A Laboratory for Interactive Design/Manufacturing Projects

Involving University and 9-12 Students

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1. Introduction

It is common for products to be designed at one location and manufactured at another location(s). Hence, systems to ensure efficient communications between the design and the manufacturing facilities are required. In order to allow students to study the problems associated with this issue, a linkage between the engineering and manufacturing facilities of Oakland University's School of Engineering and Computer Science and the engineering technology facilities of Seaholm High School in Birmingham, MI was proposed. The facilities linking these sites are called the *Remote Design/Manufacturing Laboratories*.

The Remote Design/Manufacturing Laboratories serve as the conduit in which Oakland University engineering students conduct interactive projects with Seaholm High School engineering technology and mathematics students. These interactive projects only involved the design and implementation of automated manufacturing systems during the pilot development phase of the laboratories. In these pilot projects, the Oakland University students were responsible for the engineering design and development of automated manufacturing systems as well as for project management. The Seaholm High School students were responsible for technical design issues as well as constructing the automated manufacturing systems in Seaholm's technology facilities.

The purpose of the Remote Design/Manufacturing Laboratories is to allow the university and high school students to readily interact with one another while conducting a project. These interactions are conducted by e-mail, video conferencing as well as using the internet (via Sun workstation computers with video, audio and document sharing capabilities). In addition to the Remote Design/Manufacturing Laboratories, the Oakland University students use the facilities of Oakland's S. and R. Sharf Computer-Integrated Manufacturing (CIM) Laboratory and its Artificial Intelligence and Manufacturing (AIM) Laboratory to complete the their engineering design/analysis activities while the Seaholm High School students use their technology facilities.

These interactive projects emphasize two key factors that differ from most team-based projects conducted in university engineering or high school technology programs. The first difference is that the individual teams contain members with varying levels of education and experience. In traditional university or high school team-based projects, all team members have roughly the same education and experience. For example, all team members are senior mechanical engineering students. This does not reflect the reality of the "real-world" where an engineer or technician has specified responsibilities for a project and must interact with other people on the project whose job responsibilities, education and experience differ from their own.

In traditional university design projects, an individual team is usually responsible for all aspects concerning the design and implementation of the product or system. However, each Remote Design/Manufacturing project team is responsible for only a portion of the assigned project, for example, mechanical system design or control system design. Hence, the successful completion of the assigned Remote Design/Manufacturing Program project requires cooperation among the various teams.

Note that the Remote Design/Manufacturing Program's projects place a heavy emphasis on improving communication skills across interdisciplinary/multi-educational level teams. These projects allow students to apply the engineering science or technology skills they have be studying. Students learn that "real-world" engineering and technology problems are not always readily defined and that their solutions will not be understood by others if their communication skills are inadequate.

The second major difference between the interactive Remote Design/Manufacturing Program projects and traditional university engineering, or high school technology, team-based projects is that team members are located at different facilities. In this case, Oakland University and Seaholm High School (the distance between the two facilities is approximately fifteen miles). Hence, intra- and inter-team communications is conducted via various media such as e-mail, video conferencing and the internet (using computers with interactive video, audio and document sharing capabilities).

These interactive projects provide high school students with a first-hand opportunity to observe and understand the differences between a career in technology and one in engineering. They encourage the participating high school students to advance their studies in college.

Interactive projects to be conducted during the 1999-2000 academic year between Oakland University and Seaholm High School classes will be in the following areas:

- Automated Manufacturing Systems
- Applied Mathematics
- Computer-Aided Design (CAD)

Note that such interactive projects in automated manufacturing systems and in applied mathematics were conducted during the 1998-99 academic year between Oakland University and Seaholm High School while the first interactive CAD project will be conducted during 1999-2000. In addition, preparations for the inclusion of classes from two additional high schools in selected automated manufacturing systems and applied mathematics projects are underway.

2. Remote Design/Manufacturing Laboratory Facilities

As stated earlier, the purpose of the Remote Design/Manufacturing Laboratories is to allow university and high school students to readily interact with one another while conducting a project. Collaboration requires close interaction. Ideally, a small number of participants meet together and work on materials such as a budget, a diagram or a technical specification. During such working meetings, participants usually make various modifications to these materials. In addition, participants talk and sense subtle cues such as intonations and body language while decisions are made as a group.

In real life, meetings as described above often do not happen. Participants might be separated geographically or have conflicting commitments. In our case, Oakland University and Seaholm High School are fifteen miles apart. Students at both institutions have other class commitments which leaves little time for travel between the institutions. While several media have been used to support collaboration at a distance (telephone, fax, e-mail, video conferences), none supports collaboration as well as a face-to-face meeting. Telephone calls allow parties to speak with each other, but interactions over a document with all parties free to mark in changes are not possible. Fax allows textual and graphical material to be distributed, but does not support collaborative changes in real time. E-mail has rapid delivery, but no concept of simultaneity since the receiver reads the e-mail when convenient. Video conferences come close but still have disadvantages. Video conferences are expensive and require the use of specially equipped rooms which must be scheduled around other commitments.

