Remote Data Collection and Transfer as a Teaching Tool for Process Monitoring and Control

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Abstract

Wireless technology for transferring real time process data over the Internet has created the opportunity for accessing live industrial process data from the classroom and use for analysis and feedback for process improvement. Though the teaching of data analysis and use of control charts for controlling an industrial process based on the existing data set is not a pedagogical challenge, the use of live data set from an interactive process reveals the immediate consequence of the analysis and the control method in a real process. A multivariable process station involving pressure, temperature, flow and liquid level is utilized to simulate an industrial process. The process variables are monitored and manipulated using a variety of sensor, actuators, NI PXI data acquisition hardware and LabVIEW software. The wireless and web based information technology is utilized to retrieve and transmit the refined real time process data to the remote laptop and personal digital assistant (PDA) devices in the classroom. Using the statistical methodology and the web applications, students can interact with the process actuators remotely using the PDA devices to maintain the specified process criteria. Implementation of this teaching methodology brings the reality of the subject matter in the classroom without introducing a formal laboratory component or practicum in the curriculum. The practice also allows the students to get acquainted with the wireless technology and its industrial use in process monitoring and control.

1. Introduction

The subject of process control [1,2] deals with monitoring, evaluating, and analyzing the characteristic parameters of a process to ensure that it meets its performance criteria in terms of quality and cost of product by operating optimally and improving continuously. Because of the nature of variation in product and process characteristics, lack of analytical techniques to effectively relate them in a series of industrial processes, and their effect on the overall product quality and cost; statistical tool are most effective for process improvement. Over the past several decades, wide use of statistical techniques has brought revolutionary changes in the quality of industrial products and efficiency of the related processes in Japan. Currently, use of statistical model based analysis and control for reduction of process variability is a routine practice in the industry. In the process monitoring and control classes the subject is typically taught by introducing the concepts associated with process modeling, process capability, method of monitoring of process data and use of control charts for improving the process. For practice, existing data of a process is utilized to analyze its behavior and specific process improvement measures are recommended in each case. Recently online monitoring of industrial process, analysis and control had become a major feature of industrial process control. Networking technologies, especially the Internet plays an important role for remote monitoring and control of a process. From all indications, remote monitoring and control is ready to become a major factor for industrial productivity. It simplifies the steps required for process analysis, provides network based system solution for remote product identification, physical security, operational productivity and inventory management. Beyond the manufacturing industry this philosophy is used in NASA, trucking industry, oil industry and material handling applications as well.

As industry is continuously evolving with the integration of new technology, educational curricula are under pressure to produce graduates literate in current technology without over burdening the curriculum load in a program. Based on existing technology in data monitoring and transmission, teaching process control by bringing the monitoring and analysis of actual industrial processes into the classroom is within the reach of average university programs. Garrett and Stephenson [3] utilized real time process data instead of canned data from text for teaching process analysis in the undergraduate level class. This allowed students to relate their classroom learning to actual industrial process. Esche et al. [4] implemented Internet based remote laboratory access for providing undergraduate students a limited amount of interaction with the laboratory setup as preparation for actual experiments. Others utilized online access to the laboratory data acquisition from one source and processing and experimentation using another computer. Aburdene et al. [5] used remote login from integrated engineering workstations to perform experiments in the laboratory and downloading process data in remote computers using the web. Most of these developments were geared toward laboratory practices in under graduate programs.

At Western Michigan University a project was undertaken to access a real time process from the classroom, monitor the process data, use them for teaching process analysis and make decision to rectify the out of control process as part of classroom learning in the graduate level process monitoring and control class. As a result, the students will be familiar with the process of making key decisions based on on-line statistical analysis of a real process and observe the effect of the corrective actions on a out of control process without leaving the classroom. This will enhance student learning of the subject matter and prepare the program graduates to face the challenge of the modern industry even in absence of formal laboratory component in the course. Without such learning students may find real world on-line process monitoring systems, open-ended nature of the control problems and the uncertainty in the appropriate course of action very challenging. It is beneficial for students to encounter these kinds of anxieties in a university classroom under the tutelage of an experienced educator rather than on their first job under the direction of an overbearing supervisor.

