DESIGN OF A PORTABLE DAQ SYSTEM FOR TEACHING GEOMECHANICS

Jiang Li, Matthew Y. Lee

Morgan State University/Amherst College

Abstract

The main purpose of this paper is to present the design of a portable data acquisition (DAQ) system for use in both education and research in geomechanics. This portable data acquisition system can serve not only as a simulator for various tests in geomechanics but also as genuine data acquisition equipment for multiple purposes on sites. When it is used as a simulator, it can be operated either as a helpful aid in teaching or as a physical model in research. This system can be adopted for both lab and field measurements. It is especially convenient for field projects since the DAQ system is portable and light. This system is designed for multiple purposes. For instance, the data acquisition can measure and record stress/force, strain/displacement, velocity/acceleration, temperatures, etc. that are related to projects in civil engineering such as pile driving, foundation loading/unloading and deformation of infrastructure (i.e., pavement, slope, retaining wall, bridges etc). This system can also serve as a virtual laboratory device for purposes of teaching and research in engineering mechanics (i.e., oscilloscopes, frequency response analyzers, signal generators, A/D or D/A data converters, etc.).

In the present paper, the design of the DAQ system is discussed from two perspectives: 1) design of the DAQ system with respect to necessary hardware, 2) design of the DAQ system with regard to required software. In brief, the effort made in this paper is to demonstrate new developments made with a portable data acquisition system applicable to the lab and field projects as well as teaching in geomechanics. It is clear that this convenient and powerful tool will help faculty in both teaching and research, as well as help engineering students in studies of Geomechanics or Engineering Mechanics.

I. Introduction

A revolution in high technology areas including computer technology and applications is currently in progress. Personal computers (PC) are more and more popular due to rapid technological advances and a simultaneous decrease of price. Now personal computers are smaller, lighter and more affordable, and yet faster and more powerful. Today, personal computers become an important part of our lives. It is predicted that in a few short years, supercomputers with high performance will debut and eventually become commonplace in normal families and homes. Since personal computers have become widely affordable due to the dramatic price drop in the computer industry, currently more and more universities are requiring that college students purchase a portable computer (1). Because personal computers have been physically reduced in size and weight, people's lives become more and more personalized or more and more independent of the environment and other people. A result of this personalization can be seen in possible future structures such as personal banks, personal offices, personal communication centers, etc. It is not difficult for one to imagine that it is feasible to establish personal laboratories with the development of advanced technology. The personal laboratory allows both faculty and students to work in the independent, flexible and efficient environment since the personal laboratory is less dependent on the environment and other potentially crippling dependencies (e.g., facility, time, lab technician, and other resources). In recent years, a number of new technologies have been applied to teaching in areas of higher education such as Engineering Mechanics and other engineering courses (2-9).

The design of a portable data acquisition system built with the state-of-the-art computer technology is presented. Both students and faculty can use it as portable laboratory equipment for both lab and field projects. This could become the direction and trend of reform with regard to laboratory practices in teaching and research in Engineering Mechanics and Civil Engineering because such a powerful and useful system offers increased convenience and flexibility to students and faculty. Since it is feasible for students to own such a portable system, students may benefit from this new and portable data acquisition system while they study and explore Engineering Mechanics or Geomechanics. Therefore, this could benefit the concept of personal and portable laboratory in the future as well.

II. Design of the Portable Data Acquisition System (DAQ) with Hardware

To design the hardware system, the following steps are involved. First, in order to build a portable date acquisition system, one needs to choose an affordable computer that satisfies the minimum specification requirements. The minimum requirements for computer performance, for example, should be as follows:

1) CPU should be 330 MHz or faster for collection of dynamic input,
2) RAM should be 64 MB or larger for optimization at a high scanning rate,
3) HD should be 2.0 GB or larger for storage of data files
4) A PCMCIA socket for the DAQ card (D/A or A/D)

Based on the market investigation and consideration of both price and performance, we decide to choose a Compaq laptop (Model: COMPAQ PRESARIO 1275; Compaq P/N: 119447-003; UPC: 743172831262, Retail Price: $1200) as our computer system. The detailed specifications are given in the following Table 1.

