A Creative and Low-Cost Method of Teaching Hands-on Engineering Experimentation Using Virtual Instrumentation

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ABSTRACT: Virtual instrumentation is now used in the college level to teach mechanical engineering experimentation to undergraduates at Tufts University. By combining LabVIEW® with LEGO® Dacta blocks, students learn to write virtual instrumentation programs to interact with external sensors and actuators in an innovative hands-on approach to engineering experiments. The LEGO Data Acquisition and Prototyping System (LDAPS) is a collection of versatile LEGO sensors, motors, building blocks, and a computer I/O interface as well as LabVIEW Student Edition. It provides a highly capable, infinitely versatile, and expandable system for data acquisition and experimentation. The system is inexpensive (under $500 for a complete workstation without the computer), and because of the nature of LEGO blocks, it is fun, easy to use, and inspires creativity in students. By combining the LDAPS tools with the LabVIEW graphical programming language, students can create their own virtual instruments to acquire and analyze data with LEGO sensors, perform advanced signal-processing techniques, or program LEGO vehicles for interactive control. This article presents the method by which students are taught engineering experimentation and virtual instrumentation as well as describes the college-level course where it is used and a brief outline of how the same concepts are taught to students in other classes and in grades K-12. © 1998 National Instruments. Published by John Wiley & Sons, Inc. Lab Robotics and Automation 10:63-66, 1998

INTRODUCTION

Learning is always assisted by hands-on activity, especially in the engineering fields. This allows students to learn by their own actions and their own mistakes and to see the theory they have learned in action. In the college junior-level class ME18: Undergraduate Laboratory, students use LEGO® bricks and LabVIEW® to design and build their own experiments. They also design and build the measurement instruments (sensors) used to quantify the physical concept being studied, like force, torque, lift or drag, temperature, etc. LabVIEW is used to acquire data and perform complex signal analysis from LEGO sensors like temperature, rotation (angle), light, etc. At this point in their careers, the engineering students have already had a background in heat transfer, dynamics and vibrations, materials science, etc. In ME18, they can see these concepts in action. In addition to learning how to perform an experiment, students are taught about background literature research, data analysis, and the presentation of results in both written reports and oral presentations. Students also move on to perform larger-scale experi-
ments using professional quality sensors and data acquisition equipment, programming their own virtual instruments using the skills and knowledge of experimentation learned with the LEGO blocks.

A complete LDAPS workstation consists of a LEGO Dacta kit with building blocks, motors, sensors, and lights as well as a LEGO I/O board, and the LabVIEW Student Edition for either Mac or PC (the system is platform independent). This kit costs about $500 and is suitable for a workgroup of two to three students [1] (see Figure 1).

The following sections discuss the details of how virtual instrumentation and LEGO blocks are used to teach engineering experimentation in the college level class ME18: Undergraduate Laboratory at Tufts University. Also presented is a description of how these same concepts are used to teach younger students in grades K–12.

COLLEGE LEVEL: ME18, UNDERGRADUATE ENGINEERING EXPERIMENTATION

The ME18 Undergraduate Laboratory class meets for three 1-hour lectures a week. Each student also attends a 2-hour lab session each week. Three major topics are discussed in ME18: (1) data acquisition, (2) signal processing, and (3) the presentation of results (written and oral). The use of virtual instrumentation is of primary importance in the first two subject areas where LabVIEW is introduced.

Data Acquisition

The first part of the course introduces students to data acquisition theory and techniques. Students learn to program in LabVIEW and use laboratory equipment like voltmeters and function generators. Students also learn the theory behind computer I/O interfaces like GPIB and RS232 and by the end of the course are using professional analog-to-digital I/O interfaces for performing complicated experiments. LabVIEW virtual instrumentation is taught to the students using the LDAPS LEGO blocks. They begin by performing simple I/O tasks such as turning a motor on and off or reading the temperature from a LEGO temperature sensor (thermistor) via the LEGO I/O Interface Box. The LEGO blocks inspire creativity and make the learning of LabVIEW virtual instrumentation and data acquisition techniques fun and creative. The class begins with teaching basic communication with the LEGO sensors and motors: How to make a motor turn on and then off. Students build LEGO cars, tanks, and other vehicles that they can then program and control with their LabVIEW code.

