Design of a virtual instrument for water quality monitoring across the Internet

F. Torán*, D. Ramírez, A.E. Navarro, S. Casans, J. Pelegrí, J.M. Espí

Laboratorio de Electrónica Industrial e Instrumentación (LEII), Departamento de Ingeniería Electrónica, Universidad de Valencia, c/ Dr. Moliner, 50, 46100, Burjassot, Valencia, Spain

Abstract

This article presents the design of a new distributed and multi-platform system for water quality monitoring, enhanced with powerful Internet capabilities. The measured variables are temperature, turbidity, pH, dissolved oxygen, and electrical conductivity. The signal-conditioning block has been simplified through the use of software routines for thermal compensation, hence, reducing the cost and dimensions. The system offers a wide variety of Internet capabilities, like e-mail alarm notifications, automatic storage of measured data in a remote machine via the FTP protocol, dynamic generation of HTML reports, real time graphs, and indicators visible from a remote web browser, etc. The whole system supports several types of computers, operating systems and communications hardware. Human presence near the geographic location of water is dramatically reduced, since the system automates the principal tasks of the classical water monitoring process. © 2001 Elsevier Science B.V. All rights reserved.

Keywords: Virtual instrumentation; Water quality; Internet; Real time monitoring; Distributed system

1. Introduction

The classic method of water quality monitoring consists of the following steps:

- A qualified person takes measurements of quality variables, normally using a multi-parametric instrument.
- In case of detecting a contamination alarm, a sample of water is taken and transported to a chemical laboratory in order to analyze the hazardous substances mixed with water.
- A database containing the measurements and alarm events is maintained manually.

Some of the principal disadvantages of that method are the following:

- The main part of the work has to be done by a human being.
- Frequent visits to the water location are needed. Otherwise, some contamination episodes might be missed.

References [1,2] demonstrate these facts, showing two existing networks for water quality monitoring, made up of volunteers.

That suggests the automation of the process, through the design of a distributed instrumentation system, avoiding that way the need of frequent displacements and manual data storage. The use of Internet protocols and applications increases the functionality and assures minimal design errors.

2. System block diagram

Fig. 1 shows the system’s block diagram, which clearly includes three basic scenarios:

1. Measurement station: The location where the water quality measurement process is performed is called a measurement station. It contains five sensors, the signal conditioning circuits, a data-acquisition board, and a computer running a communications program, called measurement server.

2. Control center: It contains a computer, running an application called “main program”. That program basically presents the values of measured parameters using charts, needle indicators and tables, also performing other data processing, storage, and Internet-related tasks. The computer also gives support to remote access across the Internet, through the other software components integrated in the control center.
3. **Remote stations**: Each of them only consists of a computer, which has a Web browser installed (e.g. Netscape Navigator). The Web browser provides the user-interface needed to obtain real time information about the water state.

3. **The measurement station**

The measurement station is the location where the water quality parameters are measured and sent to the control center. It consists of the following stages (see Fig. 1):

- **Sensors**: It is a block made up of five sensors. The measured variables are: temperature (Pt100 sensor), pH (combined electrode, KCl 3M electrolyte, 370 MΩ output resistance), turbidity (measured following the ISO 7027 standard directives), dissolved oxygen (amperometric measurement using a Clarke cell, Ag–Pt electrode), and electrical conductivity (unitary geometric constant graphite cell). A description of employed sensors can be found in [3].

- **Signal conditioning circuits**: It consists of five electronic circuits (one for each measured parameter), which adapt the output signal of each sensor to be easily processed by the rest of the system. Software temperature correction is used, reducing the cost and dimensions of circuitry.

- **Data acquisition**: The measurement station employs an AT-MIO-16E-10 data acquisition board (manufactured by National Instruments). An in-depth description of that board can be found in [4].

- **Measurement server**: A server program is created to send the measurements to the control center, where the corresponding client program (called measurement client) is located. When a request arrives, the server sends the measurements to the control center, expressed in convenient units. The protocol used for communications is based on TCP/IP protocol, which is the base of Internet developments.

- **GSM modem**: The communications hardware can be flexibly selected: RTB modem, LAN boards, etc. A RTB modem is useful if the measurement station is located near a telephone line. Otherwise, using a LAN board or GSM modem could be the best choice.

The software has been developed using the National Instruments LabVIEW 4.0.1 environment. That package aids the development of virtual instruments, executable within several types of computers and operating systems without changes in the source code. Any virtual instrument is completely designed graphically (via diagram blocks), using a programming language called G.

4. **The control center**

The control center is the location where the measurements are first stored, processed, and shown. The tasks are performed by a virtual instrument called “main program”.

In a second scenario, the control center gives support to remote access across the Internet, using other software components installed on the computer. The development of Internet enabled virtual instruments using LabVIEW is presented as a tutorial in [5]. The capabilities offered by the control center and the complementary software components are the following:

- **Measurement presentation**: It is done in different formats using panels. Each one shows the measurements in a specific format (charts, needle indicators, tables, etc.). The graphs panel is shown in Fig. 2.

