forwarding	
Default Server	192.168.1.11
Service name	Web server
Port	80-80
Server IP	192.168.1.11

By using the network router service Dynamic Domain Name System (DDNS) it is possible to assign dynamic IP address to a fixed host or domain. By setting the dynamic DNS at the router and forward ports at the web, the entire Internet traffic coming to the port 80 is forwarded to the local Web server. Thus the access to the Web server set at the local computer is provided by the Internet and by entering the address which is registered at DynDNS.

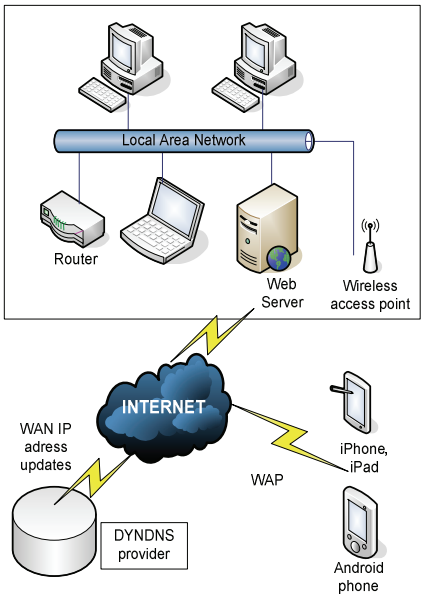

Fig. 8. Dynamic DNS IP address update

To realize the system, it is necessary to define all network protections against unauthorized access:

- Physically secure remote access servers.
- Apply and maintain a strong virus protection solution
- The NTFS file system should be utilized to protect data on the system volume
- All unnecessary services and applications not being utilized on remote access servers should be uninstalled
- Create and configure remote access policies
- Create and configure remote access profiles
- Configure remote access authentication methods
- Enforce the use of strong passwords
- Configure encryption levels to secure remote access communication
- Raise the domain functional level to provide additional security features for your remote access infrastructure
- IPSec filters can be used to protect confidential IP traffic
- Monitor remote access server activity

Table 2 shows the ports used by some Web services.

Table 2. Router port forwarding

Protocol	Port
FTP	21
Ethernet/IP	4481 (TCP), 2222 (UDP)
Http	80
Modbus	502
CoDeSys(IPC)	1200
CoDeSys(750-84x)	2455

All computers and IP Web cameras within LAN network are assigned private IP addresses, for example 192.168.1.x, while the router has the external IP address 109.92.39.79. Most routers have the option "port forwarding" specifying the number of router ports which are assigned to the wanted IP address of the computer within LAN network. The example of the parameters configuration is presented in Table 3.

Table 3. IP address and router port

109.92.39.79: 5278	192.168.1.44 : 5278
109.92.39.79: 5277	192.168.1.48 : 5277
109.92.39.79: 5276	192.168.1.52 : 5276

The access to didactic systems is done by standard Web browsers whereas their operation is monitored in real time by Web IP cameras. The system is also available through the local computer network. Time-limited access in real laboratories does not provide enough time for students to master the necessary knowledge and skills. The system for remote access enables the students to access the real didactic systems whenever they want, to acquire and check their theoretical knowledge and practical skills at their own pace. The implementation of an exercise can be repeated until the wanted results are

reached. Therefore, the students are motivated to work independently on modern mechatronics systems, to improve their self-confidence, and to enhance their creativity. The system provides individual access to learning, monitoring the students' improvement, exchange of the experience through forum and chat service, as well as team work and so on.

In order to have an on-line access to the laboratory the students must master the lessons related to the didactic systems and to pass on-line knowledge tests. The students who passed the tests are sent an e-mail containing the user name, password and time defined for accessing the laboratory. To have the remote access and to use the existing laboratories there must be a fast Internet connection with high Up/Down speed, fixed or mobile IP Web cameras of high resolution, network devices, server platform and accompanying software. It is advisable to create graphic environment for simple use of didactic systems. The disadvantage of these systems is that one didactic system can be controlled simultaneously by one user only, but there is a possibility for multi-user monitoring of the system operation by an IP camera. The students get the feedback by IP video camera, Internet browser or by special software CoDeSys [11] which has support for HMI (Human-Machine-Interface). Internet time delay generally does not influence the education process. Time delay is important for controlling real mechatronics systems by the Internet. Time limitations for accessing the Web laboratory solve the problem of simultaneous request for accessing one system. The users having a low speed of Internet access have delays.

4. CONCLUSION

E-learning is getting a new dimension by development of fast Internet, which makes it possible to transmit video and audio material in real time through the global Internet network. Nowadays distance learning enables students to access school and university laboratories in real time whenever they want and wherever they are. This paper presents one of the cheapest platforms for the Web-based laboratory for mechatronics. The laboratories can be used either by the Internet through direct access of control PLC-s or by remote access to the laboratory computers which control the mechatronics systems. A special importance of this laboratory is that students get feedback in real time during program testing. There is an option to eliminate the error on-line and to redo tests until the wanted control is reached.

The authors wanted to emphasize new possibilities for distance e-learning, the possibilities for combining theoretical and practical knowledge, comparison of simulation, virtual and real models of mechatronics systems. Creation of virtual university centers into a single system enables the scientists and students to simulate and test different mechatronics systems, to compare the results of simulation models with measured results of real systems. The development of virtual centers offers great opportunities for joint international projects.

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WEB PRISTUP U REALNOM VREMENU LABORATORIJI MEHATRONIKE U PROCESU ELEKTRONSKOG UČENJA

Slobodan Aleksandrov, Zoran Jovanović,
Stanimir Čajetinac, Milomir Mijatović

Primena e-učenja dobija novu dimenziju razvojem brzog Interneta, čime se stvaraju uslovi za prenos video i audio materijala u realnom vremenu kroz globalnu mrežu Interneta. Učenje na daljinu sada omogućava studentima pristup u realnom vremenu fakultetskim i školskim laboratorijama, sa bilo koje geografske lokacije u željenom vremenskom intervalu. Ovaj rad predstavlja jedno od jeftinijih rešenja za savremene WEB bazirane laboratorije (WEB-based control laboratory) za obrazovanje studenata u području mehatronike i automatskog upravljanja sistemima.

Ključne reči: *Eternet, mehatronika, upravljanje robotom, TCPIP, Web servisi*