Table 1. The Main Specifications for a Chosen Laptop Computer System

CPU Speed	366MHz	Display	13.0" HPA Display
Hard Drive	4.3GB	Resolution	800x600x16M
System Memory	64MB	Modem	56K ITU V.90 modem
PCMCIA Socket	Yes	Dimension	1.97"x12.1"x10.8"
CD-ROM Drive	24xMax CD Drive	Weight	7.3 lbs

Diskette Drive	3.4” 1.44 MB		Battery	Hi-capacity NiMH battery

Second, the environmental equipment should also be fast, compatible, and inexpensive. The basic components for the environmental equipment were selected from the National Instrument Co. and listed as following:

1) NI-DAQ Card (DAQCard-AL-16E-4 with 16 inputs, scanning rate 500 kS/s and 12 bit Multifunction I/O).
2) NI-DAQ Driver Software 6.5.1 for Windows 9X & Windows NT
3) NI-DAQ I/O Data connecting board (CB-68LP)
4) NI-DAQ Shielded Connecting cables (SH68-68-EP 184749-02)
5) NI-DAQ Converter for cable-card connection (1835698-01)

Third, the portable DAQ system has been assembled using the parts from the first (i.e., the computer system) and second (i.e., the environmental components) groups. An illustration of the complete selected system is shown below in Figure 1.

Picture 1. The appearance of the Portable Data Acquisition System

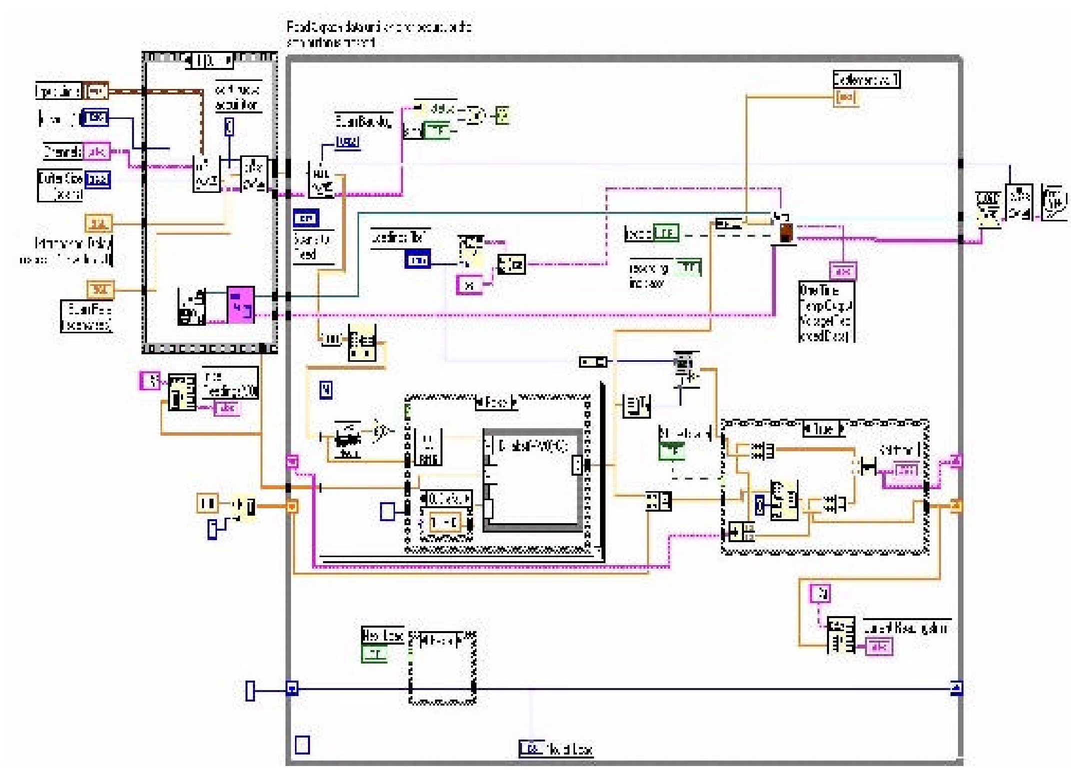
III. Design of the Data Acquisition System with LabVIEW Software

