Electro-Pneumatic Wiring Software for Distance-Learning Students in
Automation Control Laboratories

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Abstract

When teaching electro-pneumatic circuits in the automation control class for a distance-learning program, one of the main issues is how to provide hands-on experience for students. In most cases, they can only use simulation design software and watch videos solving laboratory problems without access to the actual equipment. In this paper, the authors developed an electrical wiring software and assembly platform which can help students enhance their hands-on experience when taking the course online. Results show that the performance between on-campus students and distance-learning (DL) students are very similar.
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1. Introduction

As distance-education programs become more prevalent, and as an increasing number of undergraduate engineering programs are being developed in a distance-learning format, questions about laboratories and their role in engineering education has become increasingly important[1,2]. Several approaches which were presented to resolve the issue are listed as following:

1.1 Design Software [1-2]
While DL students can have design experience and simulate the results by using the design software, they don't have the same laboratory experience as on-campus students.

1.2 Partnership with Local Institutions and/or with Industry Partners [3-4]
DL students can gain laboratory experience through internship programs; however, depending on the locations and characteristics of the institutions, students may not be able to find the same hands-on experiences as on-campus students.

1.3 Intensive Weekend Laboratory [5]
DL students are asked to come to the campus during the weekends to perform intensive laboratory work; however, the traveling cost and scheduling can become a big issue for DL Students depending on their proximity to campus.

1.4 CD –ROM Based Lab [6]
The CD-ROM shows the instructor setting up the equipment in accordance with diagrams provided to the students. The equipment is then operated by the instructor and a student assistant in a step-by-step fashion while the camera zooms in on each instrument reading and at other appropriate times. The student watching the video records the data in the same fashion as if he or she were the participating member in a group performing the test in the actual laboratory. The student then analyzes the data, prepares performance calculations and curves and submits comprehensive reports to the instructor. In this approach, DL students can only watch the operations.

1.5 Mobile Labs [7]
Since the Mobile Studio provides a portable lab facility, students can apply the tools they use in the classroom in their personal projects. The most obvious examples involve tinkering with cars and robotics. However, similar to the intensive laboratory, the traveling cost, locations, sizes of the equipment, and scheduling will become a big issue for the program and DL students.

To overcome the issues mentioned in the above approaches, this paper presents the development of a virtual laboratory which performs almost the same as the real equipment for electrical wiring. As the images of the equipment are very similar to (or look exactly the same as) the real equipment, students will be able to gain almost the same hands-on experience as on-campus students. The virtual laboratory is developed by using the following steps :(1) description of the real equipment, (2) animation wiring software development, and (3) Assembly Platform for electro-pneumatic wiring.

2. Description of the Real Equipment

In electrical wiring there are three main components of the laboratory equipment: (1) power supply box, (2) manual switch box, and (3) electrical relay switch box. Figure 1 shows the layout of the components. The red-and-blue plugs are for positive and ground connections respectively. The system can be powered on by activating the power switch. There are four contacts for each manual switch: two normally-open (N.O.) contacts and two normally-closed (N.C.) contacts; there are four N.O. contacts and four N.C. contacts for each relay switch.

3. Animation Wiring Software for Relay Schematic Ladder Diagram

Figure 2 shows the three-dimensional models of the main components which were created using CAD software. In the figure, power supply, manual switch box, and relay switch box are located at the top, bottom right, and bottom left respectively. The main goal of this approach is to develop a virtual laboratory so that the virtual equipment as wired in Figure 3 can perform the same function as the real equipment. In addition, six auxiliary icons are also created for this development: Cable Color Selection, File Open and Save, Volume Control (for short circuit warning), Help (examples), and System Close.

The wiring software has been successfully tested and its performance was identical to the real equipment. Figure 3 shows the design and wiring layout for the seal-in circuit. The virtual wiring software has been awarded a certification of United States Copyright. [8]

4. Assembly Platform for Electro-Pneumatic Wiring

Since the animation wiring software can be only applied to the electrical wiring. Another software called Assembly Platform [9] was developed for students to submit their laboratory reports, as shown in Figure 4. All electrical and pneumatic parts can be clicked and dragged to the platform for wiring. Both on-campus and DL students are given access to the software. Before students start working on lab problems, they can use an on-line tutorial to get familiarized with the software, as shown in Figure 5. Figure 6 shows an example for the wiring of an electro-pneumatic laboratory report for a seal-in circuit.

