Laboratory for Introductory Level Manufacturing Automation Course

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Abstract

This paper describes an innovative approach for conducting laboratory projects in the manufacturing automation area at the freshman/sophomore level. The students are given an operational automated system, and assigned the task of improving it in some sense. They are guided through the following steps: generate ideas for improving the existing system, prepare a proposal for approval by the instructor explaining the improvements, plan and execute the approved modifications, and prepare technical documentation. Students work in teams of three to four students. Each team is free to organize their activities, and there is no fixed time allocated for this laboratory. The projects are built using Fischer-Technik® components, sensors and actuators. They are physical simulations of various manufacturing processes, and are controlled using a personal computer. The projects are carried over from year to year. At the beginning of a semester, each team receives all the documentation generated the previous semester. The students understand that the documentation they generate will be useful for other students in the future, therefore they are motivated to produce clear and complete documentation. Developing these projects requires a variety of activities. Several of these activities can be accomplished simultaneously if there is good coordination and communication between team members. This leads to discussions about the use of tools for project planning and control, concurrent engineering, and communication. Results from this laboratory are encouraging. The level of motivation in students is very high, and most of them complete the course with a very good understanding of concepts discussed in class.

Introduction

Freshman and Sophomore level courses with laboratories usually contain demonstrations or a set of exercises with a fixed time, defined objectives, and predictable results. Although this is practical and effective in many areas of science and engineering, the tradeoff is a limitation in promoting the creative ability of students. Encouraging creativity to identify opportunities for improvement and to find solutions to problems is important in manufacturing automation because the rapid changes in new technology can make new solutions possible and feasible.

Traditionally, open-ended problems and design projects are gradually introduced in the curriculum, with larger concentration in the senior year [6][7] Although there are some recent reports of freshman engineering design courses [2][4], it is not very common. Most frequently, engineering students at the freshman level are trained in solving problems that are clearly defined, all the data required is readily available, and the problem has a unique solution. From the experience in conducting this laboratory, freshman students respond well when faced with the challenge of identifying problems and finding good solutions to design problems.

- Being able to document design projects and communicate results is an important skill for practicing engineers. There are reports in the literature [5][9] that discuss methods to improve teaching these skills to undergraduate engineering students. Audeen Fentiman [5] indicates that students do not learn much by writing final reports poorly and receiving feedback in the form of instructor comments and a grade. Students can benefit the most by doing it properly. From the experience in conducting this laboratory, students motivation to document their projects properly increases when they understand that their reports will be used by other students in the future.

This paper describes a new approach for conducting laboratory projects of an introductory level manufacturing automation course for industrial engineering students. This course and its laboratory have evolved over the last five years, and it is very likely that it will continue to change in the future. In its current format, this laboratory incorporates various aspects of engineering practice into a learning experience. The innovation in this laboratory consists of giving the students a simple operational automated system, and asking them to find ways to improve it, then after instructor approval, the students implement the planned improvements and document their work. This environment can be very effective in developing engineering skills such as problem identification, problem solving, engineering design, teamwork, project planning and control, communication, documentation, and oral presentations.

Basic Course Structure

This laboratory is part of a course oriented to freshman and sophomore level students. The course objective is to introduce students to the fundamentals of computer controlled processes and mechanisms. The only prerequisite is a previous course in computer programming in which the students learn C-language. The book "Robots and Manufacturing Automation" by Ray Asfahl [1] is utilized as the text, and is supplemented with handouts.

The lecture portion of the course includes first a discussion of various types of automated production systems. It is followed by a description of various types of sensors and actuators, control concepts and analytical tools to design switching and continuous type of controllers. Finally, there is a review of some current applications such as numerical control, industrial robots and computer vision. The course has three exams including the final. The grading criteria for the course gives a weight of 20°/0 for each of the three exams, 30°/0 for the laboratory project, and 10°/0 for all of the homework assignments.

The class size has been fairly stable between 25 to 30 students during the last few years. The students are divided into eight teams in order to develop their laboratory projects. The size of each team is three to four students, and each team works in a different project. The instructor makes the assignment of students to groups. The assignment method is similar to one of the method discussed by Brickell et al [3] (method 1), which they reported yields good results. Comparison of average GPA between various groups is fairly homogeneous, which means that all groups have homogeneous capabilities. Each team is free to organize their activities, and there is no fixed time allocated for this laboratory. The students can work at any time or day throughout the semester.

The laboratory portion of this course also includes a set of demonstrations. The demonstrations are used to illustrate the programming, operation, capabilities and limitations of industrial grade equipment such as robots, computer vision, programmable logic controllers, and numerically controlled milling machine.

