Session 2563 - 968

THE PORTABLE MANUFACTURING SYSTEM PROJECT

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1. Abstract

The Portable Manufacturing System Project (PMSP) is part of the outreach of the NSF Engineering Research Center for Reconfigurable Manufacturing Systems (ERC/RMS) at the University of Michigan, and is designed to attract new students to the field of manufacturing.

The goals of the program are to expose middle and high school students to manufacturing engineering through a hands-on engineering activity, to provide the opportunity to interact with engineering students, and to motivate the students to consider engineering and technology-related careers.

The PMSP cell is composed of a CNC milling machine, a robot, and a personal computer (PC) that controls the entire system. To facilitate simultaneous access of multiple student users, six additional PCs are included in the cell. The PMSP cell and all necessary equipment are setup at all of the participating schools.

In this two week long program, students from University of Michigan, introduce basic concepts of manufacturing, computer aided design (CAD), computer aided manufacturing (CAM), and simple computer programming to middle and high school students by using a series of modules. Building upon these skills, the students learn how to use a robot and a milling machine. The program enables students to start a project involving a simple product from the concept and design phase, and take it through the manufacturing stage. Throughout the program, the students work in groups of two, and this helps them to develop their problem solving and teamwork skills.

The Portable Manufacturing System Project was initiated in September 2001. Upon it's implementation in February 2002, the PMSP has worked directly with all of the six middle schools and one of the three high schools in the Ann Arbor Public School District. This program has introduced manufacturing engineering to over 950 students and is planning to impact 500 students in the Ann Arbor school district annually.

2. Introduction and Motivation

Education at every stage of a person's life is very important for the person's development and prepares him/her for the future. Students between the 6th and 8th grades tend to gain awareness of how things work around them and what careers they want in the future. In order to motivate students to consider engineering careers, a program that will provide them with the necessary information through classroom presentations and hands-on activities, internet-based tutorials, and games, has been developed.

Engineering is one of the many options available to students for their future career. However, the career selection is influenced by external factors, one of which is the education they get in school. There is concern that the number of students considering engineering as a future career is decreasing not only in the US but also over the globe. This decrease could be due to misinformation in the schools or the lack of information about engineering. To help change this trend, and also as part of the outreach of the National Science Foundation (NSF) Engineering Research Center for Reconfigurable Manufacturing Systems (ERC/RMS), the ERC has nurtured growth in three areas of outreach, which are (1) College-level, (2) Grades K-12, and (3) the Community.

This manufacturing engineering program focuses on outreach to K-12. The goal of the program is to expose both middle and high school students to engineering at an early age, and thereby contribute to new dimensions in teaching the engineering workforce. This is achieved through presentations on manufacturing systems and concepts, computer aided design, and computer aided manufacturing, as well as video presentations on different manufacturing processes. The program also involves hands-on activities such as creating a design using a CAD software package, and engraving that design by controlling the milling machine. These activities offer practical experience that make the students get excited. Furthermore, these activities broaden the students' knowledge and vision on manufacturing engineering and especially on reconfigurable manufacturing.

The internet is making a strong presence in every aspect of human life and is no longer used for the sole purpose of research and games. Now, the internet is also being used as a teaching tool where a variety of information is within the reach of a mouse click. Utilizing the advancements in technology, the PMSP is currently developing internet-based interactive tutorials that will play an important role in classroom as well as after school activities. In addition, being an excellent resource for learning about manufacturing engineering, the internet based tutorials will engage students with their animation and interactive capabilities. They are also essential for distance learning opportunities. They will enable anyone to learn and practice manufacturing concepts without necessarily having access to expensive equipment.

Furthermore, in order to maintain the effectiveness of reaching out and attracting students to engineering, new methods of teaching have evolved. Games such as jeopardy and magic square have been designed as part the program, which together with the interactive tutorials not only expand the variety of resources that are available to the students, but also create an exciting environment that introduce engineering as a fun and interesting subject.

