AC 2012-3841: DATA ACQUISITION AS IMPLEMENTED IN THE MODERN UNDERGRADUATE MECHANICAL ENGINEERING CURRICULUM.

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Data Acquisition as Implemented in the Modern Undergraduate Mechanical Engineering Curriculum.

Abstract

With the widespread use of flexible, affordable, and accessible data acquisition platforms, undergraduate students are becoming more and more familiar with the design of experiments and the topics associated with data collection. For this study a self-guided tutorial was developed to introduce the topics of data acquisition. Students at various stages of their undergraduate curriculum are asked to work through the tutorial. This tutorial is also used in conjunction with a cross-curricular project involving numerical simulation and experimental validation of heat transfer topics of conduction and convection. Students were surveyed, both prior to and shortly after the tutorial, to determine the perceived value of the exercise in the context of their education and future careers. The results of this study prove useful in designing an effective cross-curricular approach to the topic and in tutorial development.

Introduction

Plug and play data acquisition has made experiment design and analysis much more accessible to undergraduate students. Where in the past typical lab experiences involved pre-established instrumentation and cookbook exercises, a wealth of software demonstrations and libraries couple with flexible and easy-to-use hardware to allow for a relatively straightforward introduction to the fundamentals of the craft of taking meaningful data. As a result, the number of publications regarding implementation in case-specific applications is staggering. See, for example, McDonald[1], Zhang et al.[2], Lohani et al.[3], and Delgoshaei et al.[4].

Meaningful applications of data acquisition have, in the authors' experience, been used to experimentally validate lecture material both in course and across courses within the mechanical engineering discipline[5,6]. In other applications, though less formal, students are exposed to the principles and equipment indirectly. As this technology continues to advance in both ease of use and sophistication, the undergraduate experience can be tuned to benefit the student.

In this paper a self guided tutorial is introduced and students are surveyed to determine their appreciation of data acquisition and its relevance to their studies.

Tutorial

A tutorial was used to introduce the concepts associated with data acquisition to undergraduate mechanical engineering students. It was assumed that the students would not have any prior experience using the software and hardware. The main goals of the tutorial are listed below. The tutorial should:

- Be self-directed, with minimal or no instructor input.
- Be completed in approximately one lab period (2-3 hours).

- Be appropriate for individuals or small teams.
- Feature data acquisition of analog voltage signals.
- Introduce basic filtering techniques and data manipulation.
- Demonstrate the outputting of acquired data to an external file.

The tutorial used was created in the context of National Instruments' "Introduction to LabVIEW" Hands-On guide[7], which provides a very general framework. The created tutorial assumes that the student has access to the equipment listed below:

- Laptop computer running National Instruments LabVIEW 2009 Software
- NI cDAQ-9172 (USB data acquisition chassis)
- NI-9215 (analog voltage input module for DAQ)
- Fluke thermocouple module with probe, model 80TK (Quantity: 2)

The tutorial is broken down into five main sections which are listed below. Along the way are several exercises in which the students create LabVIEW programs to accomplish certain tasks. The exercises build on each other throughout the tutorial.

1. The LabVIEW Environment
    - Students test the data acquisition hardware, ensuring communication between the device and the computer.
2. Acquiring a Signal with DAQ
    - Students acquire an analog voltage through a Fluke thermocouple module that produces temperatures represented in millivolts. Here students learn DAQ parameters including input range and sample rate, and graphically depict the data as it is collected.
3. Automated Analysis
    - Students simulate a signal with manually adjustable parameters and analyze it for frequency and amplitude content.
    - Students investigate the effectiveness of implementing numerical filtering in the software in conjunction with the thermocouple data from Exercise 2.
    - Building on the previous exercise by incorporating a conditional write to file option. When the temperature being measured is above some threshold the data is written to file.
4. Manual Analysis
    - Revisiting Exercise 3, here the students are asked manipulate the graphed data by introducing cursors to manually measure data values.
5. A comprehensive test
    - Students apply what they have learned in each step to plot and collect temperature data in a specific heat transfer application. Two separate temperatures are measured.

