AC 2009-1492: A WEB-BASED INTERACTIVE ROAD MAP FACILITATING SELF-LEARNING FROM CAD MODELING TO RAPID PROTOTYPING

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A Web-based Interactive Roadmap Facilitating Self-learning from CAD Modeling to Rapid Prototyping

Abstract

Conventional self-learning materials, such as textbook and presentation slides, provide a one-way and one dimensional information flow (i.e. from the first page to the last page). Interactive learning tools, such as computer programs, deliver a more encouraging learning environment, especially for the younger generation. Young students tend to be attracted to interactive web-based programs which facilitate two-way communication with multiple dimensions of information flows (i.e. cross-linked with various alternative paths). Furthermore, a gaming environment attracts the attention of young students and leads to more effective learning experiences. This paper proposes an innovative web-based application, the Interactive Roadmap, to provide an exciting learning environment for high school students, who are interested in engineering. The roadmap of a manufacturing project from Computer-Aided Design (CAD) modeling to Rapid Prototyping (RP) is developed for young students to gain knowledge and hands-on experiences in the field of manufacturing engineering. The interactive roadmap, presented as a treasure map, contains several training modules under the main topic. The modules are cross-linked to provide various alternative pathways for the students to explore the whole package in the way they choose. Students gain credits as they visit each stop and complete the associated quiz or assignment until they finish the whole package. Due to availability of resources, the prototype program being developed covers CAD modeling using *SolidWorks 2007* and RP process using *Dimension SST 768*. The integration of CAD and RP is chosen for that they make a compact and self-contained system to demonstrate the concept of computer integrated manufacturing (CIM). The web-based program of the Interactive Roadmap is developed using PHP+MySQL with Flash, PowerPoint slides, and other multi-media files. With further development of training modules, the platform can also facilitate training in other topics.

Introduction

The objective of this research is to provide an encouraging learning environment for young students (i.e. high school, middle school), who are interested in engineering and willing to gain knowledge through self-explorations. This paper proposes a web-based program with an interactive roadmap to facilitate self-learning in the area of computer integrated manufacturing.

Online learning has become an important method for teaching various courses. It facilitates not only long-distance learning but also provides a new way of self-study. Conventionally, self-learning was performed mostly through reading. Textbooks and most reading materials play a passive role, which provides a bank of knowledge to those who desire to learn. Even with a motivation to learning, reading usually gives a one-way communication with no feedback or interaction. As for the contents conveyed through reading, the majority of reading materials provide only a one-dimensional information flow, which means a structured sequence from the first page to the last page. The sequence is usually what the authors believe to be the best for the readers. However, in our learning and teaching experiences, the structure of one book may not match every reader's need. Furthermore, natural learning experiences are usually not one

dimensional. We can often learn two independent sets of knowledge simultaneously that are both essential to the next subject. The precedence of some subjects is not as critical as the others. Therefore, a multi-dimensional network of subtopics, which impose only the critical precedence relations among subtopics, may better represent the appropriate sequence of learning one subject.

Beside the contents of the learning packages, multimedia often provides a more encouraging learning environment for a longer-lasting memory, especially for the younger generation. Nowadays, young students tend to be attracted to web-based interactive programs with multimedia contents and interactive communications. The web-based programs facilitating two-way communication and multi-dimensional learning sequence (i.e. cross-linked with various paths) emerges as a promising technology for self-learning.

This paper proposes an Interactive Roadmap approach to develop a web-based self-learning package. The roadmap links several modules under one subject in a multi-dimensional network that represents the critical precedence constraints of certain modules and meanwhile provides the flexibility of moving between non-constrained modules. The interactive roadmap is presented as a "treasure map," which encourages young students to explore the package through a "treasure hunt" experience. Users of the package will go through the stops on the map and collect the "trophy" at each stop by clearing the obstacles (i.e. quiz or problem solving). A trophy represents a certification of clearing a subtopic, and a necessary set of trophies certifies the user to pass on to the next stage.

The goal of this research is to provide a self-learning solution that is attractive to young students, fun, with little or no cost, and with great accessibility. The proposed learning package covers a mini-factory setting of Computer Integrated Manufacturing (CIM). The topic selected for the development of the prototype software package is the integration of Computer Aided Design (CAD) and Rapid Prototyping (RP). The CAD-RP system covers the fundamental knowledge of design and manufacturing systems, and more importantly, it requires less knowledge and experience in the field of manufacturing to be able to understand the contents. A prototype of the proposed software package has been developed with basic functionality. It is under further development and will be tested in a summer research program for high school students in 2009.

