AC 2008-1149: LABORATORIES ENHANCEMENT WITH LABVIEW-BASED GRAPHICAL DEVELOPMENT TOOLS

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Laboratories Enhancement with LabVIEW-Based Graphical Development Tools

Abstract

With the rapid development of Electrical and Computer Engineering Technology, there is a lag for the traditional laboratories to keep up with the modern industry requirement. Although there are many applications of new technologies such as MultiSim, Xilinx, and etc. that have been introduced to classroom, they may only influence one or two courses. The lack of consistent in learning creates new problems in the curriculum. To address this concern, four faculty members in the Engineering Technology department at Prairie View A&M University proposed to revamp the current Engineering Technology undergraduate lab courses with LabVIEW, aiming to improve the delivery of laboratory and corresponding lecture contents through virtual instruments and graphical tools, inspiring students' interests in STEM (Science, Technology, Engineering and Mathematics) subject by accessing the latest innovations, and strengthening their marketability upon graduation.

LabVIEW is a powerful industrial standard graphical development environment developed on a novel concept of virtual instrumentation, which utilizes computer technologies in combination with flexible software and modular hardware to create interactive computer-based instrumentation solutions. Also NI provides a standard academic educational product of ELVIS. With such a multi-functional platform, as well as many third-party compatible products, the same platform can be used in a wide variety of subjects including circuit, electronics, digital logic, network analysis, digital hardware, robotics, control, microcontroller, and DSP.

Based on the consistent platform of ELVIS and LabVIEW, a sequence of lab courses in both Computer Engineering Technology and Electrical Engineering Technology programs can be developed, from freshmen, sophomore level courses, all the way to junior and senior level courses. Totally there are eleven courses to be revamped, including DC Circuit Lab, AC Circuits Lab, Electronics I Lab, Basic Electronics II Lab, Digital Logic Circuits Lab, Network Analysis Lab, Robotics Lab, Digital Hardware Lab, Control System Lab, Microcontroller Lab, and DSP lab. Through such a plan, all the students will receive enough training on the latest innovative equipment. Also the undergraduate curriculum of Engineering Technology department at PVAMU will be strengthened by the according lab courses.

I. Background

For the past decade, computer and electrical technology has been one of the most fast growing areas in engineering territory. New equipments have come into being, new products have appeared in the market, and new theories have been applied to the existing devices. All of the above give new expectations to current engineers and technologies. At the same time, they challenge our education of modern technologists.

1. Industry Demand

In recent years, due to the aging workforce[1,2,3], and emerging techniques[4], the industry demands for the entry-level engineers are tremendous. In a study conducted by Deloitte Consulting LLP and the National Association of Manufacturers, the results indicate that at least four of five companies are experiencing moderate to severe shortages. 83% of the surveyed 800 companies report the shortages influence their ability to meet production levels and maintain customer service and satisfaction[5].

Despite of the huge amount of applicants, companies are still frustrated by the availability of qualified ones[6]. This can be considerably owed to the transition towards technology-intensive production processes and the adoption of advanced manufacturing methods, which requires the workforce with higher levels of education, current technical skills, and the ability for greater decision-making in line with enterprise objectives[4]. For example, nowadays employees are not only expected to set up and oversee equipment, but also are expected to be capable of debugging and maintaining in case of broken down. Employees who were capable of meeting these new challenges became that much more valuable to the companies and in return, could command higher levels of compensation[6]. As industry procedure becomes more complex and more technology driven, education is becoming increasingly important[4]. However, it seems that there is a gap between the industry demand and current curriculum[7], and the current school system seems not prepare students adequately and properly for their future workplace[8].

2. Education Requirement

To address the problem encountered by U.S. industry in finding technically competent and highly skilled employees to fill the vacancies of engineers, scientists, machinists, technicians and operators[3], it is very much necessary to establish a productive and innovative partnership between industry and academia to provide a well-prepared, highly trained, and intelligent workforce to maintain its global competitiveness of US industry[9]. To be specific, the advent of the computer and related Information Technologies has revolutionized the industry procedures, substantially the flexibility and agility required in this highly competitive globalize economy[2,10]. For example, with LabVIEW engineers and scientists can now rapidly and cost-effectively interface with measurement and control hardware, analyze data, share results, and distribute systems. Its popularity in many different engineering applications and industries can be mainly attributed to the software's intuitive graphical development environment. It is also one of the motivations of our adopting a graphical tool to enhance the curriculum in Engineering Technology department.

