VIRTUAL RELAY CIRCUIT BOARD FOR LEARNING

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Abstract

This paper presents the use of the Virtual Relay Circuit Board for Learning to enhance the student learning experience and outcomes in a practical workshop module for a first-year engineering course in Ngee Ann Polytechnic. Relay circuit control is the basis in automation where students are taught how relay circuits behave as switches to sequentially control the power on/off of devices. During these practical hands-on laboratory sessions, students are required to do wiring and testing of a control circuit within an allocated time. This limits the opportunities that students may have to practice their skills.

To overcome this limitation on time, a virtual relay circuit board was developed to create more opportunities for hands-on practice in a virtual manner. The introduction of this virtual relay circuit board supplements the physical laboratory sessions by providing flexibility for students to try out wiring a circuit anywhere and anytime through the use of their mobile devices outside of the classroom.

The virtual relay circuit board includes the following features:

- A FreePlay mode where users can manipulate virtual wires by drag-and-dropping and wiring up any of the components and devices in order to simulate its operation.
- A 2D schematic diagram design mode where users can design a ladder diagram based on specified test scenarios by drag-and-dropping the correct components to form a control circuit.
- A 3D virtual wiring mode where users can virtually create a control circuit by wiring up the components and devices on the board. Users can also set and adjust the timer's duration by clicking onto a test button to commence the operation.
- A Play-back option in the 3D virtual wiring mode where users are shown step-by-step how wires and devices are connected.

This study will show that the Virtual Relay Circuit Board for Learning tool has helped students to better visualize and understand the principles of the wiring circuit operation.

Keywords: Virtual relay circuit board, ladder diagram, FreePlay mode, 2D schematic diagram, 3D virtual wiring mode, Play-back.

Introduction

Electrical & Electronics Practical Skills (EEPS) is one of the compulsory workshop modules for first year engineering students. Students are taught the basics of electrical wiring and circuit design using the conventional electromechanical relay and timer to do switching and sequential control of fans, lights and buzzers. Students learn by actually building and wiring up the control relay circuit which could be very time consuming and also depend on the physical laboratory availability. With this constraint, courseware on virtual relay circuit board was developed to simulate a real world relay circuit board. Thus students are not limited by the availability of physical lab space to practice wiring of control relay circuit boards.

Literature review

Studies have shown that the use of 3D and virtual reality as learning tools allow the students to experience an entirely new side of training. This type of technology breathes life back into traditional computer based learning and re-awakens the enthusiasm in users who are used to this technology in other circles outside of training. The basis for the Virtual Reality idea is that a computer can synthesize a three-dimensional (3D) graphical environment from numerical data. Using visual output devices, the users get to experience working with a model of a real-world object and interact with computer simulated environment; this is allowed by the use of external input devices responding to the user’s reactions and motions. (Fitzgerald & Riva, 2001).

Simulation is a technique for practice and learning that can be applied to many different disciplines of Science. The use of simulation to replace and amplify real experiences with guided ones, is often “immersive” in nature, evoking or replicating substantial aspects of the real world in a fully interactive fashion. (Lateef, 2010). Simulated environments allow learning and re-learning as often as required to correct mistakes, allowing the learner to perfect steps and fine-tune skills to optimize experimental outcomes. Simulation-based learning also enhances efficiency of the learning process.
Based on the research and findings on the use of Virtual Reality in Engineering Education, we can see the positive impact it has on developing students’ competency in Engineering. With these in mind, Ngee Ann Polytechnic’s EEPS teaching team designed and developed the Virtual Relay Circuit Board.

**Virtual Relay Circuit Board for Learning**

Relay circuit control is the basis in automation whereby relay engages electrical contacts which either start or interrupt power to a device. It could be either a fixed sequence or a series of distinct operations with a definite condition to initiate each operation. The operation can be either a time-driven sequential process where each step is initiated at a given time or after a given time interval; or an event-drive sequential process where each step is initiated by the occurrence of an event. Ladder diagram is used to describe an event-driven process.

In a typical hard wired motor control circuit, a motor is started by pushing a ‘Start’ or ‘Run’ button that activates a pair of electrical relays. The lock-in relay locks in contacts and keeps the control circuit energized when the push button is released. Another relay energizes a switch that powers the device by connecting it to the main power circuit. All contacts are held engaged by their respective electromagnets until a ‘Stop’ or ‘Off’ button is pressed, which de-energizes the lock-in relay.

**FreePlay Mode**

FreePlay Mode allows learners to experience working with the virtual relay circuit board. Learners can virtually wire up any of the components and devices on the virtual relay circuit board by connecting it to the supply. They can then tap the play button and watch the animation output to understand how the selected component operates. This gives learner’s an insight into circuit operation like no equation does.

Unity3D JavaScript was used to develop navigation control in free-play mode. Learners are given the freedom to explore, navigate and interact with virtual relay circuit board. Learners can use either the on-screen control, the mouse or the keyboard to zoom, pan and rotate all by selecting the whole virtual relay circuit board as shown in Figure 1.