5. Performance Analysis of Learning Outcome

The animation wiring software was used in summer 2015 for both on-campus and DL students. Three laboratory tests (LT) were given for the performance assessment. LT1 is pneumatic circuit design/wiring, LT2 is electro-pneumatic circuit design/wiring; LT3 is PLC programming. In summer 2016, the software Assembly Platform was added to the class.

5.1 Performance Comparison in Summer 2015 – Figures 7 & 8
In the performance of LT1, 100% of on-campus students received an A while 83% of DL students received an A. However, 96% of DL students received either an A or B. In the performance of LT2, 87.5% of on-campus students received an A which is better than 78.3% of DL. However, Figure 8 also shows that 100% of DL students received either an A or B. In the performance of LT3, 100% of on-campus students received an A which is a little bit better than 91.3% of DL students who received either an A or B. Overall, the performance of on-campus students was better than DL students by a small margin.

5.2 Performance Comparison in Summer 2016 – Figures 9 & 10
In the performance of LT1, 100% of on-campus students received an A or B while 100% of DL students received an A. In the performance of LT2, 90% of on-campus students received either an A or B while 87.5% of DL students received an A. In the performance of LT3, 90% of on-campus students received either an A or B while 100% of DL students received an A. Overall, the performance of DL students performed better than on-campus students by a small margin.

6. Summary

When compared to DL students, on-campus students have an unarguable advantage of using the real equipment to gain hands-on experience. As DL programs becomes more popular, development of virtual-lab software provides a good method to reduce this gap. Since the components created in the software look almost the same as the real components, DL students can easily relate their experience to the real applications. Furthermore, a video using the real equipment for each lab is also posted on a secured website. From the results of the learning outcome, both on-campus and DL students perform approximately the same through this effort.

References

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[8] Lin, C., Shen, Y., and Tomovic, M., Certificate of Registration, "Animation Wiring Software for Relay Schematic Ladder Diagrams", U.S. Copyrights office, TXu-1-946-628

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[9] Lin,C., Verma, A., Tomovic, M., and Jovanovic, V., "An Asynchronous Course/Laboratory Development for Automation Controls", ASEE Annual Conference, New Orleans, LA, June 25-28, 2016
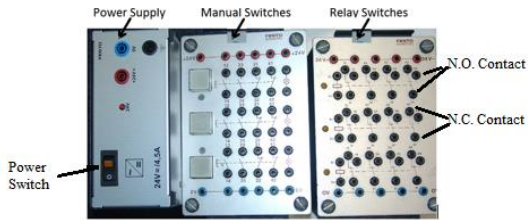
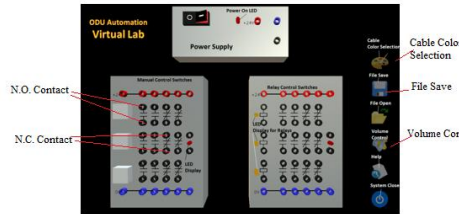Figure 1: The Three Main Electrical Components
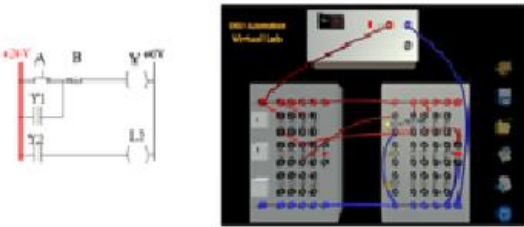

Figure 2: Computer Model for the Real Equipment
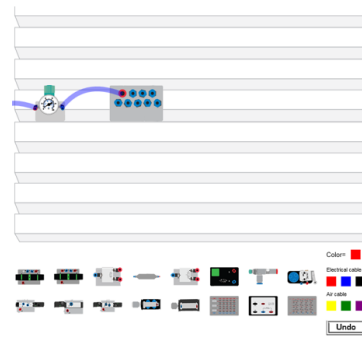