The Department of Engineering Technology (ET) at Prairie View A&M University is now offering the Bachelor of Science degree in Computer Engineering Technology (CPET) program and Electrical Engineering Technology (ELET) program. Both programs are accredited nationally by the Accreditation Board for Engineering and Technology (ABET). The total enrollments in both ELET and CPET programs take up 22% of the overall undergraduate population in College of Engineering. Particularly the female students constitute 23% of the Engineering Technology departmental enrollment, significantly higher than the average proportion of 10% nationwide. The nature of ET is more focused on application and less theories, so the curricula in both of our CPET and ELET programs are different from traditional

engineering curriculum. All of our major courses require three hour lecture accompanied by a one hour lab. They are co-requisite of each other. Students must pass both courses to go to the next level. In another word, laboratory skill enhancement is a crucial part in ET education. But the current existing problem we are facing is that for each lab course, there is a set alone equipment. We don't have a platform that can teach students different applications of the knowledge they obtained from different level of courses. This obstacle greatly hinders the professional development of technology students, because they need more hands-on experiments than traditional engineering students.

In order to better fulfill its departmental primary purpose to prepare students for a successful career in engineering technology and related fields, Engineering Technology Department proposed to introduce the latest innovations into corresponding undergraduate labs with a project entitled as "Engineering Technology Undergraduate Laboratories Enhancement with Graphical Development Tool". Due to its impressive feature of easy-to-learn, we have realized if LabVIEW can be introduced into the undergraduate laboratories, then students can utilize the interactive graphical environment to explore and visualize the theory and concept; to compute, simulate, devise and testify solutions for the assignments; and to improve their competition in job market.

II. Graphical Development Environment

Engineering is a practicing profession. Thus, from its earliest days of engineering education, laboratories have been an essential part of undergraduate engineering programs[11]. National Instruments (NI) is a leading company dedicated to engineering and science research and education. LabVIEW is a powerful industry-standard graphical development environment developed on a novel concept of virtual instrumentation, which utilizes computer technologies in combination with flexible software and modular hardware to create interactive computer-based instrumentation solutions. With tremendous customers including 24,000 companies and 5,000 laboratories worldwide, LabVIEW has been proven to be useful in facilitating experimental learning, and helping educators prepare further engineers and scientists by creating an effective and dynamic learning environment, from hands-on labs to student design projects.

1. Graphical Programming

Educators have realized that too complicated interface and configuration will substantially frustrate student motivations, and considerably dragged down the progres[12]. Due to its visualized dataflow language, block diagram approach, and intuitive user interface, graphical programming can be much easier to be grasped by novice. Through this way, students can focus their concentration on the course subject, instead of programming, configuration, or interface. Moreover, convenient

Fig. 1 LabVIEW and ELVIS

development tools will help students to build their confidence and enthusiasm in their profession, attracting and maintaining more students enrolled in the related courses.
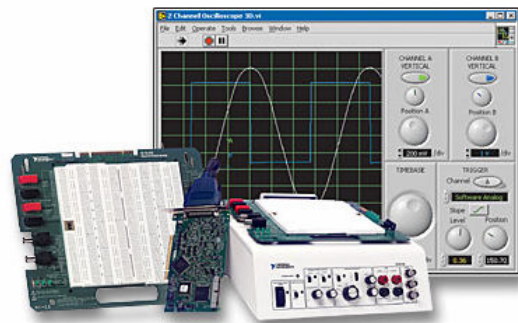
2. Diversified Platform

ELVIS (Educational Laboratory Virtual Instrumentation Suite) is a LabVIEW-based design and prototyping environment for university science and engineering laboratories, which include a virtual instrument, a data acquisition device, and a workstation and prototyping board. A set of LabVIEW and ELVIS equipment is shown in Fig. 1.