Objectives of the Laboratory Project

The main objective of the laboratory project is to reinforce the automation concepts discussed in class with practical experience. The changes in a student's level of understanding and confidence in using the technology is dramatic after only a few hours of work in the laboratory. In addition, the laboratory project offers an excellent environment to develop and practice skill such as: teamwork, problem identification skills, problem solving skills and engineering design, introduction to concepts and tools for project planning and control, and communication skills including written reports and oral presentations[9].

Laboratory Environment

The projects are built using Fischer-Technik® components. These components include a variety of building blocks, sensors such as mechanical switches and photo-resistors, and actuators such as electric motors, magnets, and lights. AH of these devices are powered using 6 volt power supplies or batteries, which is safe. It is very easy to build or modify mechanisms with Fischer-Technik® components. This is a good feature because students can go through several design iterations in a short period of time. The solution to real engineering problems is often iterative, and undergraduate students usually have few opportunities to experience refining a design.

Metrabyte boards are used to interface digital and analog signals between the projects and IBM compatible personal computers. The system used in this laboratory has the capability of 16 digital inputs, 16 digital outputs, 16 analog inputs, and 16 counters. The interface boards have been mounted in a rack and fitted with modular electrical connectors to allow for a quick changeover between projects. The computer programs are written using C-language. The control software is designed and written in a modular way, which makes it easier to understand and modify. The control software is structured to loop continuously through the following four steps: operator interface, input sensor signals, make control decisions, and output signals to actuators.

Every project is capable of handling two types of product. The product is physically simulated by using wood blocks in two sizes. The smaller blocks are 2 x 3 x 2 cm. and are painted yellow. The larger blocks are 2 x 3 x 4 cm. and are painted red. Every project has to meet the following two rules with respect to the way these two block sizes are handled. First, the arrival of blocks to the automated system can be at random, therefore the system has to identify the blocks as they arrive. Second, processing in the automated system has to be clearly different for both block sizes.

Methodology

The projects are physical simulations of various manufacturing processes, such as: automated storage, cutting, stamping, welding, parallel machines, transfer line, painting, and palletizing. No real cutting or welding takes place. These processes are simulated by turning on small motors or lights. The projects are carried over from year to year. Therefore over the years the projects are improved and augmented. At the beginning of a semester the students receive all the documentation generated by the previous semester regarding their particular project. The documentation includes: technical reports, software, video tape of final presentations, user's manual, and the physical project in operating condition. The students understand that the documentation they generate will be useful for other students in the future, therefore they perceive the need for clear documentation.

Developing these projects requires a variety of activities, such as design and construction of mechanisms, electrical wiring, design and development of control software, debugging and testing, writing reports and documentation. Several of these activities can be accomplished simultaneously if they are properly coordinated between team members. This helps to introduce the use of Gantt charts for project planning and control[8]. Students are provided with sample Gantt charts for the complete project. This sample charts are divided in two stages: project planning, and project execution (see Figure 1 and Figure 2).

ID	Name	Duratio	Predecesso
1	Project Planning & Proposal	19d	
2	Learn about the existing system	5d	
3	Video tape	1d	
4	Run existing system	2d	3
5	Review reports	2d	4
6	Find opportunities to improve existing syst	4d	5
7	Select and prioritize improvements	2d	6
8	Draw diagram of the improved system	1d	7
9	Write description of improved system	1d	8
10	Write description of automated operation	1d	9
11	Calculate expected performance improvem	2d	10
12	Prepare proposal report	3d	11
13	Submit Proposal Report	0d	12
14	Grade reports (by faculty)	3d	13
15	Correct proposal	4d	14

