AC 2010-2101: ENHANCEMENT OF INTERNET BASED LAYER MANUFACTURING FOR ENGINEERING EDUCATION

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Enhancement of Internet Based Layer Manufacturing for Engineering Education

Abstract

The objective of the paper is to design, implement, and further enhance an Internet Based Manufacturing (IBM) course on the topics of rapid prototyping and advanced manufacturing within the established programs of Industrial Engineering (Manufacturing Specialization) and Mechanical Engineering at the University of Texas as El Paso (UTEP). The aforementioned course constitute the foundation of what is commonly known as e-manufacturing systems, in which the remote monitoring, diagnosis and control of distributed manufacturing operations are the key characteristics. This paper describes an established e-Manufacturing Lab to serve two academic programs at UTEP – Industrial Engineering and Mechanical Engineering, and to support multidisciplinary education activities. Moreover, the paper also aims at developing an effective learning model to facilitate student’s learning. Student learning from both virtual and real environment are evaluated and discussed in this paper.

Introduction

The objective of the paper is to design, implement, and further enhance an Internet Based Manufacturing (IBM) course on the topics of rapid prototyping and advanced manufacturing within the established programs of Industrial Engineering (Manufacturing Specialization) and Mechanical Engineering at the University of Texas as El Paso (UTEP). The aforementioned course constitute the foundation of what is commonly known as e-manufacturing systems, in which the remote monitoring, diagnosis and control of distributed manufacturing operations are the key characteristics. With the trend of rapid globalization across almost all types of manufacturing industries, it is foreseen that the internet based manufacturing will become a significant activity in coming years. According to literatures 1-6, the IBM is one of the fast growing businesses in the manufacturing sector. A distinguishing characteristic on the delivery of the curriculum will be student involvement in “hands-on” laboratory activities and experiences. Furthermore, graduates from the program will be well-prepared with high-tech skills in the areas of rapid prototyping and advanced manufacturing technology. It is expected that nationally this curriculum reform will become a national model of teaching internet based manufacturing technology and management, while locally it will provide much of the needed manufacturing professionals for the industries. Basically, Rapid Manufacturing Systems deal with various aspects of additive, subtractive, and joining processes to form three-dimensional production quality parts.

Layer Manufacturing (LM) is an automated technique for direct conversion of 3D CAD (digital) data into physical objects using a variety of layer-based additive approaches. Manufacturers have been using these technologies to reduce development cycle times and
introduce products into the market quicker, more cost effectively, and with added value due to the incorporation of customizable features. Realizing the potential of LM in product design and manufacturing, a large number of processes have been developed that allow direct fabrication of parts from a variety of materials ranging from plastics to metals.

**Background**

Globalization has changed the landscape of manufacturing industry. Many manufacturing activities are performed at geographically dispersed locations, while coordinated and integrated by Internet-Based communication and control software. Hence, topics on distributed manufacturing are of interest in both academia and the business world. The current state-of-the-art practice includes the multinational engineering teams for product design and the global business coordination, such as supply chain management. We foresee, however, that with the advance of automation and sensing technology, integration of physical manufacturing processes into the global business and engineering functions will be the next stage of the foregoing manufacturing evolution.

**Development of e-Manufacturing Lab for Network Based Manufacturing Education**

UTEP has recognized the strategic importance of the new program to the manufacturing industries, which has materialized through a strong support in resources. This lab is the synergistic combination of manufacturing engineering, computer, information technology, control systems as well as Internet-based, advanced tools for collaborative product design, remote process monitoring & control, embedded functionality, and built-in intelligence. One critical attribute of the lab development is to excite and expose the students about e-Manufacturing through hands-on projects and summer workshops and seminars, hence encouraging them to take various courses covering rapid prototyping and advanced manufacturing that are integrated with information networks. In addition, the lab will be utilized for engineering problem solving courses aligned with current industry projects, where students work as engineering teams and simulate the functioning of a real world manufacturing enterprise. The lab will employ graduate students to help develop experimental setups along with student lab manuals and instructors’ notes. An overall architecture of the Internet Based Manufacturing Laboratory (IBML) at UTEP is depicted in Figure 1.
Figure 1. An overall architecture of the Internet Based Manufacturing Laboratory (IBML)