With the virtual instrument environment, students can conveniently display the measurement on the computer screen, and then make the data processing. It is a multi-functional platform, and can perform many curriculum applications. With the success of NI marketing strategy, more and more third party partners are now providing educational products based on ELVIS, which further facilitates the usage of the same platform to cover a wide variety of subjects from circuit, electronics, instrumentation to signal processing, control, microcontroller, DSP, communication, robotics, and etc.

3. Consistent Development Tools

If students can keep working with the consistent development tools in different courses, obviously it will greatly benefit the teaching. As a leading company in providing solutions to different industries, NI and third-party partners have developed a complete product line to cover many subjects. Thus, there is enough space for professors to arrange the education plan, such that students can gradually get familiar with those products on a consistent environment. Fig. 2 illustrates an example of circuit design.
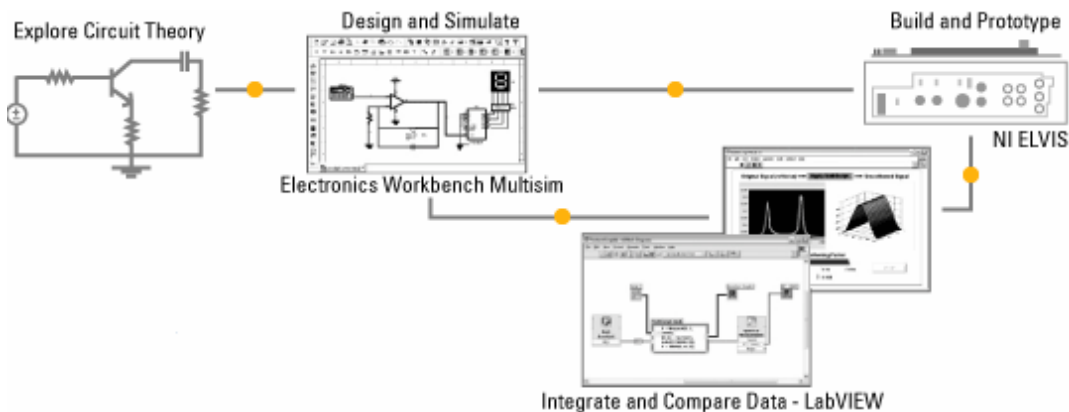

Fig. 2 Circuit Design, Simulation and Test with ELVIS, Multisim, LabVIEW

In freshmen level, students will use ELVIS in the circuit courses to establish the concept of virtual instrumentation. In sophomore level, simulation software of Multisim will be introduced in the courses of electronics and digital logic. From junior level on, LabVIEW will be utilized as the data computation and analysis tool. Finally in senior level, LabVIEW, ELVIS, together with compatible products from Quanser, TI and Freescale, will be integrated in the lab courses for students to deepen the understand of the abstract theory with physical implementation. Through such pedagogy to promote increased student learning, they will gradually become proficient with the development tool, establishing their confidence and benefiting the teaching.

4. Hardware-in-the-Loop

The following Fig. 3 demonstrates two Quanser boards, one is for DC motor control, and the other one is for rotary inverted pendulum. As the compatible products, both are as easy as plug-and-play when hooked with ELVIS. The two setups can be conveniently utilized in ELET courses of control system and robotics. With these experiment setups, this project will help students to learn how theories can be integrated with physical implementations. Besides, students will utilize the graphical programming tools of LabVIEW to realize the controller design and variable monitoring.
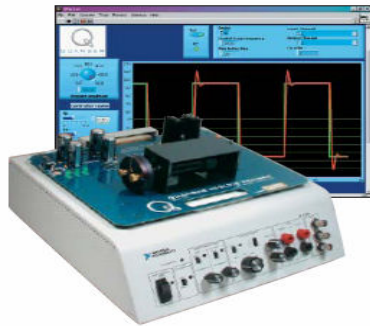

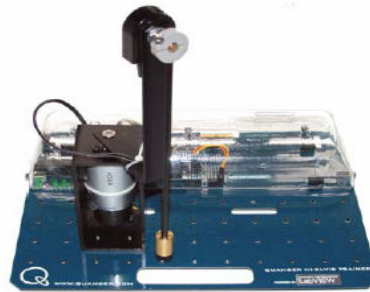Fig. 3A Quanser motor control board   Fig. 3B Quanser Rotary Inverted Pendulum

The following Fig. 4 demonstrates two setups compatible with LabVIEW, one is the Freescale HCS12 microcontroller teaching platform, the other is the TI 6416 DSP board. The two setups can be conveniently utilized in CPET courses of microcontroller and DSP. The new setups are helpful to educate student comprehensive skills in both hardware and software, to enhance their marketability upon graduation.