In this paper we present the methodology being used for wireless data transmission to a process monitoring and control class and the use of the data for online process analysis and control. Since the course does not have a formal laboratory, the idea is to monitor a live process from the classroom using web based wireless technology and utilize online process analysis techniques to correct an out of control process. As a result, not only the validity of learning will be established within the short time frame of a class hour, but also the reality of the subject matter and associated technology will come alive in the classroom. To accommodate with requirement, we plan to use a process with visible attributes and capable of reacting rapidly to the corrective signals. It is a multivariable process station involving pressure, temperature, water-flow and liquid level to simulate an industrial liquid mixing process. The process variables will be monitored and manipulated using a variety of sensor, actuators and NI PXI data acquisition hardware [6]. The wireless and web based information technology is utilized to retrieve and transmit the refined real time process data to the remote laptop and PDA devices [7] in the classroom. To add to the realism, remote video images of the process are also be transmitted to the classroom allowing students to utilize visual attributes of the process for analysis. A data base architecture, and web applications will be developed. Using the statistical methodology learned in this class and the web application developed, students will interact with the process actuators remotely from the classroom while the subject is taught through the use of PDA devices to maintain specified process criteria.

2. Classroom practice

Traditionally, teaching of such a course focuses on the statistical techniques for process analysis based on the existing data acquired from a process and methods to improve the process and in the laboratory students collect relevant data and perform required analysis and recommend appropriate actions to improve the process. Process monitoring and control identifies the proper use of control charts for quality assurance in business and industry. A variety of charting tools [1] such as mean, median, range, standard deviation, individuals, and attribute charts are utilized to provide feedback to industrial processes. These important measurement tools are part of the curriculum in quality related engineering courses; specifically, when teaching the subject of statistical process monitoring. Teaching the mechanics of process characteristics chart development and data collection presents no pedagogical challenge. However, the teaching methodology utilizing “live” dataset versus traditional “dead” dataset for analyzing, interpreting data and making process improvement decision has yet to be introduce in the classroom setting. Even though the traditional “dead” dataset allows students to understand the procedures of how to construct a control chart, the disadvantage is, it does not lend itself to address more important issues of learning process monitoring strategies in statistical analysis and interpretation. As a result, the students are prevented from gaining genuine expertise in statistical process monitoring and are not fully prepared to address the problems that they will encounter in the industry. The data collection, analysis and input method proposed is teaching tool based on real industry-like process with a technology to wirelessly transmit data to the classroom. The system is designed to give students information about the process, real time data processing, rigorous statistical analysis and the use of wireless and web-base technology for handling the monitoring and controlling the process. Normally, to gain this kind of experience, students would require both industrial experience and on-the-job training.

3. Laboratory development

The required laboratory for this effort is composed of a self-contained, water based, flow and level process station. A variable speed pump will create flow of water from a reservoir to two different transparent vertical tanks through variety of flow circuits. Water will be heated in a resistance-heating chamber to maintain desired water temperatures in different parts of the circuit. Upon return from the tanks, water can be cooled using a heat exchanger to achieve specified temperatures and flow rates of the mixture. The temperature, pressure, flow rate and level in the tanks will be monitored using on board thermocouples and transducers. The signal from the sensors will be collected by a National Instrument data acquisition system which includes a PXI 1000 Data Acquisition System Chassis, PXI & VXI embedded controllers, PXI multifunction I/O kit, shielded connector blocks and terminal block (Figure 1). LabVIEW RT software [5] for data processing and monitoring is a multi-functional software with wide range of use, from device driver controlling of specific hardware interfaces to application packages for developing complete systems.

