

# Industrial machinery optimization and maintenance system via World Wide Web

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**Abstract:** - Nowadays, it is frequent that engineering companies use Internet as the main working environment for the complementary services offered to their customers. Furthermore, Internet allow the development of powerful tools dedicated to the remote maintenance, *on-line* supervision and performance optimisation of the industrial machinery. In this *paper*, a extensive set of complementary services via Internet denominated *IngeRAS<sup>TM</sup>* that provide rapid and effective access to industrial machinery, supplied by the Basque company *Ingelectric S. A.*, is described.

Additionally, a new remote system dedicated to the *hardware-in-the-loop* (HIL) experimentation concerning the optimisation of the performance of industrial controllers installed by the company, is presented. Such a system, now under construction, exploits the *rapid prototyping* strategy of real-time computer controlled systems and is expected to be added to *IngeRAS<sup>TM</sup>* in the near future in order to be used remotely by the engineers by means of virtual instrumentation.

**Key-Words:** - Remote experimentation, Teleoperation, Virtual instrumentation, Internet, Telelaboratory, Real-time control.

## 1 Introduction

In the last years, the information and communications technologies have been largely developed in the industry. Specifically, remote control of systems via Internet by HTTP browsers is one of the main courses of such working area [1]. The significance of these systems relies mainly in the improvements obtained for the customer services and the cost-cuttings. In fact, nowadays, a large number of companies are endowed with field workstations. Some of these applications can summarize in the next examples: *Ambient* industry has a meteorological station [3], [4]. Using Internet Developer Toolkit (National Instrument Software) they transmit information about the wind speed, temperature, humidity and pressure. In the same way, *Teulades i Facanes Multinationals* has develops a remote monitorization systems in order to offer their clients a new application [2], [5]. Other name industries that use the remote control are *Anritsu Company* [6], *Portucel* [7], *Daimler Chrysler* [8] and more, see e.g. [42].

Using remote control systems via Internet, avoid displacements, reduce costs and allow the betterment of the services offered to the customers, see e.g. [10]-[28]. Therefore, considerable amounts of effort have been devoted recently to the development of such systems, see e.g. [29]-[41]. On the other hand, given that such systems are usually incorporated within a World Wide Web server, it is possible to offer personalized information to each customer. Besides, specifically designed applications can be remotely handled by means of virtual instrumentation.

Because of the interest in the design of new systems as alternatives to improve the functionality of the HTTP remote controls is a very important goal in the industries environments the university researches teams have began to investigate in this area. Some of the best known efforts in this area in the university environments are: in 1995 the University of Oregon created a laboratory to control a robotic arm [10], and in 1997 the Institute of Automatica of Lausanne (EPFL) [11] published a remote application to control a motor by means of a

PID and used LabView® to design their virtual instruments. Following this same line of work, the computer engineering department at the Siena University designed an automated tele-laboratory [12]. The Norwegian University of Science and Technology developed a laboratory for the characterization of electronic semiconductor devices [13]. The University of Tennessee's Resource Center for Engineering Laboratories on the Web offers students six experiments on process dynamics and control systems [14]. The Engineering faculty at the National University of Singapore offers virtual experiments in a variety of subjects [15]. Finally, APES group in the University of the Basque Country, has developed an innovative system that allows for the study and analysis of specific topologies of electronic circuits using an HTTP browser and Virtual Instruments [9].

The Basque engineering company *Ingelectric*, Ingeniería de Sistemas S.A. [16], offers to their customers a set of complementary services via WWW denominated *Ingelectric Remote Assistance Service* (IngeRAS™) that provides rapid and effective solutions to any problem arisen in their equipments installed at any time and anywhere in

the world. On the one hand, IngeRAS™ allows the technicians to access any equipment from anywhere in order to attempt maintenance tasks. In the other hand, actualised reports on the equipment status are offered to the customers. Of course, IngeRAS™ provides secure restricted access, by using *Virtual Private Network* (VPN), both for the technicians and for the clients. A VPN is defined as a network that is constructed by using public wires to connect nodes. These systems use encryption and other security mechanisms to ensure that only authorized users can access the network and that the data cannot be intercepted.