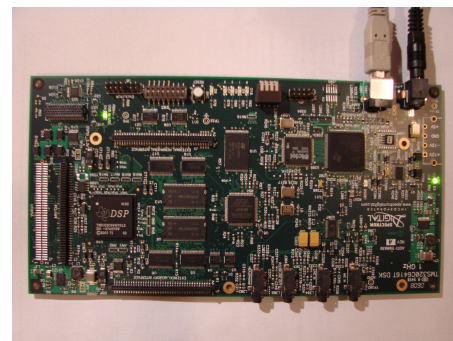Fig. 4A Freescale HCS12 Microcontroller Teaching Platform   Fig. 4B TI 6416 DSP Board

5. Equipments List

To conduct this project, following necessary equipments are listed in the Table 1.

Vendor	Products
Freescale	HCS12 Microcontroller Teaching Board
TI	6416 DSP Board
NI	ELVIS
NI	LabVIEW Teaching License
Quanser	Motor Control Board
Quanser	Rotary Inverted Pendulum

Table 1 Equipments list

III. Plan

We are going to introduce LabVIEW into the undergraduate labs through a step-by-step procedure on a consistent platform, such that students will gradually achieve proficiency in the development tool.

- ELET (Electrical Engineering Technology) Program:

In the lower level courses of Circuit Lab, Electronics Lab and Digital Logic Lab, currently students are using traditional meters and oscilloscope to make the measurement, and no simulation software is utilized in those labs. According to our plan,

(1) In the freshmen year, ELVIS will be introduced in ELET 1111 DC Circuit Lab and ELET 1141 AC Circuit Lab, and students start getting familiar with the concept of virtual instrumentation.

(2) In the sophomore year, simulation software Multisim will be involved in ELET 2221 Electronics (I) Lab, ELET 2251 Electronics (II) Lab, and CPET 2111 Digital Logic Lab. Students start using the simulation software to design the circuit, and then testify with physical implementation.

In the upper level courses, there are three laboratories to be revamped. In ELET 3241 Network Analysis Lab, experiments include basic circuit law, network theorems, circuit analysis techniques, use of controlled sources, transient, and sinusoidal circuit analysis. Currently the lab assignments are carried out with Multisim. According to our plan,

(3) Based on the Multisim simulation, LabVIEW will be introduced in ELET 3241 Network Analysis Lab to integrate the two software together with a hardware platform ELVIS for physical circuit measurement. By combining the schematic capture, simulation, and analysis tools available in Multisim and the data acquisition and measurement features provided by ELVIS and LabVIEW, real world signals are easily sampled and then incorporated into simulations. National Instruments now provides pre-built LabVIEW programs that allow users to read in and export data from and to Multisim. This provides an opportunity to easily compare simulation results to real world waveforms, and students will benefit from increased debugging efficiency, design verification, and improving simulations.

In ELET 3451 Robotics Lab, topics include testing and control of robot devices, sensors, motion system, etc. In ELET 4471 Control Systems Lab, topics include design and testing of automatic controller developed with electrical engineering techniques. Currently in both labs, MATLAB is being used for the calculation and simulation, no physical experiment setups available. Based on the proposed plan:

(4) In ELET 3451 Robotics Lab and ELET 4471 Control Systems Lab, students will learn to use the LabVIEW to control Quanser hardware setups (shown in Fig. 3A, 3B). Especially recently developed MathScript toolbox in LabVIEW has been capable to cope with almost all the undergraduate control function calculation in the environment similar to MATLAB.

