Abstract. This paper investigates current challenges in development of web-based control and monitoring systems. With recent advances in computing, communications, sensing, and software technologies, experts are dealt with a new environment that offers great opportunities for the field of control to expand its applications and its contributions to the economic growth and realization of a developed society. Currently, the Internet and networks have proved to be powerful tools for distributed collaborative works. The education via Internet has been started recently and in the future will be an efficient tool in teaching methods. The importance, concepts, applications, and general architecture of web-based control and monitoring systems are introduced here. Besides, a typical web-based laboratory developed in the Shiraz University for research and educational purposes is illustrated and some control studies are performed.

Keywords: Web-Based Control, Monitoring, Real-Time, e-Education

1 Introduction

Recent advances in computing, communications, sensing, and software technologies have created a new environment which offers great opportunities for the field of control to expand its applications and its contributions to the economic growth and more developed societies. The rapid growth of communication networks provides several major opportunities and challenges for systems and control.

In recent years, the Internet and networks have proved to be powerful tools for distributed collaborative works [1,2,3,4]. The education via Internet has been started recently and in the future will be an efficient tool in teaching methods. In the field of control systems, the advantages of Internet applications provide new techniques in monitoring and controlling a controlled object remotely. An operator could control a plant from anywhere as long as there is a PC with an Internet or an Intranet network. This is the same with education via Internet. For industry or laboratory based works or managements, these advantages include: (1) allowing remote monitoring and adjustment of plants, (2) allowing collaboration between skilled plant managers and laboratories situated in geographically diverse locations, (3) allowing the business to relocate the physical location of plant management staff easily in response to business needs.

In the last few years, networking has become one of the basic functions of computers. Furthermore, in the era of network many devices could be used with the networks. Due to technology evolution and company investments, manufacturers try to integrate new technology into their old devices to increase their abilities of competition. New devices usually show up with new technology [5,6,7,8]. Therefore, many heterogeneous devices coexist in an automation system. Many manufacturers propose their ways to coordinate all these heterogeneous devices, let them communicate and work together via networks.

Web-based (i.e. or special case, network-based) control and monitoring has, thus, become a new issue for systems and control experts. One aspect of this study is to apply “Real-Time-Control” signals to the real processes. This needs advanced methods of sending and receiving data that match the special software and hardware equipments as basically addressed in our previous work [9]. The other aspect is investigate and also develop a web-based control and monitoring system. It combines a web-based control with real-time computer-aided control system, while a remote data acquisition system is also used.
This paper aims to investigate and also develop methodologies for the design of web-based control systems for some typical plants. Section 2 provides a brief discussion on the importance of real-time and on-line control and monitoring systems, in particular for education purposes. Then, web-based control systems and their essential issues are introduced in Section 3. In Section 4, a case study is presented and the concluding remarks are given in Section 5.

2 Real-Time Control and Monitoring

In educational methodology, although simulations are good enough to be employed but in order to give students in the field of engineering better perception and understanding of a system being simulated, especially in control field, many universities in the world had developed an industry type laboratories so the students could feel like doing a task practice.

On the other hand, computer-based control has been widely used in the industries. Applications range from standalone computer-based control to local computer network-based control, such as a distributed control system (DCS). In a simple laboratory scale is can be easily achieve using powerful software like MATLAB and standard data acquisition card. For instance, a PCL-818HG DAQ-card of Advantech Company which is a high-gain, high-performance multifunction data acquisition card for IBM PC/XT/AT or compatible computers is a basic tool we employ in our study. It offers the five most desired measurement and control functions: 12-bit A/D conversion, D/A conversion, digital input, digital output and timer/counter [9]. One platform to implement the control and identification procedures could be developed within Matlab/Simulink/Real-Time-Workshop. This can be done by invoking Visual C++, Watcom and Java compilers to make a link with ISA slot [4,10]. This algorithm needs to generate the codes such as “Target Module”, “Dynamic Link Library (DLL) Files”, “Intermediate Object Files”, “Batch Files”, “Data Type Transition C Files” and “Model Header Files” which is called “Build a Model”.

The real processes under study are an experimental heating process and a three-degrees of freedom (DOF) robot both were built in Shiraz University recently. The experimental heating process is depicted in Fig 1. The process consists of a tube, an air damper, a heating element and a temperature measuring device.