Figure 3: Design and Wiring a Seal-in Circuit

Figure 4: Assembly Platform for Electro-Pneumatic Wiring
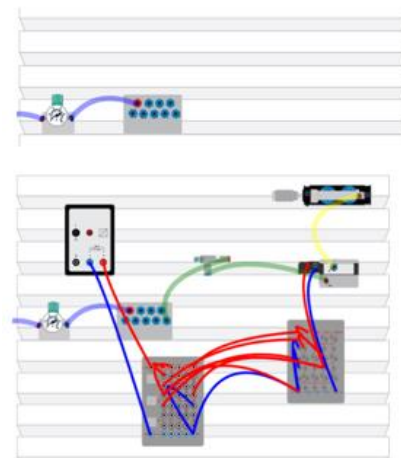

Figure 5: On-Line "Assembly Platform Tutorial" Training

Figure 6: A seal-in Electro-Pneumatic Wiring Circuit

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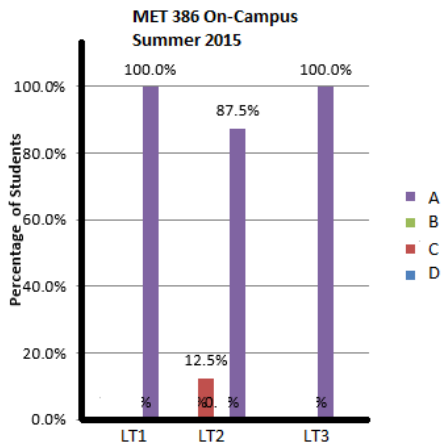*The University of Texas at Austin*
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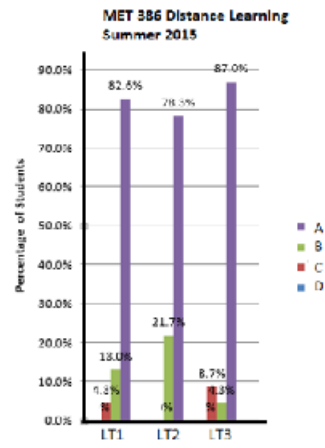Figure 7: Performance of On-Campus Students in Summer 2015

Figure 8: Performance of Distance-Learning Students in Summer 2015
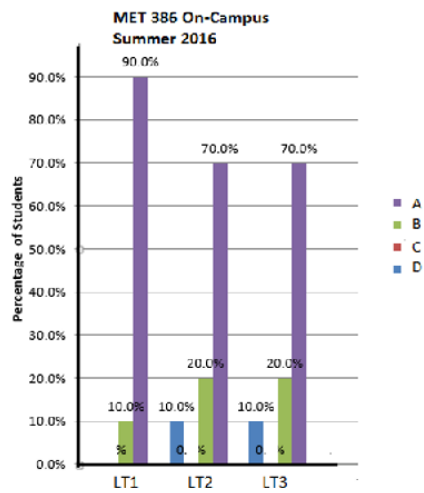

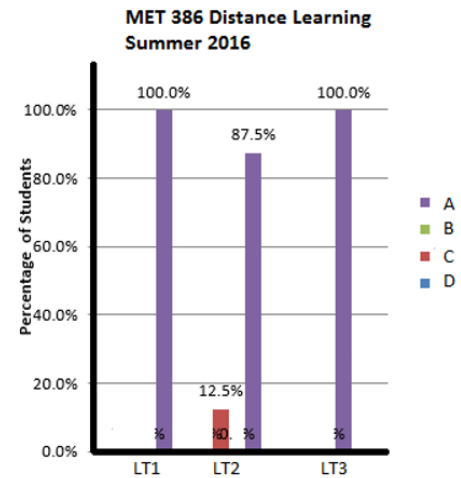Figure 9: Performance of On-Campus Students in Summer 2016

Figure 10: Performance of Distance-Learning Students in Summer 2016

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