In the final exercise, the students must write a program to acquire two analog voltage signals simultaneously (temperatures output from the Fluke thermocouple modules), scale and filter the voltages, then output the values to a file every 10 seconds. As the final exercise is comprehensive, we have included a screen shot of the code here along with a photo of the experimental setup. Figure 1 shows a photograph of the experimental setup including the data acquisition system. The block diagram of the final exercise is shown in Figure 2. The LabVIEW icons are labeled in Figure 2 to provide more information about the setup. Two temperatures are measured using the Fluke 80TK Thermocouple modules. The modules output an analog voltage in millivolts equal to the temperature in degrees Celsius. Therefore, the analog input range of the data acquisition system is set to -0.5 to +0.5 volts. The system reads in 100,000 samples at a rate of 50,000 Hz. The data is then filtered with a 2nd order Butterworth low-pass filter with a cut-off frequency of 30 Hz. Earlier in the tutorial the students are able to visually see the effect of filtered versus unfiltered data sets. After filtering, the signals are scaled by a factor of 1,000 so that the data is in degrees Celsius instead of millivolts (for example, 0.020 millivolts is converted to 20 degrees Celsius). Next, the mean of each data set is found. Finally, the data is written to a text file, as well as being displayed on the screen in graphical form (chart) and numerical form. A screenshot of the Front Panel of the code is shown in Figure 3. This final exercise is then used directly in lab in a following class period.

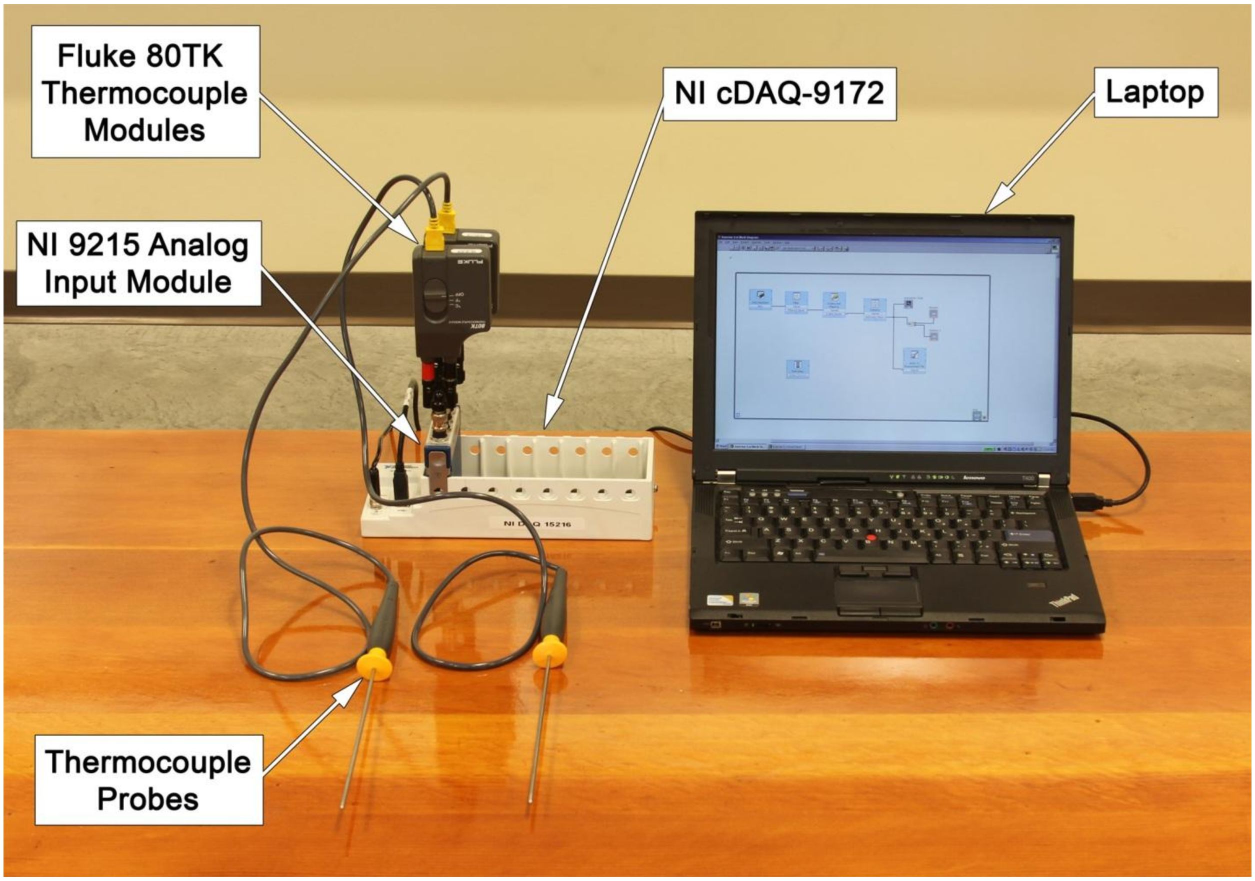

Figure 1: Photograph of experimental setup for the final tutorial exercise.