In order to better support collaborative work between small groups, two similarly configured Sun workstations are located in the Remote Design/Manufacturing Laboratories at Oakland University and Seaholm High School. These systems support collaborative engineering software initially developed at Lawrence Berkeley National Laboratory[1] and refined at the University of California - Berkeley[2] and the University College London[3]. The Seaholm workstation also provides an Apache web server and Samba file server to serve project documentation in the form of web pages and serve files to PC Window systems, respectively. The collaborative software programs are described below.

The session directory server (SDR) is the "TV guide" of the collaborative software. A session is created through an Xwindows form. Information required are: the date and times of the session; the duration of the session; the media which will be used during the session; and whether the session is periodic (meets weekly, for example) or a one time session; and a description of the session. SDR assigns network multicast addresses to the session and periodically broadcasts information about the session to all computers running SDR. All SDR windows will list the session. A session is joined by selecting the session from the list of sessions in the SDR window.

The video conference tool (VIC) broadcasts color video signals to all session participants. The type of encoding, picture quality, and data rate can be adjusted to conform to network loading restrictions. When VIC is run, an Xwindow appears which contains a thumbnail video from each broadcasting participant in the meeting. One or more thumbnails may be selected for display in a larger format. Any camera which generates standard NTSC video signaling may be used with VIC. The typical camera has a wide angle lens with a focus range from a few inches to several feet. Typical scenes are the speaker, printed material, or small apparatus. Standard video cameras can also be used.

The audio conferencing tool (VAT) broadcasts audio streams to all session participants. The typical audio source is a small microphone such as a lapel mike. Participants generally take turns speaking under control of automatic or manual session control. A participant indicates a desire to speak by pressing a mouse button.

The whiteboard (WB) tool supports written media such as text, slides and figures. Author capabilities may be assigned to a single individual, as in a lecture or seminar presentation, or shared among all participants in a collaborative session. Material may be entered as an ascii text file or postscript file. Material may also be entered in real time using capabilities similar to drawing programs such as Microsoft PowerPoint. Participants can collaborate over a drawing. Each participant might use a different drawing color to type, write, or sketch information as well as changes on top of a drawing. Each participant will see the original drawing as well as each participant's collaboration.

Thus, these four tools together provide comprehensive session announcement, video, audio, and whiteboard capabilities.

3. Automated Manufacturing Systems Projects

The Remote Design/Manufacturing Program began in 1996-97 with an automated manufacturing systems pilot project between Oakland University's SYS 484 Flexible Manufacturing Systems class (a senior level undergraduate course) and Seaholm High School's Automation and Robotics class (an 11-12 level course).

The primary goal of the pilot was to develop interactive, technology intensive projects that placed a heavy emphasis on improving both the university and the high school students' communications and team-working skills. Several studies showed these are the most underdeveloped skills in new graduates from engineering and technology programs[4-6]. In addition, these projects allowed the students to apply the engineering/technology skills they were learning to a realistic and interesting project.

These projects involve the design and construction of an automated manufacturing system. Oakland University engineering students were responsible for the engineering design and analysis of the automated manufacturing system as well as project management. Seaholm High School technology students were responsible for technical design issues as well as constructing the manufacturing system using their technology facilities.

Student developed websites presenting the results of the automated manufacturing system projects that have been completed to date can be viewed at the following URL:

- *http://www.secs.oakland.edu/SECS_courseware/sys484_courseware*.

The automated manufacturing systems project for 1998-99 involved the interaction of engineering students from the SYS 484 Flexible Manufacturing Systems class with Seaholm High School engineering technology students from three different classes. The following three systems were constructed.

- A transportation system including a conveyor and manipulator for integrating two assembly machines.

- A prototype for an amusement park ride.

- An automated cookie making machine.

The SYS 484 class was divided into the three teams due to its small size (12 students). Each of the Seaholm High School students were also assigned to one of these teams based on their project responsibilities. Some of the responsibilities for each of these three teams were as follows.

Systems & Controls: Define and analyze the control systems for each of the three systems. Determine specifications for the Programmable Logic Controllers (PLC) and design PLC programs for cookie making machine and transportation system. Analyze dynamics of amusement ride and design control system. Analyze sensor requirements and produce sensor specifications for all three systems. Analyze the performance of the systems and provide feedback concerning refining the design in order to improve performance.

Mechanical & Materials: Perform force analysis for each of the three systems . Analyze how these forces can be applied optimally (e.g., pneumatic, hydraulic, etc.) and develop specifications for these components. Perform fatigue analysis on the "tube" in the amusement ride and recommend material(s) for the "tube".