Furthermore, the mentioned toolset will be extended in the near future by the addition of a new system devoted to the remote experimentation on real-time industrial controllers. Such a system is now under construction by the company in cooperation with a specialized research group from the University. *Section 2* describes the IngeRAS™ system as it is today, *section 3* introduces the remote experimentation tool to be added soon and *section 4* presents the concluding remarks.



**Figure 1.** *Ingelectric Remote Assistance Service (IngeRAS™). Terrestrial installation.*

## 2 Ingelectric Remote Assistance Service (IngeRAS™).

IngeRAS™ is based on a central server, placed at the company headquarters in *Zamudio* (Spain), that centralizes all the entries and puts in storage all the data concerned to the installations supported by the system. Such a server is implemented on powerful machine (*COMPAQ Proliant*) running on *Microsoft Windows Server System* and equipped with a *SQL Server* database. The application have been developed in the programming environment *Microsoft .NET (Active Server Page ASP.NET)*. Finally, the system is compatible with the *Inmarsat* satellite communications systems (*Fleet33*, *Fleet55* and *Fleet77*) and any telephone operator (*France Telecom*, *Telenor*, etc,...). The structure of IngeRAS™ services on the terrestrial installations is described in Figure 1.

On the other hand, the structure of the IngeRAS™ services on the naval installations is described in Figure 2.

### 2.1 ASS (Access to Automation Systems)

This service allows to controlling systems and electronic equipment from the *Ingelectric*

headquarter or from anywhere else endowed with a Internet connection. ASS is based on the remote operation of a electronic system specially designed to permit the technicians to explore the failure and try to overcome it. The Local Area Network (LAN) of the installation is remotely accessed in order to visualize and control any element of the LAN (PLC's, HMI's, data-logger systems, ...). This way, the analysis of the breakdown, failures repairs, program modifications, operation screen changes, etc,... can be done.

Additionally, documental enquiries and event (critical alarms, production ratios, shutdown ratios, equipment operation timing, plant visualization,...) registration are offered to the customer and, sometimes, to technicians from other companies related to the installation.

### 2.2 DCS (Process Data Collection System)

Data capture concerning the signals of interest can be made by means of secure connections. These data sets allow to registry, in real time, the process variables concerning the installation analysis, optimisations and early failure detections. Optionally, the customer may prefer data to be automatically collected and put in storage by the DCS.



Figure 2. Ingelectric Remote Assistance Service (IngeRAS™). Naval installation.



### 2.3 MS (Message service)

MS can send *at any time* critical information concerning the alarms arisen in the installations via electronic mail, SMS, WWW or WAP.

### 2.4 MAVS (Multimedia Added Value Services)

MAVS insert multimedia resources in the IngeRAS™ system. Concretely, allow the control of IP cameras, strategically placed in several points of the installation in order to know visually the status of the machinery. Besides, MAVS include videoconference services to support conversations with the local technicians during a maintenance process.

Additionally, MAVS include *travelling* backup, WWW, e-mail, videoconference and gateway

services by means of other intranet/extranet operators.

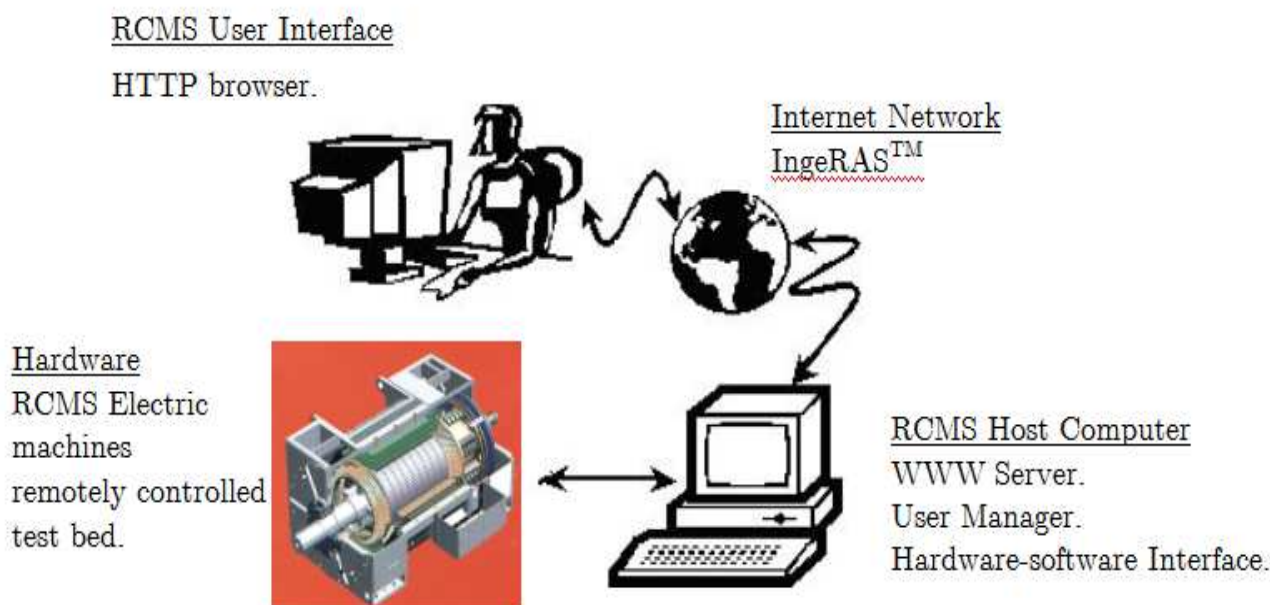
### 2.5 EDCR (Engineering and Documentation Cross-Reference)