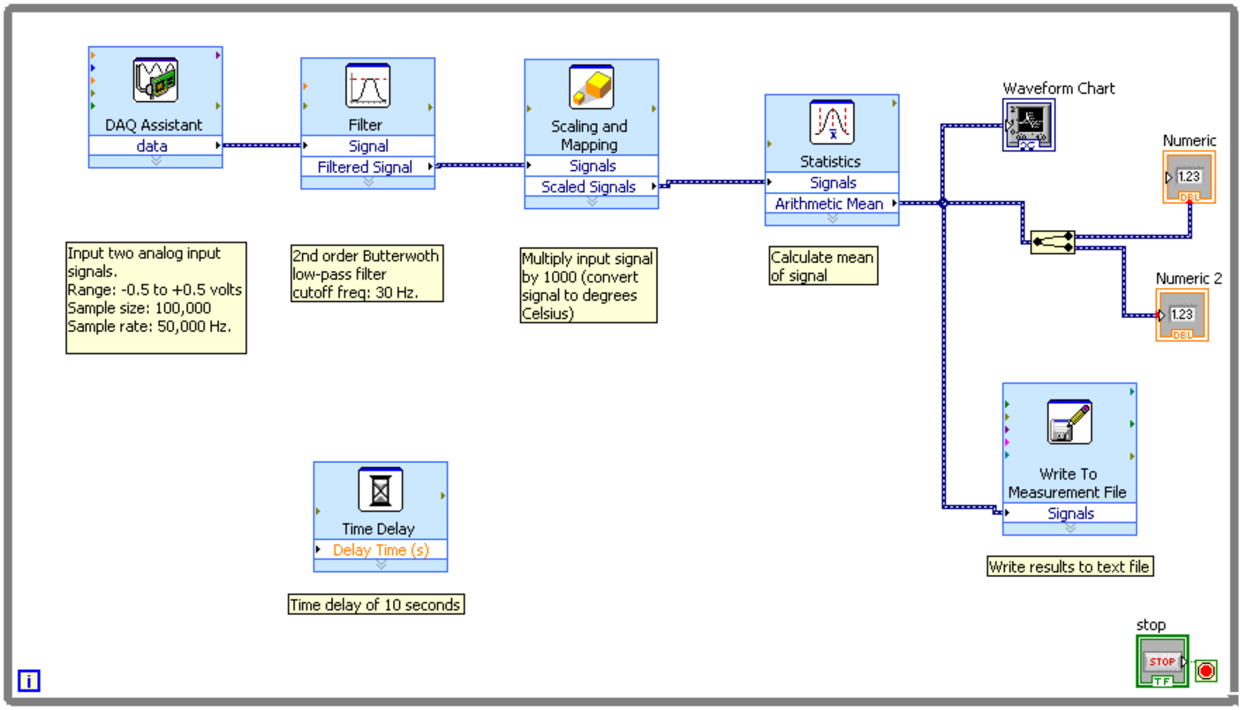

Figure 2: LabVIEW block diagram for the final tutorial exercise

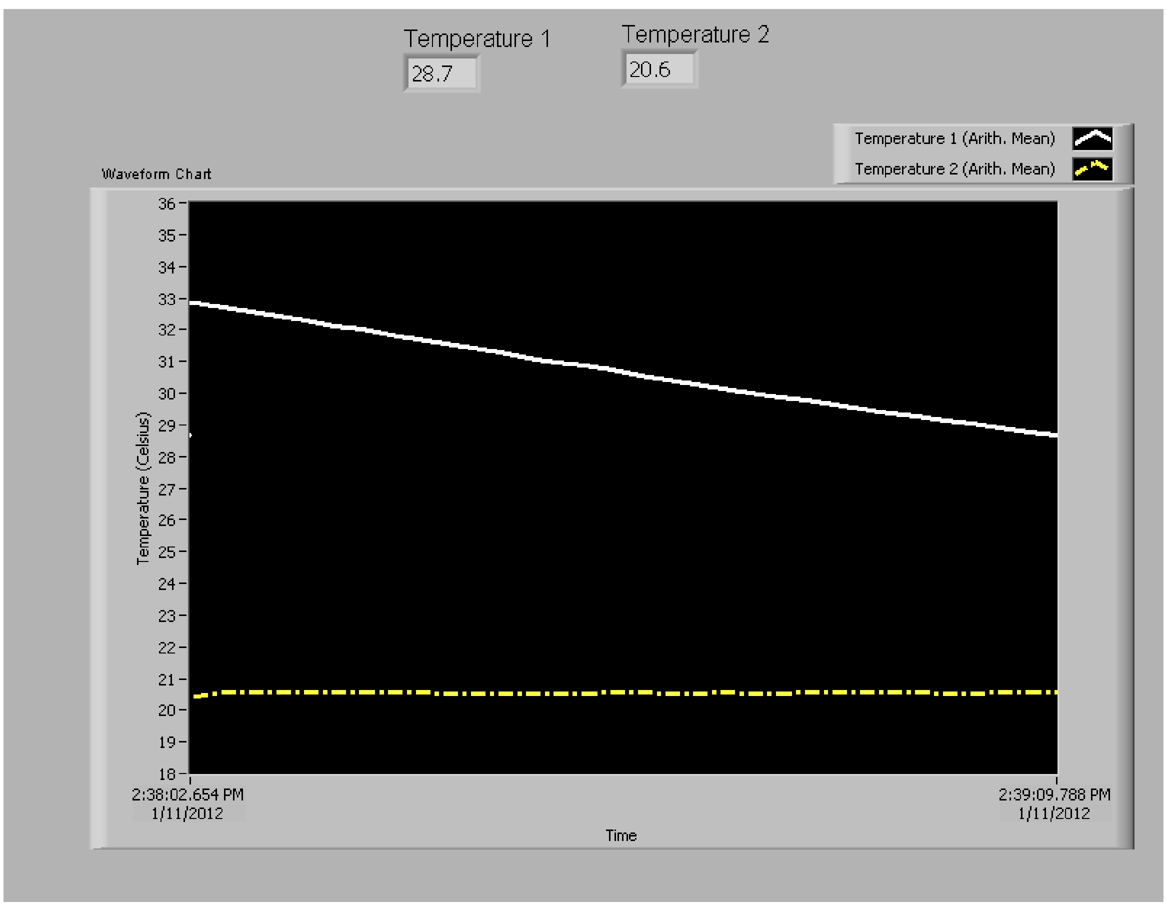

Figure 3: LabVIEW Front Panel for the final tutorial exercise.

Results and Discussion

The self-guided tutorial was used in the Fall 2010 semester to teach LabVIEW in two undergraduate courses, ME351 (Mechanical Systems Laboratory) and ME443 (Systems and Measurement). ME351 was comprised of mostly juniors while ME443 was comprised of all seniors in mechanical engineering. The tutorial was completed in groups of 2-3 students. A study of the effectiveness of the tutorial in strengthening core Heat Transfer topics has been presented by the authors[7].

The effectiveness of the tutorial as it pertains to the goals is assessed here in two methods. First, students were required to complete the tutorial in lab. Points were allocated for completing the tasks and for answering short questions on the concepts learned. In the quantitative assessment of the exercise, students scored an average of 95.1/100. Students were then given the opportunity to generate their own projects within the context of the lab. While some chose to work with programmable logic controllers, or established motion controllers, a significant portion of the students chose to work with LabVIEW for their ended project applications. While some new learning was generally needed, the topics covered in the tutorial were able to be treated as known.

Second, a survey was developed which catered to the perceived value in the exercise. The survey was conducted in the class before and after tutorial was given with the hope of finding out the effectiveness of the tutorial as well as finding out about student interest in LabVIEW. The results from five of the survey questions are given in Table 1 (before tutorial) and Table 2 (after tutorial). For the survey questions, students were asked to respond based on the following scale: 5 – strongly agree, 4 – agree, 3 – no opinion, 2 – disagree, and 1 – strongly disagree.

Table 1: Survey results prior to tutorial.

	Response		
Statement	**ME351 (juniors) n=38**	**ME443 (seniors) n=27**	**Combined n=65**
1. I have an understanding with National Instruments LabVIEW software and associated hardware.	1.39	2.44	1.83
2. I would value seeing applications of data acquisition in many of my courses.	4.03	4.19	4.09
3. I would value using data acquisition in my lab courses	4.05	4.22	4.12
4. It is important to reinforce theoretical concepts learned in lecture with lab experiences involving the same topics	4.50	4.26	4.40
5. I plan to use data acquisition (position measurement, strain measurement, temperature measurement, etc.) as a part of my senior design project.	3.92	4.22	4.05

Table 2: Survey results after tutorial.