Other projects include the building of a LEGO robot arm to simulate a robotic arm used in manufacturing. Here, students write a more complex virtual instrument that allows the robot arm to be controlled with LabVIEW. Inspired by the fun and creativity of LEGOs, some students continued on their own and worked on automating the robot arm to repeat a series of “pick and place” tasks just like in a real automated manufacturing process. By the end of the first part of the course, students have become proficient in LabVIEW and have programmed a LEGO car that can be controlled with a LEGO joystick.
Signal Processing

In the second part of the course, the students learn how to process and analyze data. In lectures, they are taught statistical analysis, Fourier theory (see for example, the virtual instrument front panel in Figure 3), sampling theory, and the effects of signal aliasing. In the laboratory, they now begin to move away from the LEGO blocks to more complicated experimentation and virtual instrumentation. A series of laboratory experiments are performed that include such topics as strain in a beam, transient heat transfer from a metal slug, steady-state heat transfer from a fin, and sound sampling of a whistle with a microphone. One
of these experiments is measuring the strain in an aluminum beam as it is deflected and vibrated. Students learn about strain-gage technology and mount their own gages on a beam. They learn to build the circuitry involved and the details behind making their own sensor, for instance, how to account for noise, uncertainty, confidence intervals, etc.

The sound sampling experiment is an excellent way to teach students sampling theory. First, students write a LabVIEW VI that will acquire a signal from a microphone via a National Instruments analog-to-digital I/O board, then they perform a statistical and Fourier analysis of the signal and plot the signal as well as the FFT on the virtual instrument front panel. By sampling at different frequencies, students can see the effects of aliasing in their signal and their FFT plot. They can even hear the effects of aliasing when the sampled signal is played back through a speaker.

K–12: LEGO BLOCKS AND LabVIEW IN OTHER CLASSES

Besides the mechanical engineering undergraduate laboratory class, the LEGO and LabVIEW technique for teaching engineering has also been applied in other classes and schools [1]. An introductory engineering class for first-year engineering students and liberal-arts majors uses LEGO blocks to teach students the engineering and physics behind “how things work.” Students then try to re-create machines using the concepts they have learned with LEGO blocks and LabVIEW. Some students have made a gray-scale scanner for scanning images with light sensors, a crane, and an amusement park ride (see Figure 4).

LabVIEW virtual instrumentation has even been brought into school grades K–12 to encourage students to learn engineering concepts. Children in kindergarten learn how an airplane flies and to interact with a computer and LEGO cars. They have even written their own LabVIEW programs to control the LEGO car (see Figure 5).

DISCUSSION AND CONCLUSIONS

Since this class was implemented only a few years ago, it is difficult to assess its worth to a student’s long-term career. However, each year a survey was taken of the students, faculty, and staff involved with the ME18 Undergraduate Laboratory class to assess the value of the course to an engineer’s curriculum [1]. More than 80% of the students surveyed believe that the LEGO blocks were an effective tool for teaching engineering experimentation and virtual instrumentation. More than 85% of the students felt that the knowledge they had gained from this class would be more useful than material learned in other engineering classes. Almost 75% of the class said they had learned more than in other classes, and yet only 65% thought there was a greater work load. The majority of the students felt that the class had improved their skills as an engineer and were pleased with the course.

Because of the students’ increase in laboratory skills, faculty and staff have noted better performance of students in undergraduate research projects. Faculty and staff have also expressed interest in the use of virtual instrumentation and LabVIEW themselves. More than 70% of the mechanical engineering faculty at Tufts University participated in a version of this course over the summer and have been increasing the use of LabVIEW in their graduate research projects.

Overall, the ME18 Undergraduate Laboratory class and the use of LEGO and LabVIEW to teach engineering experimentation and virtual instrumentation has been quite successful. It is flexible and inexpensive and is a great learning tool that can be applied to the training of a future professional engineer and to the education of a child in elementary school.

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REFERENCE