3. Methodology (Classroom Setup, Lesson Plan)

The PMSP cell is composed of a CNC milling machine, a robot, and a personal computer (PC) that controls the entire system. To facilitate the simultaneous access of multiple student users, six additional PC's are also used. The PMSP uses four different software packages, which are AutoCAD, SpectraCAM Milling, WSLM and SCORBASE for the ER 4u robot, throughout the program.

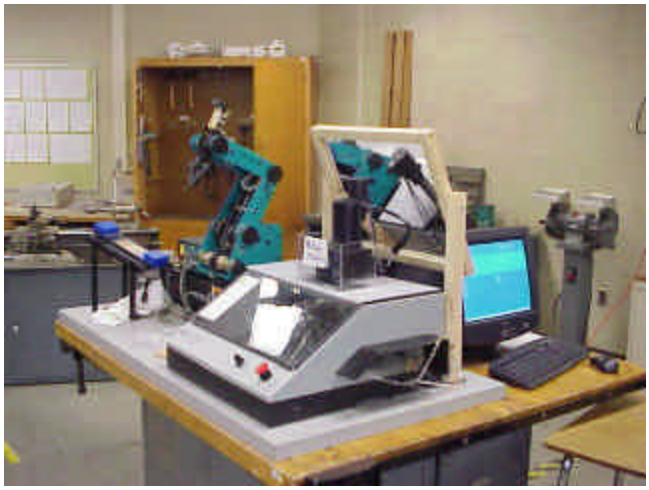

Figure 1:The CNC milling machine and the robot used in Portable Manufacturing System Project

First, students are given tutorials on computer aided design (CAD) where they learn how to use the AutoCAD 2002 software. Once students have an understanding of the AutoCAD software they are given the opportunity to create their own design using graph paper. The design that was created on the graph paper is then re-created by the student on the computer using the AutoCAD software. After the completion of the first stage, the students are introduced to computer aided manufacturing (CAM), which also includes the special software called SpectraCAM Milling. The students are thus able to define the machining operations and develop the machine code needed to run the process by using the SpectraCAM milling software. The third stage involves learning how to modify the machine code, so the students are taught simple NC programming. Building upon these skills, the students are provided with the necessary information about the milling machine and the robotic arm and learn how to control these systems. The students use the WSLM software to control the milling system, and the SCORBASE software to control the robot system. They are allowed to keep the parts that they make as a souvenir.

The program is composed of six different modules, which are as follows:

1. Introduction to Manufacturing
2. Introduction to the Portable Manufacturing Systems Project Cell
3. Computer Aided Design (CAD)
4. Computer Aided Manufacturing (CAM)
5. Introduction to NC (Numerical Control) Coding, Milling Machine and Robotic Arm
6. Machining the Final Product

Each of these is briefly elaborated on in the following paragraphs.

3.1. Introduction to Manufacturing:

This module aims to introduce the basic concepts of manufacturing to the students by a presentation that is supported by a video and a hands-on activity. The topics involved in the presentation are as follows:

- What an engineer is and types of engineering positions
- What manufacturing is and products manufactured
- What a manufacturing system is and how a manufacturing process works
- Description of three manufacturing systems (dedicated, flexible and reconfigurable)
- An overview of the Portable Manufacturing System Project

At the end of the presentation, a video provided by the LEGO Company is shown. The video presents how LEGO toys are produced, starting with the acceptance of the raw materials to the factory through assembly and packaging. It enables the students to visualize a complete manufacturing process. The last piece of the module is the balloon car design activity. The students are put in groups of four and asked to design and build a car that is activated by air using cardboard. Both the video and the hands-on activity solidify the concepts that the students learned in the presentation.

3.2. Introduction to the Portable Manufacturing System Project Cell:

This part of the program introduces the Portable Manufacturing System Project Cell to the students. At this stage, students have the opportunity to learn more about the components of the system, which are the CNC milling machine and the robot. In addition, basic safety requirements such as the importance of wearing safety glasses, how to stop the system in an emergency, acceptable standing distance from the equipment, etc. are discussed.