LabVIEW (Laboratory Virtual Instrument Engineering Workbench) is a development environment based on a category entirely different from the traditional text based code. It is a class of computer programming languages called graphical programming languages or G language. This is because the programmer never sees any code in the form of textual commands. Instead, the programmer is presented with a canvas upon which to draw a schematic of a program that closely resembles an electrical circuit (Figure 2). It is composed of logical operations, data manipulation processes, various program loops, and sub-VIs. The entire data acquisition process can be distinctly divided into several sections and is explained below.

Firstly, the LabVIEW program must gather the data from the hardware through the data acquisition card (DAQ) in the computer's PCMCIA card slot. The card selected for our use can take input data in 12-bit format from up to 16 individual channels. The program does have subroutines and functions called sub-VIs that can be called by another procedure much like textual languages can call subroutines. In the programming interface there is a pre-built sub-VI that enables data reading from multiple channels. Because the data is in multiple channels and is taken in a continuous stream, the computer sometimes may not be able to take in all the data at once. As a result, a temporary reservoir called a scan buffer holds the data until the computer has a chance to retrieve the data. The size of this buffer is limited by the amount of memory available in the computer, which is why 64MB of RAM is recommended (National Instruments recommends a minimum of 32MB, but for optimal performance 32MB may be insufficient). A variable called "Scan Backlog" is an indicator for the amount of data deposited and currently residing in the buffer. A continuously increases Scan Backlog, for example, indicates LabVIEW is not able to retrieve the data fast enough. To cure this problem, several variables for the scan rate can be altered.