- **Alarm notification**: When one or more measured variables take anomalous values, the main program attracts the
attention of the user with sounds and on-screen warning messages. The same happens, if a variable returns to its normal state. There is a panel which shows a real time visual summary of the alarm state.

- **Measurement and alarm storage**: The measured values are stored on user-selected historical files, allowing future processing of data with other analysis software. These files are also used for the dynamic on-line generation of HTML reports, visible through a Web browser. Historical files with alarm events are also generated and used in Web reports.

- **Automatic transfer of daily reports to a remote machine**: The historical files are transferred to a remote computer using the FTP protocol, at a time configured by user. Several FTP-related parameters can be configured.

- **Automatic mailing of daily reports**: The main program sends a daily e-mail to a list of recipients, containing some information in its body and the historical files of the day attached (measurements and alarms).

- **Automatic alarm notification via e-mail**: When an alarm warning is triggered, the main program sends an e-mail message to a list of recipients. The body contains information about the event (rest of measurements, date, and time, list of anomalous variables, etc.).

- **HTTP server control**: The HTTP server can be controlled from the main program. This can be useful for disabling the access from remote stations.

- **Account management**: Authorised users can be managed with ease, setting a login and a password for each account.

- **HTML documents**: A set of Web pages, providing the remote stations graphical user interface. The use of a standard Internet application avoids the need of developing specific software for remote access tasks, and enhances the learning curve.

- **HTTP server**: It is a server application that sends requested HTML documents to remote Web browsers (remote stations) using the HTTP protocol. It is implemented as a LabVIEW virtual instrument that runs in background.

- **CGI programs**: These are server-side applications, enabled to communicate with the HTTP server through environment variables. When one of those programs ends, the result is returned to the client, in the form of an HTML document. The system includes two CGI programs, dedicated to the Web report generation and remote user validation.

The computer installed in the control center must be connected to the Internet in order to allow the access of remote stations. Once again, the communications hardware can be flexibly selected. The selection depends on several factors (LAN and proxy server availability, telephone line accessibility, etc.).

5. The remote stations

Setting up a remote station is an easy and inexpensive task. It only requires a Web browser (e.g. Netscape Navi-
gator) installed on a computer, which must be correctly connected to the Internet. A typical implementation is a mobile station, based on a laptop computer and a GSM modem. The remote user connection starts by typing the control center’s URL in the Web browser. Then, an authentication page is shown, requesting a valid login and password. If this test is successfully passed, the main HTML document appears on screen, showing links to the following services:

- **Web report generation**: This service connects to the control center, where is dynamically created and returned an updated HTML report containing, at least, one of the next sections.
  - The measurements done since the beginning of day, laid out on a table.
  - The alarm/reset events, laid out on another table.
  - Information about the control center and measurement station.

![Fig. 3. A section of a HTML report.](image)

![Fig. 4. Monitoring a chart panel through a Web browser.](image)
Firstly, a configuration Web page allows selection of the sections to include, parameters to show, etc. A region of a Web report appears in Fig. 3.

- **Real time monitoring of the main program’s panels:** The control center’s panels can be tracked in real time using the Web browser. A variety of panels can be monitored: individual and global charts, indicators, alarms, etc. As shown in Fig. 4, the panel to monitor is selected with only a button click. There is a configuration section (located at the top of page), which eases the setting of refresh rate and lifespan of the animation.

All the Web forms are pre-processed using JavaScript code restricting, hence, the connections to only the necessary. Computers that store historical files (via FTP) or receive e-mail notifications are also considered remote stations. This fact allows the creation of different types of remote stations, combining one or more of the previously cited capabilities.

6. Conclusions

This article has presented the design of a new distributed, multi-platform and Internet enabled virtual instrument for real time water quality monitoring. Its powerful monitoring capabilities reduce the need of periodical visits to the geographic location of water. Several functional blocks have been reduced in price and dimensions, through the use of free software (e.g. Netscape Navigator), software temperature compensation, etc. The control center makes an intensive use of the Internet, performing tasks like e-mail alarm notification, FTP remote storage of data, etc.

Acknowledgements

This work has been supported by the Conselleria de Cultura, Educación y Ciencia through its GV97-CB-10-69 project and Plan Nacional de I + D through its 1FD1997-0508-C03-02 project.

References


Felix Torán Martí was born in 1973 in Valencia (Spain). He obtained the Electronics Engineer degree at the University of Valencia, in February 1999. He worked on a distributed and Internet enabled virtual instrumentation system for water quality monitoring for his final graduate project (directed by Prof Dr Diego Ramírez), obtaining first class with distinction. During 1999, he worked in the development of another environmental system with Dr Ramirez. Now he is researching on the improvement of lightning devices, developing a finite element analysis tool in Institute of Electrical Technology (ITE). Since 1997, he is designing and maintaining several Web sites, including the official tourism site of the Province of Valencia (“Terra i Mar”, at www.valenciaterramar.org). Next year he is going to take part in the EGNOS and GALILEO projects, working for the European Space Agency (help conceded by Ministerio de Educacion y Cultura de Spain).