AC 2010-1233: USE OF PROGRAMMABLE LOGIC CONTROLLERS TO MOTIVATE HIGH SCHOOL STUDENTS TO PURSUE ENGINEERING

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Use of programmable logic controllers to motivate high school students to pursue engineering

Abstract

The paper describes the use of Programmable Logic Controllers (PLCs) to motivate Appalachian high school students to pursue higher education in the areas of Science, Technology, Engineering, and Math (STEM). Nationally, college enrollment in STEM areas has been declining; this is particularly true for minority and Appalachian students. This project worked with two batches of twenty students each. Each batch was organized into four teams of five students. All students were first provided instruction in logic circuits and ladder logic. Ladder logic circuits for four tasks were created; a) simulation of automatic garage door, b) simulation of four way traffic light, 3) controlling a light via a physical switch, and 4) physical control of five lights. The five lights mimicked traffic lights (red, yellow, yellow left, green, and green left) at an intersection. The students were asked to control the timing sequence of the lights. Upon completion of the eight hour lecture/laboratory period the student were surveyed. Student responses indicated that a significant portion of both girls and boys agreed or strongly agreed that lecture/laboratory material improved their understanding of PLCs, Boolean algebra, ladder logic, and hardware/software integration. The activity was even considered to be fun by some students.

Introduction

This paper describes the use of Programmable Logic Controllers (PLC) to motivate high school students to pursue science and engineering. Enrollment in Science, Technology, Engineering, and Math (STEM) disciplines has been declining for some time[1]. This is particularly true for minorities and Appalachian students. A project entitled, "Engineers of Tomorrow (EoT)"[*] was under taken at West Virginia University (WVU) to recruit and retain high school students in STEM disciplines[2]. The project was supported in part by the National Science Foundation[3] and the C. W. Benedum Foundation[4]. It involved several WVU colleges (Colleges of Engineering and Mineral Resources, Human Resources and Education, Eberly College of Arts and Sciences), the EdVenture Group[5], and the Governor's Minority Students Strategies Council.

Across the nation, science, technology, engineering, and math (STEM) majors in secondary education have undergone enrollment declines in recent years. Difficulties in attracting students from Appalachia, particularly women and minorities, to science and engineering majors are especially problematic. West Virginia and the region are rural and have been isolated by topography with few high tech opportunities for college graduates; often they leave the state. Many college students are first-generation in Appalachia, and these students do not have many role models at home or in local communities, particularly in the STEM disciplines. Research suggests that high school students react favorably to learning activities that are hands-on and competitive. Our lab activity was selected because it allowed students to learn about an engineering discipline particularly industrial engineering; because it involved active, hand-on

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learning and designs with more than one possible correct outcome depending on design constraints; and because students could compete against their peers using the same design considerations.

In 2009, the West Virginia University Engineers of Tomorrow research team reviewed regional literature on STEM career opportunities for Appalachian students, and noted, "It has long been said that high tech industries with higher paying jobs would improve the lives of residents of the Appalachian region. Careers in the sciences, technology, engineering and math (STEM) are one route to improved economic stability in the region and improved quality of life for these families and their supporting economies. Yet, by almost any measure, the difficulties in attracting high school students to STEM careers are enhanced in Appalachia, and especially in West Virginia. Declining population, and particularly out-migration of college graduates and in-migration of less-than-high-school graduates characterizes this region. McDowell county in West Virginia has the lowest in-migration of the 400-plus counties making up all of Appalachia. Over 20 percent of US residents have college degrees, but only about 14 percent of residents in Appalachia have college degrees with West Virginia the lowest state on this measure. In the most rural Appalachian areas (subtracting out the large metropolitan areas), the college graduation rate averages only 7.75 percent with Lincoln County and McDowell Counties in West Virginia at the very lowest end of that scale at 4.72 percent and 4.59 percent, respectively. West Virginia has among the highest dependency ratios of the region. [note: Dependency ratio is defined as the number of dependents under eighteen years, plus those dependents over sixty four years, divided by the number of those persons between eighteen and sixty five, living in the same household, or DR = (n <18 + n>64)/(n 18 64)]. Among all 13 states, northern Appalachia including West Virginia has the highest mortality at 10.24 persons per 100 residents compared to the US rate of 8.8, complicated by the lowest fertility rates among women 15-44 years of age, at 55.42 births per 100 residents compared to the US rate of 66.70. Residents in the region of Appalachia have lower median family incomes than the rest of the US, and in the very poorest areas, the disparity has actually accelerated"[6]

The EoT program was executed through four tightly coordinated strategies for outreach to high school students and for retention of college freshmen, each tied to West Virginia curriculum standards, for specific desired outcomes[2]. This program provided intensive training and learning for 80 to 100 students. Students attend in cohort groups of 20 for one week and interacted with each other in the year-round program through WVU engineering student mentors. The program consists of introductory engineering training; basic math, science, and technology skills: ACT/SAT[7] preparation and study skills necessary to endure on a large college campus. The programs emphasis is primarily on mathematics, physics, engineering, and internet technology.