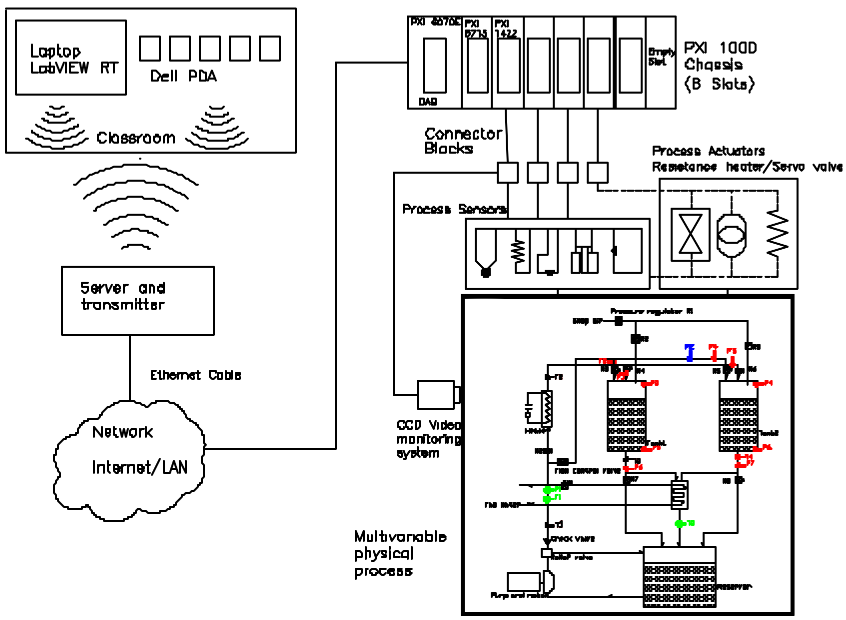

Figure 1: A multivariable process data acquisition and monitoring system

This process is designed with the goal of simulating a fast reacting industrial process within the laboratory in a cost effective manner. Integration of NI hardware and the LabVIEW RT software with the process equipment will allow the students to gain in-depth experience in process monitoring, data acquisition, data processing and feedback to the system in a realistic industrial setup while learning the theoretical aspects of process data monitoring, analysis and control in the class. The remote video camera and the PXI video card will allow students to see the consequence of their analysis and subsequent decision in a live process as well as utilize the visual attributes of the process for additional analysis. To induce a problem in the process, a fault generation tool (e.g. timely power interruption in the water heater) will be developed. The goal is to see if the student can identify the underlying cause of a systemic behavior of the system using the analysis tools without prior knowledge of the problem. Action taken to address such problem will remove the cause of process data variation and bring the process in control. The overall system is a cost effective solution of the four variable (temperature, pressure, liquid level and flow rate) process monitoring and control problem. It allows for remote monitoring, data acquisition, processing and control of the process using the current wireless data communication infrastructure of the university. In addition, compared to a hardwired complete system, use of a mix of different components in the overall process is a cost effective way to create the possibility of future expansion and potential diverse use of the laboratory, such as in other departmental classes and in training industrial personnel in the field.

4. Information Technology System

The core components of the system are its database, analytical engine, and coding system. The database is where the data will be stored. The analytical module provides meaningful access to the data by the end user. The engine provides totals, averages and quartiles (to expose variance in the data). Views are provided in both tabular and graphical formats (bar charts, pie charts, scatter plots, etc). Each view starts with the user's selection criteria, and then the user may "drill down" to see even more detail as needed. The main features of the system are:

- Operating System: Windows NT/2000/XP.
- Database: Microsoft Access and Microsoft Excel.
- Web design: Perl5, XML.
- Reports: Crystal Reports.
- Online Web Applications: Access the database via the online web applications with a set of modules representing different options for access to real-time data.
- Data from the Process Control System: A database containing data derived from the application of the data standards and processes to data extracted from the process control system.
- Online Database Web Applications: A series of applications for the analysis of data and management of the database.
- Web Browser Flexibility: The entire website will be Netscape 4.76+ and IE 4.0+ browser compatible.
- Website Security: The website may be secured utilizing 128-SSL encryption technology. Digital certificate technology such as VeriSign can be used to secure sensitive transactions.

The data flow structure and web development plan are shown in Figure 2 and 3.