3.3. Computer Aided Design (CAD):

Computer aided design is involved in the initial stages of part production. The students are first asked to come up with a design that would fit into a 2"x3" rectangular space because during the manufacturing stage of the program, each student will be provided with a 2"x3" acrylic block on which they will machine their design. The students are given markers and graph papers to create their designs. On completion, the students are given a presentation that involves the following topics:

- What design is
- The design options (drafting, computer aided design)
- The drawing types (two and three dimensional)
- Different CAD software packages
- How to use the AutoCAD 2002 software (how to open and save a file, and basic drawing and modification commands students will need while drawing their designs on the computer)

Since the CAM software (SpectraCAM Milling) used in this program is only compatible with certain drawing commands, specifically the line, arc and circle, the students are asked to use only those three drawing commands. At the end of the presentation, the students are given handouts related to the AutoCAD software to assist them with their drawing.

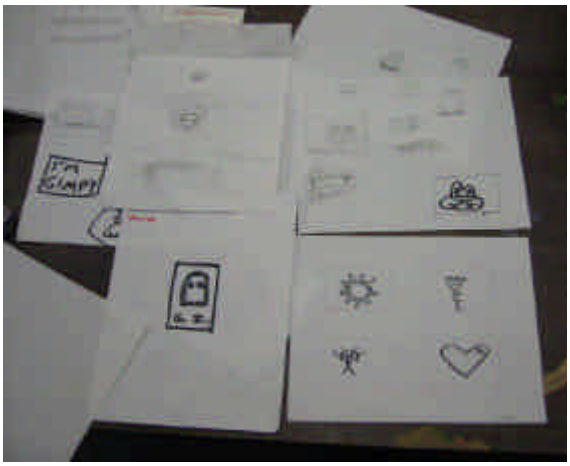

Figure 2: Some design ideas students created

A template called “aaps.dwt” has been prepared for the students to facilitate the drawing process and also in visualizing the actual machining process. The template consists of a 2"x3" rectangle, which represents the surface area of the acrylic block that will be machined. The other important feature of this template is the pre-set line thickness. Since the cutting tool used in the machining operation is ⅛ inch in dia., the thickness of the lines in the template are arranged such that the drawing created with this template will give the students an idea of the actual machining process. This second feature is also provided to avoid unexpected overlapping during machining.

In addition to the template, a library composed of lower case and upper case letters, as well as the digits from 0 to 9, has been prepared to assist students who might have difficulty in drawing their initials and to facilitate expansion of the program to primary schools.

3.4. Computer Aided Manufacturing (CAM):

The fourth module of the lesson plan involves computer aided manufacturing. The topics presented to the students are as follow:

- What CAM is and the role of CAM in the PMSP program
- Introduction of different machines used in the industry (e.g. lathe, mill)
- How to use SpectraCAM Milling software (how to open a design, different types of machining operations available in the software, how and where to perform them, and how to save the NC code)

Students are also given handouts related to the SpectraCAM Milling software to assist them with their project.

SpectraCAM Milling software requires the user to define certain features such as the type and the size of material, the cutting tool, the cutting speeds, the depth of cut, the step sizes, etc. In order to eliminate the complexity involved in the software, a template called “base.scm” has been prepared. In this template, the material being cut, which is Acrylic material; the size of the material, which is 2"x3"x0.5"; the cutting tool, which is ⅛ inch in dia. end mill; and all the other necessary features are set.

Figure 3: Students at Scarlett Middle School are working on SpectraCAM software

3.5. Introduction to NC Coding, the Milling Machine & the Robotic Arm:

At this stage, the students learn how to operate the milling machine, and the robotic arm. They are also exposed to the basics of NC coding. With this information, they modify the NC codes they created, to enable the robot position the block at a specific location that is suitable for the milling process.