Air enters the tube and is warmed up by the heating element. The temperature of the air is measured by the temperature sensor and is feedback to the controllers to make a proper signal. The variables are:

- Input voltage \( u(t) \) which is applied to the heater and changes by the fire angle of a BT-137 Triac.
- Fan driver \( v(t) \) that is considered as a disturbance and changes by the potentiometer which controls the fan driver containing two BD-140 and 2N-3055 Transistors.
- Output temperature \( y(t) \) which is measured by an LM-35 Transistor and amplified by an OP-07 Op-Amp. The measured output sensitivity is 1V/20°C.

Figure 1: Schematic of the Thermal-Process

Figure 2: The robot used in the Lab.
The robot as shown in Figure 2 is a 3 DOF robot consisting of three parts, the mechanical part, the driver of stepper motors, and control software.

2 Features of a Web-Based Real-Time Control and Monitoring System

Nowadays, with the advancement of computers and Internet, the real-time and on-line remote monitoring and control of a plant is basically possible [2,5,8,9]. The Internet makes the data transmission possible to be sent out from a PC that acts as a server to another PC that acts as a client, all around the world, which is connected to World-Wide-Web. In education field, it can be applied as a long-distance learning and computer based self-tutoring systems [6,11]. So remote laboratories could be set up [7,12]. It will be is a combination of audio-visual interface with devices or plant in the laboratory. In this way, the experiments could be accessed from anywhere. Nevertheless, introducing the Internet into the control system has introduced many new features such as [11]

- Web-related traffic delay
- Web-based interface
- uncertainty of who users are
- Web-related safety

which should be considered in the design of web-based control systems. These new features make the design methodology for web-based control systems different from that for ordinary computer-based control systems. Five basic issues that arise from Web-related features of web-based control will be briefly investigated here, which are [11]

- requirement specification
- selecting architecture
- Designing Web-based interface
- control over the network with Web-related traffic delay
- Checking system safety.

3.1 Requirement Specification

Specifying requirements for Internet-based control is very important because different requirements may lead to different control structures [8-tank]. These requirements should only include process monitoring and control objectives that are entirely achievable through the Internet control level. For example, tasks which require considerable timing should be avoided because they may not be achievable due to Web-related traffic delay. The major task in the requirement specification is to identify and resolve tradeoffs between goals and constraints of the system that are conflicting or not completely achievable. The hypothesis is that the possible requirements for Internet-based process control are only composed of those requirements, which are achievable through the Internet control level, for plant-wide optimization level, supervisory level, and regulatory level in the process control hierarchy. More details can be found in [tank, monitoring].

3.2 Selecting Architecture

As shown in Figure 3, Internet-based control should be linked with the correct level in the control system hierarchy in order to efficiently carry out the control and monitoring tasks. It is also necessary to minimize the load of communication between the Internet level and the existing control level. The possible architectures can be determined based on the control and monitoring requirements specified above and the available hardware and software tools, such as communication protocol and mechanisms for data exchange.

In general, direct access to a controller is not a requirement and is probably not desirable. In addition, information exchange between process plants and Internet-based clients can be achieved through corporate systems – such as relational databases or real-time databases, instead of control units. For example, information from the corporate system can be wrapped in a self-describing object written in the Java programming language, and seamlessly and efficiently sent to the client’s workstation, ready to be published or included in usable formats. Interested readers are referred to [11, 12].

![Figure 3 Tele-operation via network.](image-url)

3.3 Designing Web User Interface

Advances in control and information technology have shifted the operator role from being the key element in the control loop to the new function of...
plant supervisor and troubleshooter. Internet-based process control will speed up this shift since many routine control functions have been taken over by computer-based control system at the regulatory level in the process control hierarchy. The Web-based user interface should be designed to suit this shift. The central design objective for a Web-based user interface in Internet-based process control is to enable the operator to appreciate more rapidly what is happening in process plants and to provide a more stimulating problem-solving environment outside the central control room. It should be born in mind that medium available in the Internet environment outside the central control room will be very much limited compared to those in the central control room. It has been discovered that technologies from the areas of “multimedia” and “Virtual Reality” show considerable potential for improving yet further the human-computer interface used in process control technology [11,13], and different media can transmit certain types of information more effectively than other and hence, if carefully chosen, can improve operator performance [5,12, 13].