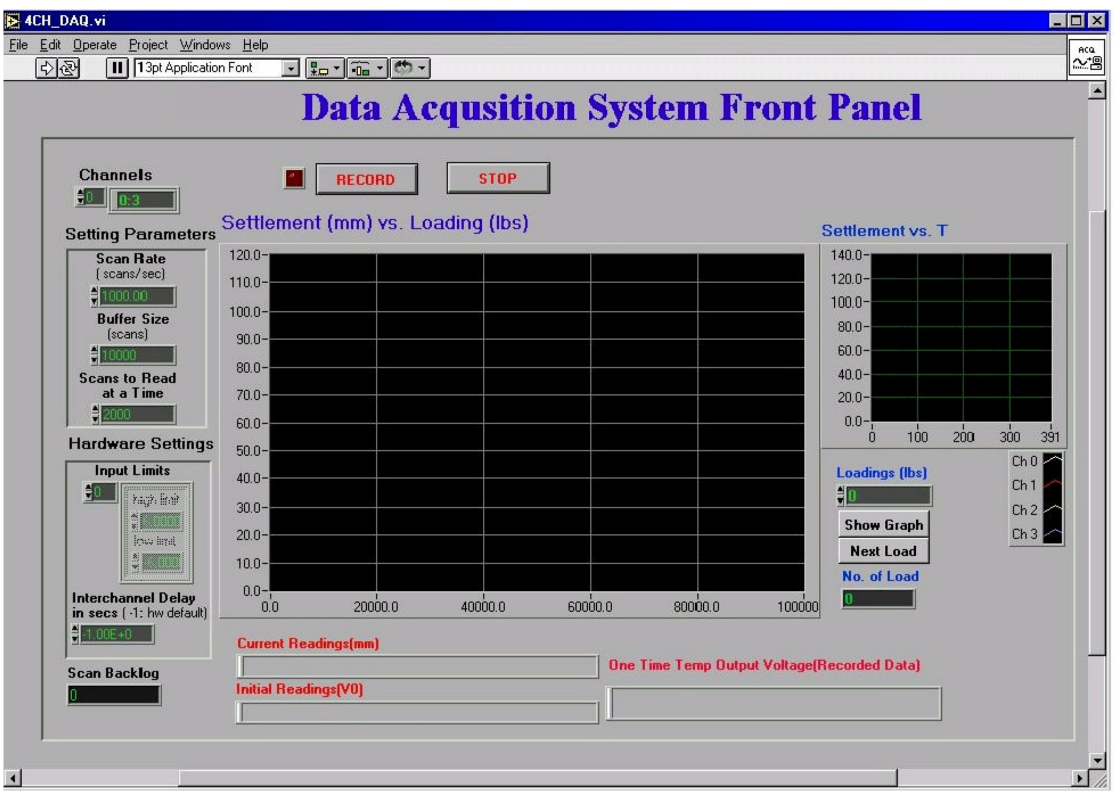
Secondly, the data that LabVIEW has gathered must be analyzed and processed. The data retrieved by LabVIEW is in a two-dimensional array namely columns of numerical data. Each column represents a respective channel. Once this array is retrieved, it can be manipulated with various functions and sub-VIs. The data manipulation includes the translation between raw data to consequential information. This process can take place inside a calculation or formula loop with multiple parameters inputs and only one output figure. After the data analysis is complete, the data is placed back in an array for any further processing that's necessary. The completion of the data analysis segment brings up the third section of the data acquisition process. Once the final data is reached, it is still not visible to the user on the front panel. The next step in the data acquisition process is the plotting and graphing of the immediate data to the user. This is done with the help of the various Waveform controls that are included with LabVIEW. Inside the diagram, the control is only represented by a small blue rectangle. This block requires only one input namely the data to be graphically displayed. This input will accept a two-dimensional array as input argument and the output is the display. The two-dimensional array is simply two columns of data; one represents the X-axis values while the other represents the Y-axis values. The Waveform control then plots the data points according the data that the input has specified. After the user has seen a graphical representation the data that that environmental instruments has collected, the data acquisition process can progress to the fourth and last step namely the exporting of the data. A majority of the time, the user does not want to look at the data only within the LabVIEW program. More specifically, the user may wish to export the data to a file so that it may be accessed at a later time possibly with another program such as Microsoft Excel. This is a common function and offers more flexibility with regard to data handling. The writing of data to a file is not included in any pre-defined sub-VI. Instead, a user is offered sub-VIs to open a file for input/output, read/write lines of text from/to an already opened file, and closing a file once all the operations are complete. A "home-made" sub-VI is constructed to perform all these tasks and write information that is provided from the array data. This sub-VI is then called by the main VI and given the data array as input. The sub-VI will independently feed the array information to any text file the user specifies and writes according to the format of the array.

Picture 2. The block diagram of multi-simulator VI



Finally, the user interface that sits between the user and an executing block diagram is the front panel. The front panel consists of four main sections as well. The first is related to the data acquisition parameters. This includes such conditions as the number of channels, scan rate, buffer size, amount of data to read per scan, and data minimum/maximum values. These conditions deal with the hardware settings and the data acquisition settings needed for the DAQ hardware to properly acquire data from the analog inputs. With the current program, all of these hardware configuration parameters must be entered prior to the running of the VI. The next section is the main control section of the VI. This consists of only the *Record* button and the *Stop* button. The *Record* button writes the read data to the specified file. The *Stop* button terminates the entire VI. The third section is the graph displays that occupy most of the front panel space. The two displays offered display information differently, namely different a X-axis. One uses relative time as the X-axis while the other uses the load as the X-axis. The last section is the runtime control section. This consists of four items: *Loading* button, *Next Load* button, *Show Graph* button, and the total number of loads. *Loading* refers to the amount in the current load. *Next Load* button increments the total number of loads properly adjusts the x values for data points on the discrete waveform graph. The *Show Graph* button displays any updates in the graph from the current load data. Together these form the front panel used in the data collection process.