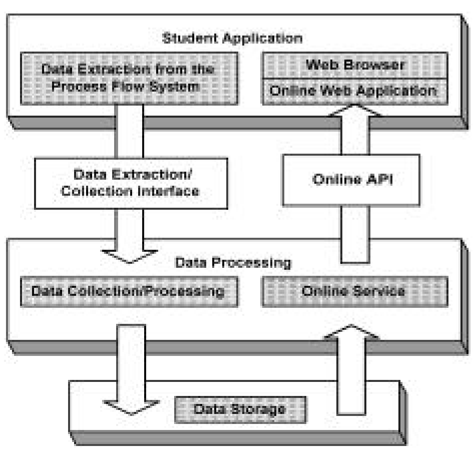

Figure 2. Data flow structure

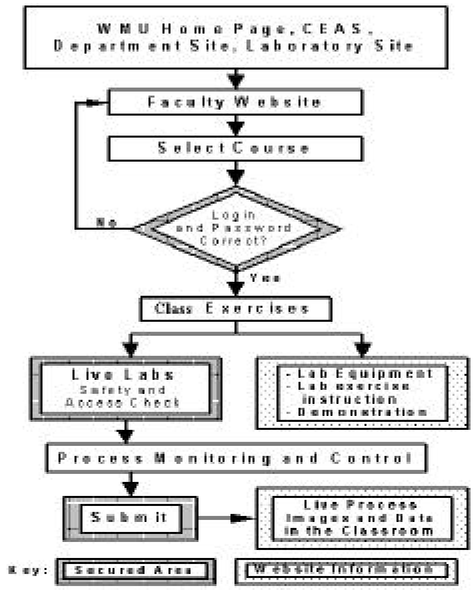

Figure 3. Web site for access to the process

5. Example of process monitoring and control exercise

In the class students will be taught a variety of process analysis techniques. Here, an example of a simple in class exercise is presented for clarity. Students and the instructor will receive the data and video images from a Flow/Level process for heating and mixing water. The on board sensors and thermocouples will monitor the temperature, pressure and flow rate in a systematic, sequential fashion (e.g. chronologically at one-second intervals) through the use of a web based data management system. The instructor will establish specifications for the process and control limits based on nature of the process and overall objectives. Using the online data from each instrument in the system any process changes, adjustments, and systemic variation labeled as "out of control" condition(s) will be identified. Anticipated outcomes are:

1. Using the "rules for out of control",
   - Identify the time instances when an "out of control" conditions are detected.
   - Identify the "out of control" point(s) on control charts based on established rule.

2. For every "out of control" condition suggest related cause(s),
   - Where in the system the "out of control" occurred?
   - What caused the "out of control" condition?
   - Recommend the process adjustments to bring the system into "control".
   - Implement any changes feasible through online instruction to the process.

3. Conclude about the "capability" of the charting tools.
   - Which was the appropriate charting tool for the process?
   - Why?

- Was the process improved as a result of the analysis and action taken?

4. Identify optimal temperatures and flow rates for the system.
   - In terms of energy conservation.
   - In terms of productivity.

To be most effective, the in-class exercises are chronological and all experiences are at the macroscopic level where physical and mechanical phenomena dominate. It is largely by "seeing" that students gained experience. Hence, students will take data points more seriously when they can see them being generated in a simple, easily understood fashion. Students will utilize the online data management tool to plot the sequential random data in a systematic manner. It will reveal the nature of the web based system tool for process control utilizing the computer data acquisition techniques, whose inner workings are usually much further removed from the world of the average university student. The results of such lessons are:

- Control charts for the processes can be developed using the online tools and students benefit from seeing the nature of the process characteristic data take shape as the trend develops.
- Students can examine the effects of different sample sizes (varying the rate of data collection) and the use of different charting tool ($\overline{X}$ -*R*, median or individuals).
- Obtain a meaningful standard deviation and examine the significance of the control limits for the process monitored based on the sample size and of control charts used.
- Identify the underlying cause of out of control conditions and the nature of the remedy. If the problem can be solved by online action, appropriate signal to the physical process control system can remove the systemic cause of variation and the out of control condition.
- Use of the wireless access to the system from the classroom will let the students see actual application of the theory in a live process without leaving the classroom.

To add a bit more realism to the exercises, the students will experience the variability found in a work environment, on equipment, and in the materials used. Besides teaching the subject based on a live process, development of the tool will also allow students to access to the process data from remote workstations around the campus and use them for assigned problem solution.

The measure of the success of this project will be the enhancement of student learning, level of confidence in dealing with the real industrial process and job preparedness due to exposure to current technology. In future, the laboratory and the process monitoring tool developed can also be used to expose undergraduate students with automated measurement of pressure, temperature, flow rate and liquid level, technique of data acquisition and data processing for monitoring purpose as well as training industrial personnel in instrumentation and process monitoring.

6. Conclusion

The paper presented a methodology to utilize a modern industry like process, current web based data acquisition system and wireless data communication technology to teach how to monitor a modern industrial process and apply various analysis technique to ensure that the process is under control while learning the subject in the class room without resorting to time consuming laboratory exercises. The methodology can act a model for other classes for providing realistic industry like experience in the lecture classes using the available wireless technology on campus. Once implemented, the effectiveness should also be assessed and evaluated to improve the learning process continuously. The methodology can also be replicated to enhance student learning in other lecture classes.

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