Hands-On Component-Level Automation Courses for Technology and Engineering Students

Gale R. Allen, Ph.D.
Department of Electrical and Computer Engineering and Technology
College of Science, Engineering and Technology
Minnesota State University, Mankato
Mankato, Minnesota 56001

Introduction
In spring 2006 work was started on creating a laboratory and courses for training students in component-level industrial automation at Minnesota State University, Mankato. In each of the past two years, senior students in four-year degree programs in Electronics Engineering Technology (EET) and Computer Engineering Technology (CET) have taken two semesters of training in automation. The students learned details of automation components including programmable logic controllers (PLC’s), motors, sensors, and operator control displays and they developed automation systems to demonstrate their understanding of the subjects.

The primary financial support for creating the laboratory was provided by the Minnesota Center for Excellence in Manufacturing & Engineering. The Center was established by a state initiative in 2005 and consists of seven institutions: Alexandria, Anoka, and Hennepin Technical colleges, Normandale Community College, Northeast Higher Education District, South Central College, and Minnesota State University Mankato which serves as the lead institution and headquarters for the center. In addition significant funding was provided by the College of Science, Engineering and Technology and by the Department of Electrical and Computer Engineering and Technology.

Industry provided strong support for creating the laboratory. The equipment from Rockwell Automation, National Instruments, Fluke, and PCB Piezotronics was provided through their education discount programs. The automation equipment provided by Rockwell Automation formed the foundation of the laboratory. Many employees of Rockwell Automation and their local distributor Werner Electric have helped to set up the laboratory and provide technical support during the past two years. The technical and financial support of all of these companies was very much appreciated as it has greatly benefited the students.

Course Description
The two semester sequence covers automation components and subsystems involving sensors, PLCs, actuators, encoders, stages, motors, and drives. Students design, simulate, build, test and document automation systems for capstone projects. The initial version of the courses and laboratory was described in a paper in late fall 2006. Since then, several different types of equipment have been added and the course syllabus and material has been improved. Several short projects have been added to the course and students have developed and completed over twelve capstone projects. Course material was drawn from Rockwell Automation training material, websites, equipment manuals, other publications, Jon Stenerson’s Fundamentals of
Programmable Logic Controllers, Sensors, and Communications, and Irving Gottlieb’s Electric Motors and Control Techniques.

The topics covered in the courses include the following:

<table>
<thead>
<tr>
<th>Control</th>
<th>Sensor</th>
</tr>
</thead>
<tbody>
<tr>
<td>ControlLogix</td>
<td>Vision, Photoelectric, Limit Switch</td>
</tr>
<tr>
<td>RSLogix 5000</td>
<td>LabVIEW</td>
</tr>
<tr>
<td>Documentation, Links and Resources</td>
<td>Basics I</td>
</tr>
<tr>
<td>Creating Projects &amp; Designs</td>
<td>Signal Conditioning</td>
</tr>
<tr>
<td>Controller Documentation</td>
<td>Feedback Control</td>
</tr>
<tr>
<td>RS-232 Connection, Instruction Tags</td>
<td>Accelerometer Spectra</td>
</tr>
<tr>
<td>IP Network, Ethernet Connection</td>
<td>Motion</td>
</tr>
<tr>
<td>Timers, Counters, Subroutines</td>
<td>Motion Axis, Drive, &amp; Servo Motor</td>
</tr>
<tr>
<td>Digital Input &amp; Output Modules</td>
<td>X-Y Stage Motion</td>
</tr>
<tr>
<td>Analog Input/Output Modules</td>
<td>AC, DC, Stepper Motors</td>
</tr>
<tr>
<td>Relay and Counter Modules</td>
<td>Issues Discussions</td>
</tr>
<tr>
<td>Cables and Connectors</td>
<td>Ethics</td>
</tr>
<tr>
<td>Input/Output</td>
<td>Communication</td>
</tr>
<tr>
<td>Switches, LEDs, Touch Panel</td>
<td>Economic</td>
</tr>
</tbody>
</table>

**Laboratory Equipment**

The eight stations in the laboratory each have the following equipment:
- Rockwell Automation 1756-L60M03SE 3-axes ControlLogix controllers
- SERCOS Kinetix 6000 Servo Drives, 2094-AC05-MP5
- Servo motors TL-A120P-BJ32-AA
- X-Y stage
- Analog, Digital, and AC Input/Output Modules
- EtherNet/IP, ControlNet, DeviceNet
- Relay, Counter, and Temperature Modules
- PanelVIEW touch panel
- Vision, photoelectric, and limit sensors
- Switch and LED I/O Panel
- NI signal conditioning units and digital acquisition PC cards (LabVIEW)
- Fluke portable oscilloscope & multi-meter
- Computer, power supplies, function generator

Other equipment in the laboratory includes the following:
- PCB Piezotronics accelerometers, torque sensor, sound meters, microphones, and hand shaker.
- AC motors, DC motors and AC drives.