Management: Produce a formal project timeline, arrange all video conferencing sessions, arrange visit of Seaholm teams to O.U., create and maintain a web site describing the project, and coordinate the integration of all the Oakland University teams' final reports into a single project final report. Determine the capital cost of each system. Determine the cost of the engineering and technology labor used to design, analyze and construct the each system. Handle all requests concerning pricing of components and labor from the various teams.

Note that each team was required to produce final report describing its activities and results. In addition, each team member maintained a log of their activities (e.g., correspondence with other teams or outside companies, minutes of meetings and working sessions, outlines of ideas considered during the design and analysis of the systems, etc.) that was submitted with the team's final report. The Oakland University members of each team also made a final video conferencing presentation of their results to the Seaholm classes.

4. Applied Mathematics Projects

Engineering and technology fundamentally involve the application of mathematics. One of the major goals of the Remote Design/Manufacturing Program's applied mathematics projects is to increase the 9-12 students interest in mathematics by involving them in some engineering and technology applications[7] as well as providing them a preview of the engineering and technology career fields.

Remote Design/Manufacturing projects in applied mathematics concern the following two areas.

- Statistical Process Control (SPC)
- Engineering Geometry

Pilot SPC projects involved the manufacturing of a Styrofoam tetrahedron[8] and a plastic chain[9] (similar to one used on a bicycle). These pilot projects were successfully used during 1997-98 in a Seaholm High School Advanced Mathematics course. The results of these pilot projects were presented by the Seaholm students to Oakland University's SYS 485 Statistical Quality Control course (containing both undergraduate and graduate engineering students) via video conferencing.

Results from these pilot projects are presented on a website, developed by the Seaholm High School students, which can be viewed at the following URL:

- *http://www.bizserve.com/seatec/spc.html*.

Projects in the area of engineering geometry are currently under development with initial plans for the design and development of a high school level course of the same title. This course's goal will be to teach the high school students geometry through the use of various engineering and technology applications.

Some of the interactive projects planned for use in this course will require university engineering students to send geometry problems from their engineering design projects to the high school geometry students to be resolved. The high school students will then send their solutions to the university students for use in their engineering design project. In keeping with the technology intensive nature of the program, the transfer of these materials (sketches, documents, drawings, etc.) will be via the internet.

5. CAD Projects

Currently, an interactive CAD project is being developed for use during the 2000 winter semester. The CAD project will involve interactions between Oakland University's ME 486 Machine Design class and Seaholm High School's CAD Engineering class. In this project, Seaholm's CAD Engineering class will serve as the "CAD Department" for the ME 486 engineering design projects.

The Oakland University ME 486 students will send sketches of the parts they are designing to Seaholm students via the internet using the scanning equipment in the Remote Design/ Manufacturing Laboratories. Seaholm High School's Remote Design/Manufacturing Laboratory is equipped with fifteen seats of AutoCAD and MechanicalDesktop, which their students will use to produce the CAD drawings of these parts. Once finished, the CAD drawings will be sent back to the Oakland ME 486 students for modifications or final approval.

Future plans are for including Seaholm's Machining class in the CAD projects. After the CAD drawings are reviewed and approved by the ME 486 students, Seaholm's Machining class will produce prototype parts from the CAD drawings.

6. Future Development Plans

Current plans for the continued development of the Remote Design/Manufacturing Program are concerned with two projects. The first is the development of a Flexible Assembly Cell. Initial support for seeding the development of this cell has being obtained from Trellis Software and Controls Inc. (a subsidiary of Kuka Robotics Inc.).

The centerpiece of the Flexible Assembly Cell will be a six-axis Puma 560 robotic manipulator. The Puma's original controller will be replaced by an open-architecture unit, produced by Trellis Software and Controls Inc., called the OpenRobot Controller System.

The first interactive project to be conducted using the proposed Robotic Assembly Cell will be between Oakland University's SYS 491 Senior Design course and two Seaholm High School courses, Industrial Drawing Practices and Automation/Robotics. This project will involve the initial set-up of the cell after Trellis' modifications to the Puma robot are completed. The assignment will require the Oakland University engineering students to design a generic set of flexible fixtures and grippers for use in the cell. The Seaholm High school engineering technology students will be required to develop CAD drawings of all components and also construct them using their machining facilities.

The second development project planned for the Remote Design/Manufacturing Program concerns the development of an Alternative Energy Laboratory to be located at Seaholm High School. The laboratory will be used in Seaholm's Introduction to Energy Technology course for the 9-10 grade levels. The course is designed to have a strong laboratory emphasis giving the students hands-on experience in applying physical science principles. Activities consider the study and application of alternative energy sources such as solar, wind and thermal.

The Alternative Energy Laboratory will not necessarily be used for interactive projects between university and 9-12 students. However, the design and implementation for some of the Alternative Energy Laboratory's experimental facilities will be accomplished via design project assignments in Oakland University's SYS 491 Senior Design and ME 486 Machine Design classes. The Alternative Energy Laboratory will be housed in a remodeled room for which the Birmingham Public School District has already committed the capital funds.

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