Recent trend in engineering education facilitated by the Engineering Criteria developed by the Accreditation Board of Engineering and Technology (ABET)[8] encourages integration of design throughout the engineering curriculum. It also promotes integration of both the soft and technical skills to increase academic knowledge, life skills consistent with undertaking responsibilities within the engineering profession. During summer of 2007, the EoT program conducted several summer camps for high school students. This paper describes the activities of one camp that focused on utilizing PLCs to teach Boolean algebra, ladder logic, hardware/software interfacing, and real time control of a physical system.

Programmable Logic Controllers

Programmable Logic Controllers (PLCs) were first introduced in the sixties to eliminate much of the hard wiring associated with conventional relay circuits. Today, the PLCs are used in numerous applications, such as, filling soft drink bottles, controlling vending machines, controlling traffic lights, etc. However, the concept of a PLC was new to high school students. We first instructed the students in Boolean algebra, logic circuits, delays, and timers, and then introduced ladder logic for real time process control using a PLC. The ladder logic circuits were first tested on a simulation software before downloading to a PLC.

The first task was to develop a garage door control system, using five inputs and five outputs. The five inputs were: 1) a normally closed limit switch to sense if the door is closed, 2) a normally closed limit switch to sense if door is fully open, 3) a push button to open the garage door, 4) a push button to close the garage door, and 5) a push button to stop the garage door if it is moving. The five outputs were: 1) a red light to show the garage door is ajar, 2) a green light to show the garage door is completely open, 3) a yellow light to show the garage door is fully closed, 4) a motor to open the garage door, and 5) a motor to close the garage door. The students were asked to work in teams of five. The garage door exercise created a lot of excitement. The students were able to test their circuits on the LogixPro[9] simulator. Figure 1 shows a screen shot of the garage door simulation. The second task was traffic light simulation. The purpose of this exercise was to introduce timers and delays. The task given to students was to time the red, green, and yellow traffic lights, in the North (N), South (S), East (E), and West (W) directions, according to timing sequence shown in Table 1. A screen shot of the traffic light simulation exercise is shown in Figure 2. The students were amused when errors in their logic caused cars to crash.

Table 1: Traffic Light Timing Sequence		
Red: N/S (30 s)	Green: N/S (25 s)	Yellow: N/S (5 s)
Green: E/W (25 s)	Yellow: E/W (5 s)	Red: E/W (30s)