EDCR offers to the customer a personalized access to the Ingelectric central information servers, where any document, ranging from industrial plant layouts to installed hardware manuals, can be consulted. In the same way, personal backups and software applications can be downloaded on demand. The consultations may be done simultaneously by several clients and about different areas of the same project.

IngeRAS™ has been successfully applied to the industrial installations detailed in the Figure 3, where the terrestrial installations (industrial factories) are depicted by red squares and the naval installations (ships) by blue squares.



**Figure 3.** Ingelectric Remote Assistance Service (IngeRAS™). Present installations.



**Figure 4.** Remote Control Experimentation Service Scheme.

### 3 RCMS (Remote Control Experimentation Service).

A new tool is actually under construction in order to be added to IngeRAS™. The company engineers have been very interested during years in the development of a remote test bed [17]. This service will enable them to check the practical performance of the diverse control loops that may be implemented by using the company's equipment from anywhere via Internet by means of a mere HTTP browser [18], [19]. In order to attain such a goal, the scheme presented in Figure 4 may be utilized [20]. Such scheme is divided into three main parts, namely, a remotely controlled test bed based on electric machines, the *hardware-software* interfacing system and the graphic user interface of the RCMS, inserted in the IngeRAS™ server.

The different parts of such a systems are described individually in the followings subsections 3.1, 3.2, and 3.3.

#### 3.1 RCMS Electric machines remotely controlled test bed.

In order to improve the closed-loop performance of the controlled actuators installed (or immersed in the process of installation) by the company, is it very useful to have a test bed for real-time

controllers. In the *Ingelectric* headquarters in Zamudio, a test bed based on two confronted electric machines has been settled up. Concretely, it is formed by a AC machine (1500 r.p.m., 2.2 kW., optical encoder 1024 imp.) connected directly with a DC machine (1500 r.p.m., 6 kW., optical encoder 1024 imp.) –see Figure 5 a.-. The AC machine is fed by a vector control inverter of 5 kW. and the DC machine is fed by a drive of 30 A., both of them provided by TEAM S.A. –see Figure 5 b.-.

During the experimentation process, one machine is operated as actuator and the other as variable load. Besides, both machines can be operated as a motor or as a generator and are controlled by real-time digital controllers based on DSP devices. Such controllers can be reprogrammed dynamically from a host computer connected to the IngeRAS™ Server, by means of the *RCMS hardware-software interface*, described in the following subsection.

#### 3.2 RCMS Hardware-software Interface.

On the one hand, the RCMS host computer –see Figure 6- implements the protocol that allow the communications with the controllers of the electric machines (controlled actuator and variable load) described in 3.1. On the other hand, starting from the request of the remote user, the system generates automatically the code for both controllers. The request for each experiment is collected by the *RCMS HTTP User Interface*, described in the



subsection 3.3. and contains all the necessary parameters for the appropriate configuration of the test bed for the experiment. Finally, the generated code is sent via Ethernet to the controllers by using the mentioned communication protocol (TCP/IP). Naturally, after the experiment execution, the previously ordered results are transmitted back to the host in order to be dispatched to the *RCMS HTTP User Interface*.