Problem Description

The ABET Engineering Criteria states the engineering students should be able to communicate effectively, function on multi-disciplinary teams and use the techniques, skills and modern engineering tools necessary for engineering practice. This requires the development of creative education model to promote team-based collaborative learning focused on engineering projects, establish close ties among different schools and programs, and promote interdisciplinary education. Yet current education models are primarily based on the learning in the classroom with a clear delineation between disciplines. Students attend the lectures and are evaluated through homework problems, class projects and exams. Even though the importance of team work has been stressed over the years for the successful engineering career development, the extent of implementation is limited to the team projects in the classroom. Many engineering/business courses are pure lecture-based, and do not usually contain components that help student to boost their communication skills within the framework of engineering problems. The limited exposure to this critical success skill has resulted in isolated learning experience. Students lack the broad understanding in other areas of study and oftentimes speaking different languages between the disciplines. Many industries (i.e., automotive, aerospace, electronics, etc.) are complaining about the lack of preparation future engineers are receiving in colleges and universities. The industries pointed out that there exists a huge, yet common deficiency among the engineering students, asking that students should learn how to communicate effectively. This is aligned with the exponential growth of advanced, sophisticated technologies that resulted in an increasing demand for engineers. The report prepared by the Society of Manufacturing Engineers (SME) listed 14 competency gaps that engineering graduates are lacking quality, product/process design. To address this concern, there is a need to develop and incorporate an innovative education model to engineering curriculum to
ensure that engineering graduates are equipped with appropriate knowledge and necessary skills in active learning, communication and information seeking.

What is giving added challenges to such education model is the emerging distributed operations in industries. In recent years, the centralized companies of the past have been replaced by geographically dispersed, remotely located companies collaborating on a common project. The technical advances, especially the Internet, have been the major driving force behind this trend. Surprisingly, the full potential of these technologies are not currently used in the classroom settings \(^5\). \(^6\) There is no comprehensive education model fully integrating available Internet technologies into classroom with an emphasis on the improvement of students’ skills in information seeking and communication \(^7\). In most cases, it is limited to the on-line course delivery, emails and e-bulletin board between students and instructors \(^8\). Therefore, the authors have implemented a **digital image based approach** to explore the use of Internet for active learning and information seeking skills enhancement in engineering curriculum.

**Digital Image Based Approach for Effective Learning**

The term “Internet Based Manufacturing (IBM)” refers to the information technology based principle, modeling approaches and computing networks, used to design products with built-in intelligence. According to the Report of the NSF subcommittee on Manufacturing Infrastructure \(^9\), to enable the Nation’s Manufacturing Capability, “next generation manufacturing equipment will require the integration of fast manufacturing architecture, intelligent controllers, intelligent sensors and actuators, and innovative machining and tooling concepts”. Internet based manufacturing through information and communication technologies are key elements to deploy real-time control of production processes in a global manufacturing enterprise. The role of communication vehicles such as Internet/Intranet in the creation of supply chain management has been recognized \(^10\)-\(^11\).

The proposed digital image based approach aims at taking advantages of the pedagogical strategies and techniques, to improve students’ learning. Basically, asynchronous digital image based approach is self-paced, highly interactive, results in increased retention rates, and has reduced costs associated with student travel to an instructor-led workshop. In addition, the digital image based approach allows for easy access to the content and requires no distribution of physical materials. This feature translates into the following specific benefits like (1) **Access is available anytime, anywhere, around the globe**; (2) **Per-student equipment costs are affordable**; and (3) **Content is easily updated**.