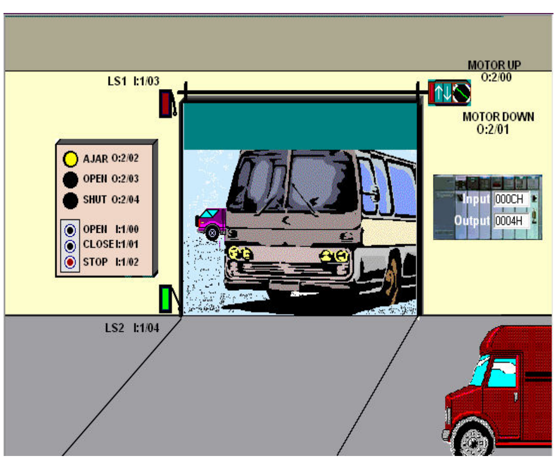

Figure 1: Screen Shot of LogixPro Garage Door Simulation

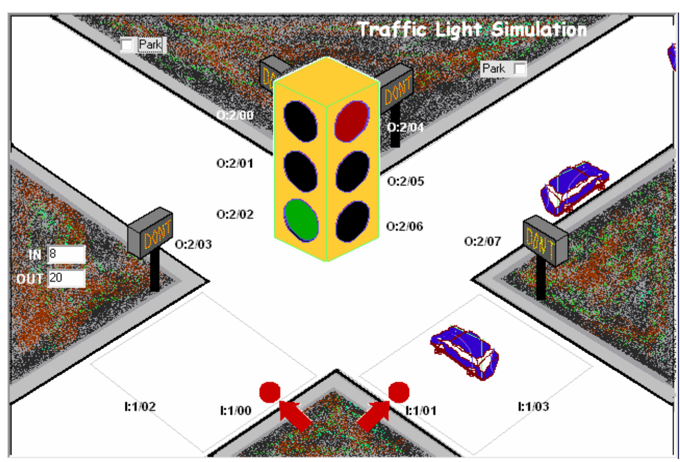

Figure 2: Screen Shot of LogixPro Traffic Light Simulation

Control of a Physical System

The above simulation exercises laid a foundation for introducing control of a physical system. The students were eager to experiment with real hardware. The first exercise in this area involved a single input (a switch) and a single output (a light). A switch and the light were connected to a PLC. The physical setup is shown in Figure 3. A low cost PLC (T100MD888) card[11] by Triangle Research was utilized to build the physical system. The T100MD888 provides 8 digital inputs, 8 digital outputs, 6 analog inputs (10 bit resolution), and two analog outputs (8 bit resolution). The PLC card was connected to a personal computer via the RS232 serial port. The T100MD888 hardware comes with TriLogi[10] software and data communication software. The TriLogi software enables the user to develop and debug ladder logic circuits. The debugged circuit can then be downloaded to the PLC for execution. The first task on the physical setup was to down load ladder logic circuit to turn on light L1, when the push button PB1 is pressed. The screen shot of the ladder logic diagram is shown in Figure 4.

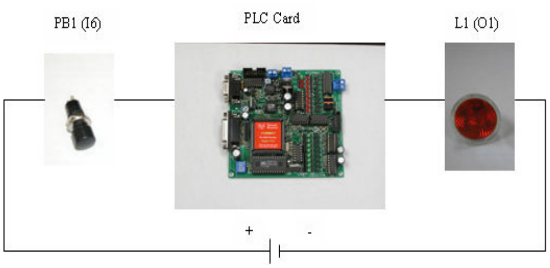

Figure 3: Physical Setup for one input and one output

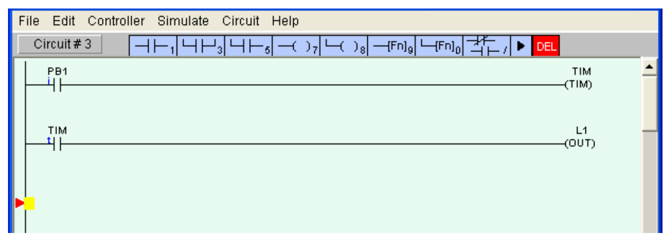

Figure 4: Ladder logic diagram for one input and one output circuit

The next exercise was to control timing of five bulbs simulating a traffic light. The five lights were; Red, Yellow, Yellow Left, Green, and Green Left. The students were also provided eight switches (six on/off switches and two push button switches). One on/off switch was to be programmed as a manual and auto switch. That is, in auto mode, the lights operated automatically according to the timing sequence shown in Table 1. In the manual mode, each light was controlled by a switch. If switch one is closed, the red light comes on, if switch two is closed, the yellow light comes on, etc. The eight switches were connected to the eight digital lines of the T100MD888 card and the five 12 VDC lights were connected to the digital output lines via relays. The schematic diagram of the physical traffic light system is shown in Figure 5. The entire set was placed in a cardboard box as shown in Figure 6. The hands on traffic light exercise generated a lot of excitement. The students were particularly impressed when the light operated automatically. It provided them an understanding of programming and real time process control.