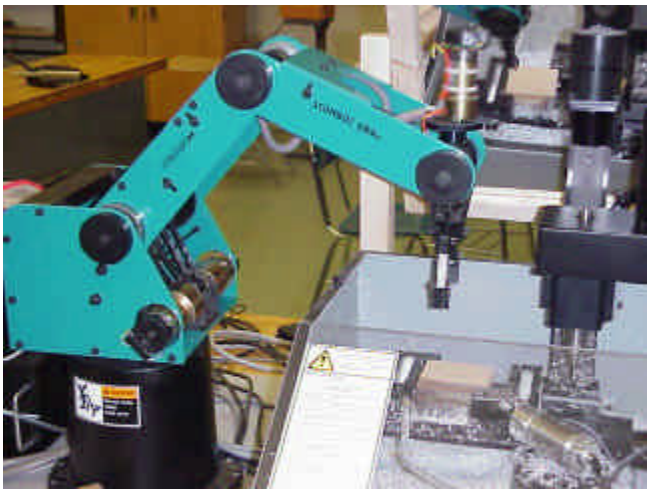

Figure 4: The block is placed into the workplace and the robotic arm is returning to its home position

3.6. Machining the Final Product:

This is the final stage of the program where the students engrave their design onto the acrylic block in the milling machine. Figure 5 shows some of the designs that are machined.

4. Accomplishments and Results

The Portable Manufacturing System Project is a two week program that targets students in 7th grade and higher. Students work in groups of two throughout the program, and this helps them to develop their problem solving as well as teamwork skills. During the past two academic years,

2002-2003, the Portable Manufacturing System Project has been implemented as part of the Technical Education class in seven schools in the Ann Arbor District, six of which are middle schools. Over 950 students are exposed to the program and 820 of those are middle school students. In the Ann Arbor School District, the PMSP is planning to serve over 500 students annually.

Figure 5: Some of the student designs that are machined

The schools that have been involved in the program so far are provided below in the order of visit:

1. Tappan Middle School
2. Forsythe Middle School
3. Ann Arbor Open House (Mack Middle School)
4. Scarlett Middle School
5. Slauson Middle School
6. Clague Middle School
7. Roberto Clemente High School

The ethnic and gender distribution of the students participated to the program is as follows:

Ethnic Code Key	M	F	Total
Caucasian	44.1%	15.7%	59.8%
African American	15.5%	7.1%	22.6%
Latino or Hispanic	2.9%	0.8%	3.8%
Asian	5.3%	2.4%	7.7%
Other	4.5%	1.6%	6.1%
Total	72.4%	27.6%	100%

On a scale of 1 to 10, 78% of the students involved in the program rated the program as 8 or above.

The results on the pre and post evaluations show that there has been over 20% increase in the number of students who would consider engineering as a future career.

A web page is currently being developed to create an environment for distance learning. It can be accessed at the following URL: http://eclipse.engin.umich.edu/pmsp

5. Conclusions

The biggest challenge faced so far is finding undergraduate students who have class schedules that are flexible enough to participate as instructors. Since the program involves actual visits to the schools, the students should be able to go to the schools whenever they are needed. To overcome this difficulty, it is essential that the teachers become actively involved. The ERC/RMS is planning to train the teachers and provide them the necessary materials and tools so that they can perform the program by themselves.

The goal of the ERC/RMS is to expand the PMSP program to a greater number of schools and expand it to a global endeavor. Therefore, as the first step, ERC/RMS has initiated plans to incorporate web-based tutorials. This will facilitate the use of distance learning tools, making the program globally accessible. The tutorials are interactive, and some of the lessons and quizzes are structured as games to make them more attractive to the younger age group. As the second step and because of the safety concerns, the PMSP program is executing the milling operation online. The students have control and can operate the CNC milling machine, which is kept in ERC/RMS lab, from their school through the web.

Furthermore, ERC/RMS is planning to test the distance-learning component of the program first with a high school in Ghana.

6. Acknowledgements

"This work was supported by the Engineering Research Center for Reconfigurable Manufacturing Systems of the National Science Foundation under Award Number EEC-9529125."

7. Biography

NAZMI CEM DINCER, Visiting Research Investigator at the NSF Engineering Research Center for Reconfigurable Manufacturing Systems at University of Michigan. He received his dual M.S.E. in Mechanical Engineering, and Industrial Operations Engineering from the University of Michigan. His research interests include design, manufacturing and application of these to engineering education.

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