Despite these potential benefits, empirical studies typically have failed to find statistically significant differences between digital image based and face-to-face (FTF) course performance. The major drawback, when compared to synchronous FTF instruction, is the lack of human contact, which greatly impacts learning. While students can use their Web connection to e-mail their instructors or post comments on message boards, FTF classroom real-time interaction between instructor and students may be still superior.
Case Study: Comparison of the Conventional Approach and the Digital Image Based Approach for Effective Learning in Layer Manufacturing

UTEP has offered a Layer Manufacturing related course in summer, 2010. The course title is Design for Additive Fabrication (MFG 4395/5390). Basically, the course is an introduction to Layer Manufacturing (LM). LM technologies fabricate three-dimensional (3D) parts using layer-based manufacturing processes directly from Computer-Aided-Design (CAD) models. Direct Digital Manufacturing (DDM) or Rapid Manufacturing (RM) is the use of LM technologies in direct manufacturing of end-use parts. In this course, the students learned about a variety of LM technologies, their advantages and disadvantages for producing both prototypes and functional parts. The faculty is interested in exploring if a non-traditional teaching approach can compete and/or substitute the traditional method (i.e., a face-to-face class).

To perform these tasks, we divided the students into two groups. The first group (18 students) had the course contents presented in the traditional way (i.e., face-to-face) with the instructor. Video recording was done during this session. The video recorded during the first session was shown to the second group (12 students). The first group called the “control group” because the students were learning by having face-to-face communication with the instructor. The second group called the “experimental group” because they did not have face-to-face communication with the instructor and only had access to the video that taped during the lecture for the control group. The course lectures were burnt to a DVD and students had to learn by watching these videos from the DVD. Students took notes and discussed the video with their peers. Students were asked to (1) conduct an experiment to calibrate the support tip and set the flow rate of material on the FDM 3000 machine and also (2) take a written test related to the lectures.

In conducting an experiment on the FDM 3000 machine, all of the students included in the control and experimental groups were divided into teams of 4 (i.e., 4 students in one group). Each individual group was given an identical task of performing the previously determined experiment to calibrate the tips and set the material flow rate. The part produced in this process can be seen in Figure 2 and Figure 3. Therefore, the instructor was able to judge and compare the performances. Whenever they were not quite sure about the right solutions during any stages of making the part, they were allowed to look over the video again. Note that one of the instructors also played a role as a facilitator to provide limited instructions in order to avoid damaging the facility during the experiment for both groups.
Figure 2: The part produced and used in the process of calibration and setting up the material flow rate. The extreme lines show the width of model material laid by model tip and the central line is laid by support tip (of support material). The alignment of central line with edges is used for calibration and width of model material is used to set the material flow rate.

Figure 3: Students in the experimental group (i.e., using a DVD) participating interactively in operating the FDM machine to produce parts.

According to the instructor, both groups performed almost equally well in performing the experiment. In average, the score of the control group is 9.1 out of 10 while the score of the experimental group is 9.3 out of 10. In the next section, the written test performance from each group will be analyzed and discussed. One critical thing observed is that students from both the groups took help from the instructor which shows that during the lab experiments, there is a need for the presence of an instructor to speak to them (oral communication which can be made online).
Written Test Performance by Both Groups

To analyze and compare the performance of the two groups, a test was conducted after the class but during the course. The test consisted of ten questions in total related to course materials and documents from Society of Manufacturing Engineers (SME). The test scores from both groups were tabulated and shown below:

Table 1: Test results for students in group 1 and 2

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<th>Group 1 For 10</th>
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<td>Average</td>
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<td>Average 4.583333</td>
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</table>

The figure below illustrates histograms for student’s performance. The x-axis denotes number of questions answered correctly. For instance, there are four students got 7 questions answered correctly while only one student got single question answered correctly. The Y axis is number of students. In the figure below the histograms for “control” (Group #1) and “experimental” (Group #2) groups are presented. Note that the total score is 10 points and the total number of questions is 10. Consequently, one question is worth one point.
Figure 4: Histograms representing frequency of correct answers provided by the students in the (a) control group and (b) experimental group