Once the virtual relay circuit board is loaded, learners can proceed to wire up any of the components and devices on the virtual relay circuit board by using a mouse to select the pin-hole of a component followed by selection of another pin-hole of next component. Virtual wires created are drawn overlapping one another...
in 3D dimensional and different coloured wires can be used to differentiate the connections between components and devices as shown in Figure 3.

Figure 3 : Virtual wires created are drawn overlapping one another

Learners can tap the play button to see the animation output: lamps turn on/off, buzzer sounds and mini-fans rotate etc. This simulation output allows the learners to understand how relays, timer relays and other components on the relay circuit board operate.

2D Schematic Diagram

Ladder diagrams are 2D schematic diagrams commonly used to illustrate how electromechanical switches and relays are interconnected. They are called ‘Ladder’ diagrams because they resemble a ladder; The two vertical lines are called ‘rails’ and are attached to opposite poles of a power supply, 12V DC or 240V AC. Horizontal lines in a ladder diagram are called ‘rungs’, each one representing a unique parallel circuit branch between the poles of the power supply. In ladder diagrams, the load devices, such as lamps, relay coil, fans, solenoid coils, etc are always drawn at the right-hand side of the rung. While it doesn’t matter electrically where the relay coil is located within the rung, it does matter which pairs of relay’s contacts, NO or NC contacts are used to turn on or off the devices sequentially.

NO = Normally Open. Open means that no current can flow through.
NC = Normally closed. Closed means that current can flow through.

Ladder diagrams are the most intuitive way to represent relay circuits. They are much easier to read & understand than wiring diagrams.

In the Quiz Mode, learner can design a ladder diagram based on specified test scenarios by drag-and-dropping the correct components to fill up a partially complete 2D schematic diagram in the order in which the sequence occurs. Learners are also prompted to key in the pin-numbers of the relay’s contacts for the selection of normally open or normally closed contact to produce the desirable set of outputs, as shown in Figure 4.

Figure 4 : Screen shots of designed 2D ladder diagram

Learners are given 3 attempts to submit their designed 2D ladder diagram. The system will then show the correct 2D ladder diagram before proceeding to the 3D virtual wiring mode.

3D Virtual Wiring

Unity3D game engine was used to develop the 3D virtual wiring mode. It features visual simulation capabilities with interactive functions and offers ease of use in the context of geometry data input and output.

In 3D virtual wiring mode, learners can virtually wire up components & devices onto the virtual relay circuit board, including power and signal connection. The workflow for the learner is to create virtual wires between pinholes of the components and devices on the virtual relay circuit board and set the right configuration setting for the components and devices to produce the correct output operations as dictated by the ladder diagram in the designing of 2D schematic diagram.

Learners are given 3 attempts to submit their 3D virtual wiring once they have completed wiring up the components. Upon submission, a dialog box will appear for the wrong wiring, to inform the learner of the wiring
configuration errors while the components or devices that were wired in-correctly will be covered with faint red bounding box. The dialog box also shows the number of attempts left for the learner to try again. Figure 5 shows an incorrect wiring submission, the dialog box indicates that timer 1, timer 2 and fan 2 are wired in-correctly and are covered with faint red bounding box, and the learners can proceed to amend his wiring if he has not exceeded 3 attempts.

Figure 5: Wrong Wiring submission

Figure 6 shows an example of correct 3D virtual wiring submission. Here learners can interact by tapping the play button to see simulated output of the operation: lamps turn on/off, buzzer sounds and mini-fans rotate etc.

Figure 6: Correct wiring submission. Learner can tap the play button to see simulated output operation

There is also a Play-Back [step-by-step] option in the 3-D virtual wiring mode which shows learners step-by-step how wires and devices are connected up, including the configuration setting for the components and devices in order to produce the correct output operations. As can be seen in Figure 7, the play-back option has clearly shown the step and the order of wiring connection, ‘wire the components and devices top-down, left to right, starting from line 1 of ladder diagram’. This Play-Back [step-by-step] option is a very good learning tool for students to visualize how components and devices are connected to produce the desired sequential output operation and understand the circuit design.

Figure 7: Play-Back option, showing step-by-step how wires & devices are connected up

The Order of wiring and Manner of connection are crucial in 3D as it simplifies the trouble-shooting process. If the wired virtual relay circuit does not function or works partially, learners are able to zone it or zero into the particular component & device level to examine what has actually gone wrong rather than trying to figure out why certain wires (in the wrong order or sequence) were added which may result in short-circuit or malfunctioning of the circuit.
Survey & Discussion

As part of the learning experience in EEPS, students are required to participate in on-line quizzes on the wiring and testing of the virtual relay circuit board during the semester. The purpose is to allow students to evaluate their own understanding of the electrical wiring and circuit design after physically hard-wiring the relay circuit board in the experiment. Quizzes are conducted in two stages where students must first design and draft out the 2D schematic diagrams or the ladder diagrams based on specified test scenarios. Students will drag-and-drop the correct components to fill up a partially complete 2D schematic diagram in the order in which the sequence occurs. In the second stage, they will virtually wire up components & devices, including power and signal connection onto the 3D virtual relay circuit board to produce the correct output operations as dictated by the ladder diagram in the designing of 2D schematic diagram.