Picture 3. The Front Panel of LabVIEW DAQ System



IV Design of the Virtual Instrument for Multiple Purposes

The data acquisition system has been designed with eight analog data scanning channels. In other words, the program has been coded for measuring up to eight variables simultaneously. In engineering applications, these variables may be such variables as:

a. Stress or force measurement in dynamics and statics
b. Strain displacement measurement in dynamics and statics
c. Velocity and Acceleration measurement
d. Flow measurement
e. Temperature measurement

LabVIEW can be applied to develop the virtual instrument or simulators in the laboratory. The current and future programs are designed for emulating the following virtual equipment:

a. Oscilloscope
b. Signal Generator
c. Signal Converter for A/D or D/A
d. Signal Analyzer with multi-channels
e. Frequency analyzer

The above virtual devices are important and essential lab tools in helping engineering students learn or enhance their understanding of principles in engineering.

IV. Summary and conclusion

In the present paper, the design for the data acquisition system has been discussed. The DAQ system has been designed and built using hardware (i.e., the laptop system plus some basic environmental components made by the National Instruments) and software (i.e., the Laboratory Virtual Instrument Engineering Workbench). This system is portable, convenient and affordable since it is light, small and inexpensive, especially for those students at engineering schools at which the laptop is required, and NI-DAQ cards and software at the laboratory are available or partially available. With the help of quick developments in computer technologies and further dramatic drop in prices, more and more faculty and students can purchase and build such a system for assorted purposes in teaching, research and study. The personal laboratory equipment or data acquisition system has a number of advantages. Many physical limitations or difficulties due to lack of resources (e.g., funding, time, room, equipment, lab technicians, etc.) can be overcome. The design of the personal data acquisition systems or virtual devices presented in this paper will provide a good example for one to build his or her personal laboratory equipment that will allow students and faculty to have more convenience and flexibility. Therefore, the effort made in designing such a system will lead us toward a new direction of laboratory development in the future. It is undoubtedly the idea of personal laboratories will become more feasible, practical and popular in the near future.

Moreover, an undergraduate course especially designed for the implementation of such a portable DAQ system and application of LabVIEW is to be recommended and will likely be added to the undergraduate curriculum in the near future at the department of civil engineering.

Acknowledgement

This project is supported by the US Department of Transportation via the National Transportation Center (NTC) at Morgan State University, Baltimore, Maryland, USA.

Bibliography

1. Gramoll, K. C. (1999). Teaching Statics Online with Only Electronic Media on Laptop Computer, in the Proceedings of the ASEE 1999 Annual Meeting, Charlotte, NC, CD-ROM Session 1668.
2. Gramoll, K., Abbanat, R., and Slater, K. (1996). *Multimedia Engineering Dynamics*, Addison Wesley Interactive, Reading, Mass.
3. Holzer, S. M. and Andruet, R. H. (1998). Learning Statics with Multimedia and Other Tools, ASEE Annual Conference and Exposition, Seattle Washington, pp. 120-126.
4. Li, J. and Lee, M. Y. (2001a). Online Modeling in Geomechanics via the Web Site, in the Proceedings of the 2001 ASEE Annual Conference, Albuquerque, NM, USA, CD-ROM, Session No. 2793, Paper No. 175.
5. Li, J., Zhao, X. and Lee, M. Y. (2001b). Applications of ColdFusion to Interactive Teaching in Engineering Courses, in the Proceedings of the 2001 ASEE Annual Conference, Albuquerque, NM, USA, CD-ROM Session No. 2793, Paper No. 1474.
6. Li, J. and Lee, Y. M. (1998a). Teaching Mechanics with Multimedia Tools, the Proceedings of the 1999 ASEE Annual Conference at Charlotte, NC. USA, CD-ROM, Session No. 1668.
7. Li, J. (1998b). Teaching Engineering Mechanics with the Internet, Abstracts in the Proceedings of Workshop of Reform of Undergraduate Mechanics Education, Pennsylvania State University.
8. Li, J. and Lee, Y. M. (1998c). An Experiment of Teaching Engineering Courses with the Internet, in the Proceedings of the 1998 Fall Regional Conference of Middle Atlantic Section of ASEE for Engineering Education, Howard University, Washington D.C., pp. 78-83.
9. Wilson, J. M. and Byron, P. R. (1996). A Multimedia Model for Undergraduate Education, *Technology in Science*, Vol., pp. 315-387.