Type	Course	ELVIS	Multisim	LabVIEW	Others
Required	ELET 1111 DC Circuit Lab	X			
	ELET 1141 AC Circuit Lab	X			
	ELET 2221 Electronics (I) Lab	X	X		
	ELET 2251 Electronics (II) Lab	X	X		
	CPET 2111 Digital Logic Lab	X	X		
	ELET 3241 Network Analysis Lab	X	X	X	
	ELET 3451 Robotics Lab	X		X	Quanser
Elective	ELET 4471 Control Systems Lab	X		X	Quanser

Table 2 New stuffs to be used in ELET revamped laboratories

Through such a procedure, students will gradually become proficient in the hands-on skills and enhance their capabilities in both hardware and software. The details of the hardware and software to be used in the related courses are listed as the above Table 2.

- CPET (Computer Engineering Technology) Program:

In the freshman and sophomore year, the departmental required courses are the same in both CPET and ELET programs, thus the current situation and corresponding plan in CPET is also the same as of ELET program in the lower level courses.

(1) Same as of ELET program.
(2) Same as of ELET program.

In the upper level courses, there are three laboratories to be revamped. In CPET 3251 Digital Hardware Design Lab, experiments include design of digital computers and computer controlled devices; the internal operation of a microprocessor and computer; register and timing control, programmable gate arrays, array processors as computer models. The current equipments available are digital logic training boards and the stand-alone Multisim. Students are now performing the labs either by simulating circuits in Multisim, or by wiring real circuits on breadboard. We are planning to

(3) Introduce LabVIEW in CPET 3251 Digital Hardware Design Lab to integrate the two software together with a hardware platform ELVIS for physical circuit measurement. Similar description can be found in the proposed plan in ELET program.

CPET 4391 Programmable Microcontroller Lab, experiments using microcontrollers to control various devices. Read input from sensors, perform analysis through software, and then provide corresponding control signals. Currently, students perform labs on stand-alone project MPU project boards. Another course is CPET 4381 Digital Signal Processing Applications Lab, experiments in signal processing using commercial DSP processors for performing various image and speech processing task. Previously, the lab is made through MATLAB simulation, and TI DSP 6416 boards just become available recently. We are planning

(4) To introduce LabVIEW to integrate the Freescale or TI board with the software. Embedded project manager is an add-on toolbox to make teaching embedded systems using DSPs or MPUs easy and affordable. LabVIEW can automatically generate C code and build applications on target hardware through simple operation, which makes it easy for students to simulate, download code, debug and deploy their assignments.

Type	Course	ELVIS	Multisim	LabVIEW	Others
Required	ELET 1111 DC Circuit Lab	X			
	ELET 1141 AC Circuit Lab	X			
	ELET 2221 Electronics (I) Lab	X	X		
	ELET 2251 Electronics (II) Lab	X	X		
	CPET 2111 Digital Logic Lab	X	X		
Elective	CPET 3251 Digital Hardware Design	X	X	X	
	CPET 4391 Programmable Microcontroller Lab	X		X	Freescale
	CPET 4381 DSP Lab	X		X	TI

Table 3 New stuffs to be used in CPET revamped laboratories

The details of the hardware and software to be used in the related courses are listed as the above Table 3.

IV. Conclusions

To summarize this ongoing lab enhancement project, we believe it will benefit not only the students, but also the academic department and industry. The expected outcomes are listed below:

1. The pedagogy of using consistent graphical tool from circuit to senior course is successfully integrated into several lab courses, and students will benefit from the shortened study curve, and improved concentration on the course subjects.

2. Enhancing student comprehensive capability from hardware to software, benefiting their future career development and also motivate more students of choosing STEM related majors in their undergraduate studies.

3. Promote the integration of research and education in department and support faculty professional development.

4. Some other universities who have similar program can follow this exemplary pedagogy of using consistent graphical tool from freshman to senior courses to benefit more students.

To evaluate this on-going project, we plan to have the data gathered from Engineering Technology department to show the differences in graduation and retention rate. Those two data can serve as the objective evaluation of the project result. We are also going to send out student survey on each course that involved in this renovation. Students will provide their subjective feedbacks on the effectiveness of this laboratory enhancement project.

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