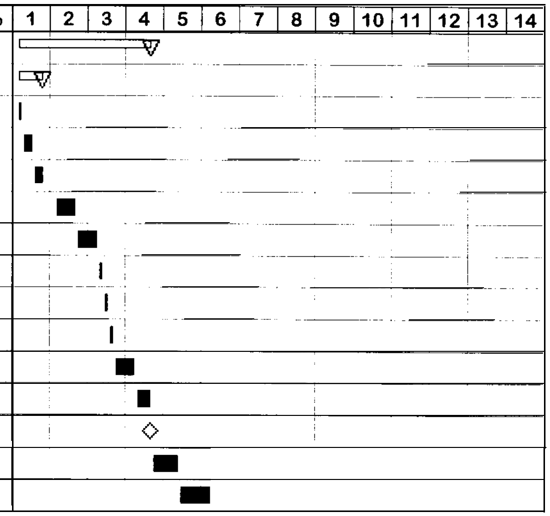

Figure 1. Gantt Chart for Project Planning and Proposal

ID	Name	Duratio	Predecesso
1	Project Development	37d	
2	Mechanical modifications (construction)	14d	
3	Table of input and outputs	3d	
4	Draw wiring diagram	3d	[redacted]
5	Electrical modifications (wiring)	4d	4,2
6	Test electrical connections & operation of se	3d	5
7	Draw state-transition diagram	8d	
8	Software modifications	8d	7
9	Test & debug software (by modules)	4d	8,6
10	Test & debug software (integrated)	5d	9
11	Write final report and user's manual	5d	10
12	Prepare final presentation	2d	11
13	Submit Final report	0d	12
14	Grade final report (by faculty)	2d	13
15	Corrections to final report	5d	14
16	Submit complete documentation	0d	15

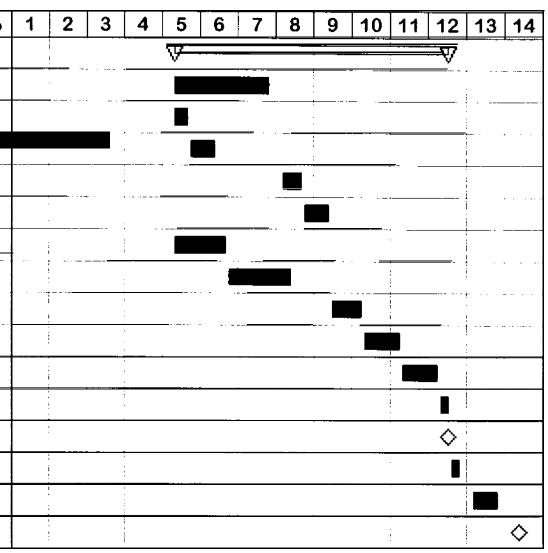

Figure 2. Gantt Chart for Project Development

These sample Gantt charts are spread over a 14 week period, which is enough time for conducting it in a regular semester.

Evaluation

Projects are assigned a grade based on the following aspects: quality of the project plan, technical content of the improvements to the project, creativity in applying concepts or finding solutions, timeliness or ability to follow the project plan schedule, proper operation of the project as set in the project plan, quality of the technical documentation, and oral presentation.

When students work in groups, it is fairly common to find disparities in the amount of work done by individual team members[6]. This topic is discussed in class, and students understand that the grade they receive for the laboratory portion of the course is affected by individual participation. All members of a team do not necessarily receive the same grade in the project. In order to asses the amount of work done by individual members of a team, students are asked to fill a project evaluation form at the end of the semester. In this form students are asked to: evaluate the contribution of every member of their team, including themselves, and rank all the projects.

Results and Conclusions

Results from conducting this laboratory are very encouraging. The level of motivation in students is very high, and most students complete the course with a very good understanding of concepts discussed in class. In addition, the students benefit from practicing various engineering skills such as:

1) Teamwork. Students are assigned to groups for the duration of the project. They are expected to organize their teams and assign responsibilities on their own. They are encouraged to collaborate with other teams in the execution of their projects.

2) Problem identification skills. At the beginning of the project, students are asked to brainstorm and find opportunities to improve the existing system. Most sophomore students are perfectly capable of doing this, but some suffer a kind of mental block because they are used to receive clear and complete problem statements in exams and homework.

3) Problem solving skills and engineering design. There are usually many possibilities to implement the planned improvements. The various alternatives usually have advantages and disadvantages, as well as tradeoffs between simplicity and reliability. Sometimes the selected approach does not work as expected and often engineers find that they need to “go back to the drawing board” to find better solutions. The use of Fischer-Technik® components makes it easy to change the design and try a different approach in a short time.

4) The laboratory project provides an opportunity to introduce concepts on project planning and control. Several of the activities required to complete the project can be accomplished simultaneously, if there is proper coordination and communication between team members.

5) Students are required to think about design specifications and performance evaluation. Each team has to include in the proposal a description of the increases in performance they expect to achieve by implementing

the planned improvements to the existing system. At the end of the project they are required to measure and report the changes in performance achieved.

6) The project is also used to develop communication, documentation and oral presentation skills. Students understand that the documentation they generate will be used by other students in the future, therefore they perceive the need for preparing clear documentation. Each team makes a 15 min. oral presentation of their project at the end of the semester. All presentations are video taped and copies are made available to students that request them.

References

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