Statement	Response		
	ME351 (juniors) n=30	**ME443 (seniors) n=29**	**Combined n=59**
1. I have an understanding with National Instruments LabVIEW software and associated hardware.	3.83	3.62	3.73
2. I would value seeing applications of data acquisition in many of my courses.	4.17	4.55	4.36
3. I would value using data acquisition in my lab courses	4.13	4.48	4.31
4. It is important to reinforce theoretical concepts learned in lecture with lab experiences involving the same topics	4.57	4.38	4.47
5. I plan to use data acquisition (position measurement, strain measurement, temperature measurement, etc.) as a part of my senior design project.	3.90	4.24	4.07

Results from the survey indicate two primary trends. The first is that familiarity with and appreciation of data acquisition is greater among seniors than it is with their underclassmen counterparts. Keeping in mind that both juniors and seniors are being introduced to the data acquisition tutorial simultaneously, this is an indication that student appreciation of data acquisition is growing with their undergraduate maturation. It may be the case that students are exposed to the process indirectly through demonstrations or project work. Most likely it is an indication that as students approach their senior design capstone work, they realize that some form of testing will benefit their design process, and that the skills associated with data acquisition are desirable.

The second trend, which is intended, is that both juniors and seniors feel they are more familiar with and more in appreciation of the LabVIEW data acquisition materials. The jump in appreciation is more pronounced among juniors, with an increase from 1.39 to 3.83. This implies that students have seen and thought less about the process at the junior level, and therefore have the most to learn from the introduction. With this being the first iteration on the tutorial, these results will serve as a baseline for future versions as the form and content are further developed.

Other observations include the following: It is apparent that the introduction has not changed the student's plans for use within the context of senior design. Question 5 shows no significant change regardless of year or completion of the tutorial. It is assumed here that the seniors have already made decisions about their use, and juniors have not yet thought about their capstone projects. In the future a better phrasing of that question might be "I see value in applying data acquisition in my academic and professional career". Also, despite the process being hands on, students showed no preference to seeing it in lab rather than in the classroom. This opens the door for many forms of exposure, including demonstrations and project work designed to validate theory. Curiously, seniors tended to value the use of experiment to validate theory slightly less than their junior counterparts, though both indicated they strongly agreed with the idea.

In addition to the survey results presented in Tables 1 and 2 previously, the survey also asked the students in what academic year they feel the topic of data acquisition should be introduced. The results for this question are presented in Tables 3 and 4 below. The results show overwhelmingly that from the viewpoint of the students, the topic of data acquisition should be introduced in the freshmen or sophomore year.

Table 3: Student response prior to tutorial to question "In what year do you feel this topic (data acquisition) should be introduced".

	ME351 (juniors)	ME443 (seniors)	Combined
Freshmen	53%	42%	48%
Sophomore	38%	54%	45%
Junior	9%	4%	7%
Senior	0%	0%	0%

Table 4: Student response after tutorial to question "In what year do you feel this topic (data acquisition) should be introduced".

	ME351 (juniors)	ME443 (seniors)	Combined
Freshmen	44%	29%	38%
Sophomore	30%	67%	46%
Junior	26%	0%	15%
Senior	0%	5%	2%

Conclusion

In the paper a self-guided tutorial for data acquisition is introduced. This tutorial is given to both juniors and seniors in the Fall of their respective school years. Assessment of demonstrated skills indicates that the students were able to complete the tutorial with little or no assistance from the instructor. It was also seen that the skills learned were easily implemented in a variety of applications of the student's own generation for project work. It was observed, however, that students would greatly benefit from an introduction to actuation as a step in the tutorial. This would enable students to activate relays, heaters, lights, pumps, etc. Similarly, some students were inclined to perform more advanced digital signal processing. This is outside the content of this course, and is best handled on a need-to-know basis.

Surveys given just before and just after the tutorial indicates that the tutorial is effective in showing the importance of understanding how to acquire data and that students appreciation of the process is more evident to seniors. This is not an indication that the material would be best introduced in the senior year. Instead, it is interpreted as an indication that its value is more obvious to those who have been through the bulk of their undergraduate program.

These results motivate a proposal for a holistic integration of data acquisition into the mechanical engineering undergraduate curriculum. The details of this integration are the subject of on-going efforts.

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