### 3.3 RCMS HTTP User Interface.

This HTTP user interface, developed in the programming environment *Microsoft .NET (Active Server Page ASP.NET)*, is preformatted in such a way that allows the remote user to choose all the aspects of the control experiment. For example, the type of controller and load, the reference input, the desired performance of closed loop, the parameters of the controller, duration, identification algorithm, data to be collected from the experiment, etc,... can be selected in the application. After the execution, the results are sent and/or displayed in the user remote computer.

In the following section, the server dedicated to the remotely controlled experiments is described.

#### 3.3.1 Servers for remotely controlling the experiments.

This section discusses the software and developments needed to set up a laboratory with remote access experiments, data transmission, and access to real applications using VIs designed with LabView®.

With this aim in view, in the server computer have been installed two web servers in two different ports. Obviously, we need LabView® package installed and continually running on the server machine, because the HTTP server programs are installed through this program.

One of the servers (G Web Server, depicted in Figure 8), executes CGIs (Common Gateway Interfaces) and the other one (HTTP Server), publishes the HTML pages with designed user/process interface like ActiveX controls.

In addition to these servers, a VI designed with LabView® stores relative data on resources and user access. Such information is constantly required by different interfaces in order to work accurately. One of the more important VI is the VI that saves Global Variables (see Figure 7), that is to say, variables that contain the necessary information for VIs executing in different instants.



Figure 5. a. Confronted electric machines.



Figure 5. b. Power electronics and digital controllers.

Figures 5. RCMS Electric machines remotely controlled test bed.

The number of users that have access to the system is limited by the server computer capacity to load in memory and run different VIs at the same time.

The G Web Server (Figure 8) was configured to allow remote user interaction via CGI's. The designed CGI's have two functions when the users access to the system. The first one is devoted to administer remote user access to any open work space at a particular moment, so that once all work spaces are occupied, no other remote user can gain access. To carry out this action, the user selects "Check Occupation" in the home web page. Then, the browser calls a GCI that check out the occupancy. In case that there should be a free work place, the user access to the system and the CGI marks in A in figure 7 a new occupied place.

The second CGI function is to load in memory the VI associated with the front panel to embed like ActiveX control in the remote user HTTP browse. Once the VI is loaded in memory, the other server, the HTTP Server, come into play (Figure 9).

A specific CGI opens a new HTTP page, located in this server, with a front panel embedded on this page like an ActiveX control. By using these controls, the front panel that appears on the browser and the associated VI running in the

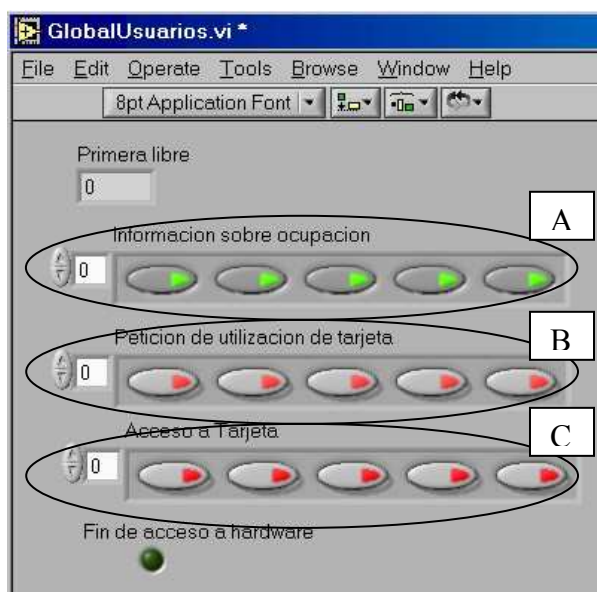
system computer can interact. From this moment, the front panel is accessible through the user web browser.

Additionally, an application was implemented that administers the sequential user access to the electric machines test bed. The user requests for data acquisition access are implemented after the selection of both the type of controller, the values of the parameters of such scheme and the profile to be applied to the load. At this moment the "experiment access" request is added to a waiting list (B in Figure 7). Then, when the users turn comes up (C in Figure 7), the chosen experiment is configured in the hardware described in the section 3.1., the input signals are generated and the response signals from the test bed are acquired. The experiment implemented by each user begins when the user pushes the "Start Experiment" in the front panel bottom and finish with the acquisition of the response signals. In this interval, the communication protocol is executed. The whole time to make up all the tasks is about 15 seconds, but the design reserves 50 seconds for each user in order to create a security margin.