A courseware survey was conducted on 21 Nov 2012 with cohort size of 40 students who have taken the quizzes on the virtual relay circuit board. Table 1 tabulates the courseware survey results.

<table>
<thead>
<tr>
<th>Virtual Relay Circuit Board Courseware Survey Results</th>
<th>Percent Agreed</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A) Learning value</td>
<td></td>
</tr>
<tr>
<td>1. The activity helped me understand the topic</td>
<td>100%</td>
</tr>
<tr>
<td>2. The activity stretched my thinking</td>
<td>98.8%</td>
</tr>
<tr>
<td>3. The activity motivated my interest in the module</td>
<td>95.0%</td>
</tr>
<tr>
<td>4. The activity motivated me to learn</td>
<td>94.4%</td>
</tr>
<tr>
<td>(B) Visual Design</td>
<td></td>
</tr>
<tr>
<td>5. The navigation was user-friendly</td>
<td>88.8%</td>
</tr>
<tr>
<td>6. The visuals helped my learning</td>
<td>83.3%</td>
</tr>
<tr>
<td>7. The instructions on how to use the courseware are clear</td>
<td>94.4%</td>
</tr>
</tbody>
</table>

Table 1 : Courseware Survey Results

There were 2 key findings from the survey:

1. Students had developed greater understanding through the use of the virtual relay circuit board. Survey results showed that all the students agreed that the virtual relay circuit board help them to understand the electrical wiring and circuit design.

Some comments extracted from students who had displayed satisfaction with the wiring & testing of the virtual relay circuit board are as follow:

"This software helps me to understand how relays, timers and other components on the relay circuit board operate."

"This software helps me to understand the module better, eg : designing the circuit & connecting them together."

2. This virtual relay circuit board motivated the students and stretched their thinking. One of the key challenges in teaching engineering students is to motivation as the topics are often dry and technical. However, the use of virtual relay circuit board has increased students’ participation. Survey results indicated that 98.8% of students felt that the programme has stretched their thinking and 96.8% said that they were more motivated to learn.

This has also been supported by written comments such as the following:

"This program motivates me and makes me understand this module better."

"3D wirings with different colours have stretched my thinking further as it gives me a clearer and more effective perception of how the components are connected."

To triangulate the results of the first survey, another comparison was made on test results before and after their learning experience with the virtual relay circuit board. Table 2 tabulates students’ mean test marks before and after the implementation of the virtual relay circuit board courseware. A bar chart of students’ mean test marks is shown in Figure 8. The chart shows that students’ test marks have been increasing over time indicating improvement in performance after participating in the online quizzes on virtual relay circuit board.

<table>
<thead>
<tr>
<th>Relay Circuit Board Final Test Marks</th>
<th>Semester</th>
<th>Mean Test Score</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>April 2011</td>
<td>65.17</td>
<td>Without Virtual Relay Circuit Board courseware</td>
</tr>
<tr>
<td></td>
<td>October 2011</td>
<td>69.41</td>
<td></td>
</tr>
<tr>
<td></td>
<td>April 2012</td>
<td>76.85</td>
<td>Implemented Virtual Relay Circuit Board into module</td>
</tr>
<tr>
<td></td>
<td>October 2012</td>
<td>74.01</td>
<td></td>
</tr>
<tr>
<td></td>
<td>April 2013</td>
<td>77.15</td>
<td></td>
</tr>
<tr>
<td></td>
<td>October 2013</td>
<td>76.82</td>
<td></td>
</tr>
</tbody>
</table>

Table 2 : Students’ Mean Test Marks

Figure 8 : Bar Chart of students’ mean test marks
While it cannot be concluded that the improvements in the test result is directly due to the virtual circuit relay board, the increased practice opportunities, the increased in understanding and motivation to think arising from the use of the system may be said to contribute to higher assessment results.

Conclusions

As evident from students’ responses in the courseware survey and the students’ final test on the electrical wiring of the relay circuit board, it is apparent that the use of the virtual relay circuit board has indeed enhanced the student learning experience and outcomes of Electrical & Electronics Practical Skills module. Learning is found to be more fun and engaging as students can practice wiring of the virtual relay circuit board anywhere and anytime with the use of mobile computers. Wiring up the virtual relay circuit board is as simple as drag-and-dropping of wire connections to any of the components and devices followed by testing its operations by tapping the play button. Students are motivated to participate in on-line quizzes and practices through the virtual wiring in multiple-attempts as a way to evaluate and test their concept and understanding of the electrical wiring and circuit design. By clicking onto the Play-Back option in the 3D virtual wiring mode, students can learn how wires and devices are connected up step-by-step, including the configuration setting for the components and devices in order to produce the correct output operations. In conclusion, the virtual relay circuit board provides students with the opportunity to practice wiring of control relay circuit in a fully interactive and engaging virtual environment.

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References