The first group of students, those who were taught in the traditional manner by the instructor, earned an average score of 5 (out of 10); while the second group of students who learned by watching the video earned an average score of 4.58 (out of 10). To know if the average scores obtained by the students from the two groups is significantly different, a two sample t-test was conducted on the values obtained. P-value > 0.5 obtained indicates that the difference between sample averages as highly insignificant. The analysis performed using Minitab®. It is through a 2-t test on the aforementioned two samples. The result has concluded that there is no evidence to reject the null hypothesis.

Null Hypothesis: Ho = μ1 - μ2, where μ1 and μ2 are the mean from population 1 and 2

Test Statistic:    To = (x̄1 - x̄2)/ (s_p \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}) = .68, where, x̄1 and x̄2 are the sample average from sample 1 and 2, s_p is the pooled standard deviation and n1 and n2 are the sample average from sample 1 and 2

By comparing the values for tα/2, at 90% and 95% confidence levels, we can conclude there is not much difference between two groups. In other words, the scores obtained by students from two groups were almost the same and the difference in average scores may be contributed from individual difference.

Survey Results from MFG 4395/5390-Design for Additive Fabrication

Pre-course and Post-course Questionnaire: Pre-course and post-course questionnaires were developed in order to know the initial opinions of the students about distant education, the technologies involved, and if there is any change in their opinion after getting exposed to the new method. The pre-course questionnaire was given to both the groups whereas the post-course questionnaire was given only to the second group (i.e., the experimental group) which was exposed to the video recordings. The compiled responses for the pre-course questionnaire (a total of 28 students attended the class on
that day) are tabulated. Responses were tabulated for undergraduate and graduate students separately in order to know if any difference in opinion existed.

**Pre-Course:**
Pre course questionnaires are to survey what background students have in the content of the MFG 4395/5390 - Design for Additive Fabrication course. The data collected for undergraduate and graduate students are shown in Figure 5 and Figure 6 respectively.

The final results of the questionnaire for pre-course survey are shown in the histograms. The graph is drawn with the question numbers on the X-axis and number of students on the Y-axis. The following figures show the histogram for undergraduate and graduate students in the pre-course survey.

![Figure 5: Survey results for the undergraduate students](image-url)
Figure 6: Survey results for the graduate students

Post-Course:
Post course questionnaires are a way to survey the student’s learning after they took the MFG 4395/5390- Design for Additive Fabrication course (Note: This was only for the experimental group). The data was collected for undergraduate and graduate students and the results of the survey are shown below. Moreover, there is no quantitative (i.e. multiple choices) type of survey in Post-Course questionnaire due to the multiple choices survey is focusing on student’s awareness and understanding of online laboratory learning. Consequently, it is not necessary to conduct post course survey. When Pre-course and Post-course responses are compared, it was found that the students’ opinion of the online education had changed and the responses were more positive in post-course. Similarly, when the responses of undergraduate and graduate students are compared, it was found that graduate students were more positive towards online education. Most students thought that with a proper use of the technology and teaching methods, the experience will be more or less similar to that of traditional instruction. After the course, they could specifically address the strong points of online education. Students also expressed concerns about the lack of hands on experience in online education. This may be due to the fact that online operation of the machine was not included in this exercise. The other concern most students expressed is of the availability of the instructor to answer their questions. They seem to agree that the appearance of instructor through Internet will be satisfactory to this purpose.

Conclusions
According to the survey, after experiencing with the alternative learning method, more students were able to accept this pedagogy instead of the traditional approach (i.e., face-
to-face instruction). Moreover, the test results illustrate that there is no significant difference between the control and experimental groups. The findings from the aforementioned analysis provide an indication of how to effectively study the online bio-manufacturing laboratory problem in our future investigation.

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Bibliography