Proceedings of the 2008 ASEE North Midwest Sectional Conference
Instruction Approach
Active learning and hands-on learning are the basis for instruction in the courses. Each course is taught as a combined lecture and laboratory. All of the classes are held in the laboratory. Each topic is introduced using the white board, computer slide projection, and automation equipment. Students use the lab equipment to work one or more exercises related to the topic and the instructor provides help as needed. Students work in two or three-person teams. For reference, the lecture material is available on the computers at each station.

This teaching format evolved quickly during the first semester when the course was started. A few lectures sessions held in a classroom during which topics from the text were covered. These were alternated with working in the laboratory. It soon became clear that students learned much more working with the hardware and software in the lab as compared to talking about it in the classroom. Soon all the class sessions were held in the lab and brief lectures were injected at appropriate times.

Many times the students are required to develop controller designs that involve several topics. Each of these projects usually involves more than one class period and additional work in the laboratory outside of scheduled class hours. At the mid-point of each semester students start to plan capstone projects that will bring together technology from all of topics covered during the semester and involve use of technical skills learned in other courses.

While working the capstone projects students experienced issues typical of culminating projects. These included unforeseen tasks, design errors, schedule skips, testing difficulties, teamwork problems, and overly ambitious goals. Early design ideas did not work as expected. Details of component and equipment operation were not fully understood. Poor vendor documentation on electronic components caused misunderstandings.

In course evaluations the students made several positive comments about the capstone projects. These included learning about teamwork, persistence, and technical skills. Several students said they learned the most in the course while working the capstone projects. A few examples of capstone projects are briefly described in the next section.

Capstone Projects
The capstone projects employed the hardware and software elements covered in the courses to simulate an example automation application. For example, the Car Wash shown in Figure 1 involved use of X-Y stage, photosensors, contact sensors, motors, and moving subassemblies. Students simulated washing a car with rotating elements fastened on a carriage that the horizontal stage moved along the length of the car. Small motors drove rotating spray wands that were moved by the wash arm down to the front and to the back of the car. Other motors drove rotating tire scrubbers. Photosensors signal the position of the carriage. The students designed and built all of the mechanical parts and the electronics.

The RSLogix controller design implemented the system design that controlled the overall process. The PLC-based program received information from switches and sensors via the Digital Input modules. It performed decision processes and provided signals to LEDs and motor...
drivers as part of the control process. The Controller involved many lines of ladder logic organized in subroutines.

The students developed the hardware and software phases, testing each section. As they learned from mistakes, gained new insights, and learned more in class they modified the overall system and detailed design.

![Diagram of Car Wash Capstone Project – Fall06](image)

The Elevator Capstone project shown in Figure also involved use of X-Y stage, photosensors, contact sensors, motors, and moving subassemblies. Students simulated an elevator that moved up and down to several levels. The horizontal stage opened and closed an elevator door. A photosensor and limit switch were used in the door assembly.
Two examples of capstone projects involved use of LabVIEW, vision sensor, and touch panel are shown in Figures 3 and 4.

**Figure 2. Elevator Capstone Project – Fall06**

**Figure 3. Towers of Hanoi Capstone Project – Spring08**
Conclusion
The topics being covered and laboratory equipment seem to be a good match for the two semesters of instruction time. Enough time is available to introduce all of the topics in several ways including a first pass, short assignments, small projects, and the capstone projects. The equipment is sufficient in quantity to support the number of students in the technology programs and is representative of state-of-the-art automation technology. A few small robot arms might be candidate for future equipment additions.

Changes in the courses will probably be made for several years. In the second year more time was spent on LabVIEW, a tool currently used by many companies. Several students used LabVIEW in their capstone projects. In the area of motors students are introduced to the general capabilities of AC, DC, servo, and stepper motors and methods of control. More technical material on motors and related exercises may be added in the future. This year the torque sensor and load that was developed earlier will be put to more use.

Several engineering students have asked that an automation course be offered in EE and CE programs. The faculty will consider this and perhaps a one-semester or summer course could be an elective offering.

The laboratory and courses seem to be moving in the right direction. The use of active learning and hands-on teaching seems to work well. Students seem to be very interested in learning the material. They show great determination to succeed in working their projects and they are
particularly enthused about the capstone projects. Adjustments are on-going. More exercises and projects will need to be added in almost all areas.

References


Biographical Information
Professor GALE R. ALLEN, Ph.D. held engineering and management positions in companies in the Minneapolis-St. Paul area for many years and in 2004 became a member of the faculty at MSU, Mankato. He is currently teaching and working to improve education in electronics, communications, and industrial automation. He is a Senior Member of IEEE and is active in amateur radio.  gale.allen@mnsu.edu