3.4 Control over the Internet with web-related traffic delay

Information exchange between process plants and Internet-based clients allows the clients not only to remotely monitor the behavior of the process plant, but also to respond immediately to changes in quality or yields. The difficulties in Internet-based process control are Web-related traffic delay and uncertain users. The Internet time delay increases with distance, but the delay depends also on the number of nodes traversed. Also the delay strongly depends on the Internet load [14]. So it is somewhat unreasonable to accurately predict how much Web-related traffic would occupy the Internet and to model the Internet time delay. Therefore, a control system architecture insensitive to the time delay is needed. The Virtual Supervision Parameter Control (VSPC) strategy is one practical approach for Internet-based control [5,11]. The detailed control functions are implemented in the local process control computer. Internet-based control over VSPC is invoked only when the updated parameters like setpoints and Proportional-Integral-Derivative (PID) parameters are required to send to the local process control computer.

3.5 Checking System Safety

Potential hazards introduced by the Internet should be systematically identified and further actions should be recommended for improving the design of Internet-based process control. For the sake of simplicity, we assume that the secure access to the local control system (i.e. management database, real-time data and DCS) can be provided by the existing Internet security methods, like firewalls and authorization. Some hazard analysis frameworks for computer-controlled plants and safety checking are introduced in [4,10,11].

4 A Typical Laboratory and The Case Study

A typical development and implementation of a monitoring and control system for web-based tele-operation is presented here. The developed system was implemented for control and monitoring of two laboratory-scaled mini-plants in the Advanced Control Laboratory, at the school of Engineering, Shiraz University. The first plant is the heating process introduced in Figure 1, and the second plant is a 3 DOF robot given in Figure 2. The Data Acquisition (DAQ) card introduced in Section 2 is attached to the main server (i.e. a personal computer) to enable a direct data acquisition from the plants. The plants are connected to the server and through that to local area network (LAN) and Internet and several computers on these networks. The basic architecture of the web-based tele-operation developed here is shown in Figure 4. The system consists of a PC called mini-plants server that acts as a server and as a far node controller. A PCL-818 HG as an data acquisition card has been placed in the ISA slot of the mini-plant server. PCL-818 HG converts analog input of data from transmitters into a digital input that will be used as input data for the controller. The controller program, PID controller, processed the data and sent the result as digital output to PCL-818 HG to be converted into analog output.

In order to monitor and control the system remotely from anywhere, the server was linked into LAN and Internet. Some other PCs that act as clients will run a browser to do the tele-operation. At this stage, our experiments and early design were based on one single client. Basically there are three types of software available on the server to communicate with the plants. The first one is LabVIEW 6.0 which provides tools that could be used to display the
actual representation of measuring instruments or performance of a plant such as those one considered here. Graphical analysis and presentations are also available [15,16]. The second one is MATLAB/SIMULINK with real-time workshop (version 6.5) environment. The third one is a applications software specially written using visual basic 6 and C++ to facilitate control and monitoring of the robot and also the heating process. In order to monitor and control the system remotely from anywhere, the server was linked to Internet via a LAN. Some PCs that act as clients are able to connect to the server (both via LAN and via Internet) and run a browser to do the tele-operation. An operator at the client side could monitor the physical situation of the two mini-plants via two web-cameras with two separate windows on the main screen. Besides, various measurements of the plants and the control loops parameters such as the set point, Kp, Ti, and Td to control the performance of the mini-plants are accessible (see Figures 5, 6). In this experiments, ordinary PID control and multiple-model based PID control of the heating plant were carried out results depicted in Figure 7.

5 Concluding Remarks

This paper has described the challenges in development of a web-based control and monitoring systems. The importance, concepts, applications, and general architecture of such systems were presented. It was also emphasized that in web-based control all the issues of real-time control and monitoring plus several other more issues are concerned. Then, a typical web-based laboratory developed in the Shiraz University for research and educational purposes was also introduced. Even though various control and monitoring methods can be used here, only a PID control for demonstration purposes was given here. In this lab, several simulation types software for control studies are also available to access remotely but no detail was given here due to the shortage of space. Currently, only computer based control part for web-based control is complete, but PLC and mini-DCS connection is also under development.

References


Figure 4. Web-based tele-operation architecture

Figure 5. The remotely accessed panel and pictures of the Visual C++ windows of the server by a client.

Figure 6. A typical LabVIEW program of an ordinary PID controller.

Figure 7. Closed-loop responses of the heating plant with PID controller of two types.