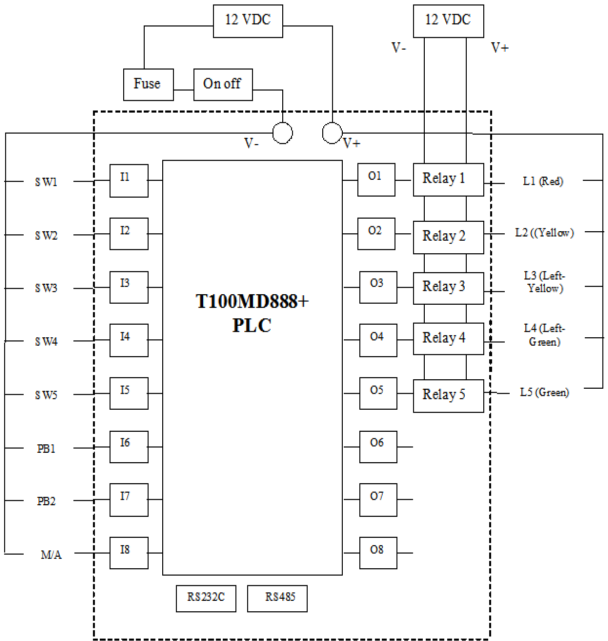

Figure 5: Schematic Diagram of the five outputs and eight input system

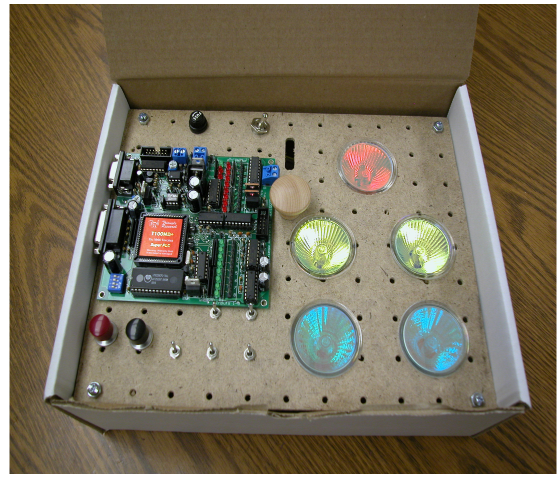

Figure 6: Physical setup with five lights and six switches

Upon completion of the eight hour lecture/laboratory period the students were surveyed. The various questions and student responses to the questions are summarized in Tables 2-7.

Table 2: As a result of this week's activity, I gained an understanding of how Programmable Logic Controllers are utilized in industry			
	Frequency	Percent (%)	Valid %
Strongly Agree	5	21.7	21.7
Agree	15	65.2	65.2
Neutral	3	13.0	13.0
Total	23	100.0	100.0

Table 3: As a result of this week's activity, I can "read" a ladder logic circuit			
	Frequency	Percent (%)	Valid %
Strongly Agree	3	13.0	13.0
Agree	16	69.6	69.6
Neutral	4	17.4	17.4
Total	23	100.0	100.0

Table 4: As a result of this week's activity, I can develop ladder logic circuit			
	Frequency	Percent (%)	Valid %
Strongly Agree	3	13.0	13.0
Agree	17	73.9	73.9
Neutral	3	13.0	13.0
Total	23	100.0	100.0

Table 5: As a result of this week's activity, I can Trilogi PLC software			
	Frequency	Percent (%)	Valid %
Strongly Agree	4	17.4	17.4
Agree	16	69.6	69.6
Neutral	2	8.7	8.7
Disagree	1	4.3	4.3
Total	23	100.0	100.0

Table 6: As a result of this week's activity, I can understand the relationship between Boolean Logic and Programmable Logic Controllers			
	Frequency	Percent (%)	Valid %
Strongly Agree	2	8.7	8.7
Agree	13	56.5	56.5
Neutral	6	26.1	26.1
Disagree	2	8.7	8.7
Total	23	100.0	100.0

Table 7: As a result of this week's activity, I can develop ladder logic circuit			
	Frequency	Percent (%)	Valid %
Strongly Agree	3	13.0	13.0
Agree	17	73.9	73.9
Neutral	3	13.0	13.0
Total	23	100.0	100.0

The student responses indicated that a significant portion of both girls and boys agreed or strongly agreed that lecture/laboratory material improved their understanding of PLCs, Boolean algebra, ladder logic, and hardware/software integration. In response to an open ended survey question, several students described the activity to be "fun". As a result of this, and several other activities, the freshman enrollment in the College of Engineering has been steadily increasing. It is however difficult to precisely quantify the impact of this specific project on freshman enrollment.

Conclusions

The objective of this project was to utilize programmable logic controllers to motivate Appalachian high school students to pursue science, technology, engineering, and math as possible disciplines for further studies. The project was carried out over a one week period during summer of 2007. Four traffic light simulation kits were developed. Four teams of five students each were instructed in Boolean Logic, LogixPro and TriLogi software. They were then provided the kits and asked to develop ladder logic circuits to control the traffic lights. The circuits were first tested on a simulator and then on the physical hardware. The student response to the hands on activity was overwhelmingly positive. Freshman engineering enrollment has also been increasing. It is likely that this project may have motivated some students pursue engineering in college.

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