**Figure 6.** *RCMS Host Computer.*

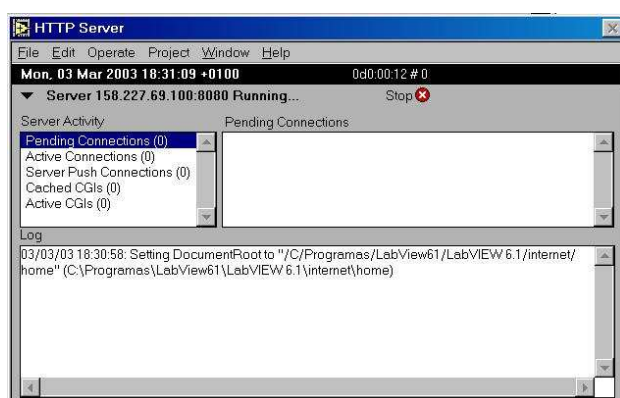
This small time is possible because the signals are saved in a text file and, therefore, the access to the test bed is not necessary in continuous time.



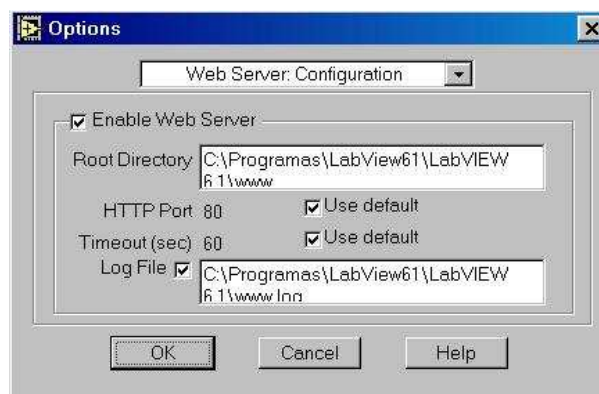
**Figure 7.** Virtual instrument panel saving the global variables.

Everything described in this section occurs with complete transparency to the remote user. He or she only has to connect to the main page and request a free work space. If there is a space free, a Web page will open and the remote user can choose a controller, parameters and interactively study the closed-loop behaviour.

Remark that the remote access to experiments through an internet browser does not require installation of LabView® on the remote user's computer.



**Figure 8.** G Web Server panel control.



**Figure 9.** HTTP Server panel control

## 4 Conclusion

A novel remote system, devoted to the remote experimentation on industrial real-time digital controllers via Internet, is proposed. Such a system is designed to be inserted in a previously existing platform, provided by the Basque company *Ingelectric S. A.* A test bed based on two connected electric machines that can be configured -as actuator and dynamic load, respectively- and programmed in detail is the central element of the development proposed. The design schemed is based in the rapid prototyping of digital controllers by using a *host-target* environment, controlled remotely via a HTTP secure server. Besides, the system grants the lively *hardware-in-the-loop* experimentation in order to optimise the performance of the controlled machinery with a solid reliability.

The described system may be utilised both by the production engineers and the researchers from the University. The research group from the University is very interested in the execution from the Campus of advanced experiments concerning control theory and model estimation by operating common industrial devices.

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## References:

- [1] W. Holmes, D. E. Mcmillan, R. R. Smith, "Using LabVIEW to Access and Control a Harsh Environment Laboratory through the Internet", *Laboratory Automation, Users Solutions*, <http://www.ni.com>.



- [2] [http://www.bellera.org/fotovoltaiica/temps\\_real.htm](http://www.bellera.org/fotovoltaiica/temps_real.htm)
- [3] <http://www.ambientweather.com/>
- [4] E. Edelman , "Creating a Virtual Weather Station with LabWindows/CVI", *Industry Customer Solutions*, <http://www.ni.com>
- [5] H. Assama, "Sistema de monitorización de Centrales Eléctricas Fotovoltaicas y Visualización a través de Internet", *Industry Customer Solutions*, <http://www.ni.com>
- [6] R. Davoli, "Remote Diagnostic in a Fiber-Optic Network"; <http://www.ni.com/telecom>
- [7] J. P. Caetano, R. J. Jesús, P. A. Alves, V. F. Dias, "EcoMonitor- A Continuous Air Quality Monitoring System", *Industry Users Solutions*, <http://www.ni.com>
- [8] R. Conde, "Emissions Testing fuel Handling System", *Industry Customer Solutions*, <http://www.ni.com>
- [9] A. Etxebarria, I. Oleagordia, M. Sánchez, "Laboratorio de Electrónica Analógica controlado por Instrumentos Virtuales local o remotamente", *SAAEI'01*, Septiembre 2001, Matanzas Cuba.
- [10] B. Aktan, C. A Bohus, L. A. Crowl, "Distance learning applied to control engineering laboratories", *IEEE Transactions on Education*, Vol. 39, No 3, 1996, pp 320-326.
- [11] D. Gillet, C. Salzmann, R. Longchamp, D. Bonvin, "Telepresence: an opportunity to develop real-world experimentation in education", *European Control Conference*, Belgium 1997.
- [12] M. Casini, D. Prattichizzo, A. Vicino, "The Automatic Control Telab: a Remote Control Engineering Laboratory", *40th IEEE Conference on Decision and Control*, Florida USA, December 2001.
- [13] T.A. Fjeldly, M.S. Shur, H. Shen, T. Ytterdal, "Aim-Lab: A System For Remote Characterization Of Electronic Devices And Circuits Over The Internet", *Int. Caracas Conference on Devices, Circuits and Systems ICCDCS-2000*, Cancun, Mexico
- [14] J. Henry, "Controls Laboratory Teaching via the World Wide Web", *ASEE Paper*, Washington, DC, June 1996.
- [15] C.C. Ko, B.M. Chen, J. Chen, Y. Zhuang, K.C. Tan, "Development of a Web-based Laboratory for Control Experiments on a Coupled Tank Apparatus", *IEEE Transactions on Education*, Vol 44, No 1., February 2001, pp 76-86.
- [16] <http://www.ingeteam.com/ingles/index.asp>
- [17] C. Colwell, E. Scanlon, M. Cooper, "Using remote laboratories to extend access to science an engineering", *Computers and Education*, Vol 38, 2002, pp. 65-76
- [18] M. Casini, D. Prattichizzo, A. Vicino, "The Automatic Control Telab: a Remote Control Engineering Laboratory", *40th IEEE Conference on Decision and Control*, Florida USA, December 2001.
- [19] A. Etxebarria, I. Oleagordia, M. Sánchez , "Power Electronics and Basic Electronics real experiments through the World Wide Web.", *Frontiers In Education (FIE'2001)*, 2001, Reno (EEUU).
- [20] A. Etxebarria, I. Oleagordia, M. Sánchez , "Telelaboratory : Real-Time Remote Access in Internet", *CSCC'99 3rd World Multiconference on Circuits, Systems, Communications and Computers*, July 1999, Athens (Greece).
- [21] H. Wei, C. Tianzhou, S. Qingsong, J. Ning, 'A Data Centered Approach for Cache Partitioning in Embedded Real-Time Database System', *WSEAS Transactions on Computers*, Vol. 7, No. 3, March 2008, pp. 140-146.
- [22] S. Borza, D. P. Brindasu, L. Beju and M. Inta, 'E-Research Centre and E-Creative Design new Trends for E-Activities Platform', *WSEAS Transactions on Computers*, Vol. 7, No. 4, April 2008, pp. 273-280.
- [23] T. Weng, 'Application Internet Multimedia on Region Travel Route Information Establishment', *WSEAS Transactions on Computers*, Vol. 7, No. 7, July 2008, pp. 941-950.
- [24] K. Y. Wong, K. H. Yeung, 'A Dispatching Technique to Solve the Overloading Conditions of Web Cache Servers', *WSEAS Transactions on Communications*, Vol. 5, No. 5, May 2008, pp. 725-731.
- [25] K. Y. Wong, K. H. Yeung, 'Analytical Study on Web Caching Systems using Closed Queuing Network Modeli', *WSEAS Transactions on Communications*, Vol. 5, No. 5, May 2008, pp. 732-737.
- [26] W. Wen, L. Keqing, C. Zichen, 'Study on Monitoring Approach of 3D Scanning and Measuring Machine Based on Internet/Intranet', *WSEAS Transactions on Communications*, Vol. 5, No. 5, May 2008, pp. 753-758.
- [27] D. Brull, B. Schwarzer, S. Oschatz, A. Steinmetz, 'Dataflow Based Visual Programming of Dynamic Web Applications',

- WSEAS Transactions on Communications*, Vol. 5, No. 9, September 2006, pp. 1624-1629.
- [28] Y. Chu, C. Y. Ju, H. Yang, H. Yang, W. Hu, 'A Study of the Intension of Using Computer as a Strategic Resource of Web Searching', *WSEAS Transactions on Communications*, Vol. 5, No. 9, September 2006, pp. 1852-1857.
- [29] V. Nikolopoulos, N. Karadimas, I. Lykourantzou, G. Mpardis, V. Loumos, E. Kayafas, 'A Web-based Interoperable Method for Accessing E-Learning Remote Repositories using directed XML-based Remote Procedure Calls', *WSEAS Transactions on Communications*, Vol. 5, No. 10, October 2006, pp. 2020-2023.
- [30] J. D. Jackson, D. W. Callahan, D. S. Appleby, L. B. Callahan, 'Architecture for a TCP/IP Based Robotic Protocol', *WSEAS Transactions on Communications*, Vol. 6, No. 1, January 2007, pp. 98-103.
- [31] G. Chis, H. Grebla, D. Matis, R. Nistor, A. Darabant, 'Web Services for E-Learning and E-Recruitment', *WSEAS Transactions on Communications*, Vol. 6, No. 1, January 2007, pp. 132-136.
- [32] J. A. J. Montes, 'Towards the Virtual Communities of Learning in the E-Learning (from a Pedagogical Design for the Practice Community): The Possibilities of the Platforms (LMS)', *WSEAS Transactions on Communications*, Vol. 6, No. 1, January 2007, pp. 269-273.
- [33] V. Tosic, A. Erradi, P. Maheshwari, 'On Extending WS-Policy with Specification of XML Web Service Semantics, Monitoring, and Control Driven by Business Value', *WSEAS Transactions on Computers*, Vol. 6, No. 5, May 2007, pp. 805-812.
- [34] I. H. Doh, S. H. Noh, 'An Implementation Study of an IP Layer Light-Weight Cluster Control Protocol for Scalable Web Cluster Systems', *WSEAS Transactions on Computers*, Vol. 6, No. 5, May 2007, pp. 821-828.
- [35] E. Z. Liu, 'College Students' Attitudes toward Web-based Forums and Communities', *WSEAS Transactions on Computers*, Vol. 6, No. 4, April 2007, pp. 674-679.
- [36] E. Z. Liu, H. Lin, S. Yuan, 'The Integration of Web-based Course Management System and Portfolio', *WSEAS Transactions on Computers*, Vol. 6, No. 4, April 2007, pp. 686-691.
- [37] C. Wang, C. Kao, C. Tsai, 'Improving Network Learning Performance using an Interactive Adjusting Algorithm', *WSEAS Transactions on Computers*, Vol. 6, No. 4, April 2007, pp. 715-724.
- [38] W. Lien, M. Chang, K. Chu, 'Using Internet Technology to Make Students Learning Better in Video/Audio Design Course', *WSEAS Transactions on Computers*, Vol. 6, No. 3, March 2007, pp. 433-440.
- [39] S. Ting, H. H. Ker, Y. K. Yew, 'Implementing E-Learning System using Web Services', *WSEAS Transactions on Computers*, Vol. 6, No. 3, March 2007, pp. 597-604.
- [40] C. D. Lo, Y. Tai, K. Psarris, 'FPGA-Based Hardware Acceleration on I/O-Bound Scientific Applications', *WSEAS Transactions on Computers*, Vol. 5, No. 12, December 2006, pp. 2977-2983.
- [41] O. Honda, H. Ohsaki, M. Imase, 'Ring-VPN : Ring-Based Virtual Private Network Supporting a Large Number of VPNs', *WSEAS Transactions on Communications*, Vol. 6, No. 9, September 2007, pp. 789-795.
- [42] I. Ozimek, T. Javornik, G. Kandus, M. Švajger, 'Using TETRA for Remote Control, Supervision and Electricity Metering in an Electric Power Distribution System', *WSEAS Transactions on Communications*, Vol. 7, No. 4, April 2008, pp. 289-299.