Online Learning

Due to the rapid progression of web-based technology, online learning has become an important tool for educators. Online learning packages can be divided into two major categories. The first category covers the "teaching assistant" packages, which provides a way for the instructors to organize online curriculum to facilitate classroom or off-class activities. The second category is the "interactive programs," such as simulation games and other interactive modules. Many programs/packages have been developed for both categories by researchers, instructors, and professional software provides.

For the teaching assistant packages, most (if not all) higher education institutes have been using at least one package. In the university where the authors serve, three systems have been used. The school is in transition from the WebCT system[1] to the Blackboard system[2], which gives the authors an opportunity to gain hands-on experiences on both systems. These systems provide a

web-based interface for the instructors to post and manage the online course materials. As shown in Figure 1, students can browse through the presentation slides, reading materials, video clips, etc., to gain knowledge. Some of them provide the interface for quizzes and further interactions, and most of them facilitate online discussion forums. In the authors' academic department, a third online learning package, LearnMate[3], is available. It provides an integrated grading system in addition to the interactive online curriculum. There are more similar commercial packages that the authors did not have an opportunity to evaluate, but the three packages give a good overview of the "teaching assistant" type of online learning systems.

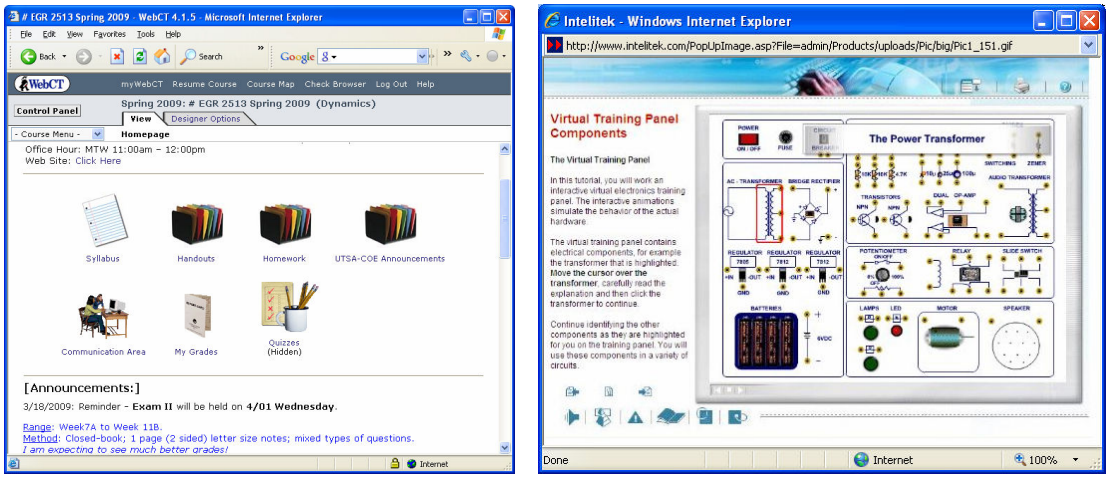

Figure 1. Examples of teaching systems: (a) course management (b) online learning[4]

The other category of online learning applications is the interactive programs. Various modules and packages have been developed to enhance the online learning experiences via more interactive activities. Simulation and gaming are the main methods to achieve this goal. Pure simulation demonstrates a process or the operation of a system and may also provide data for further analysis. Using proper computer programs, simulations can be developed for mechanics, finite element analysis, manufacturing systems, etc. Three-dimensional graphical simulations provide a vivid image to students, especially in the engineering discipline. However, pure simulation usually does not involve to much interaction with learners. Simulation game is another important pedagogy, which uses simplified and well-structured scenarios to allow the learners to make decisions and gain knowledge through certain level of hands-on experiences[5]. Unlike pure simulation, simulation games are more interactive and require more involvement of learners. Many simulation games have been developed for classroom practices in the past, but online simulation games are available only in recent years[6, 7, 8, 9, 10].

The existing simulation and gaming programs serve as good modules of interactive online learning. They can be included in the "teaching assistant" learning systems to enhance the effectiveness of online learning. On the other hand, the learning systems can actually benefit from adopting the "gaming" concept in the design of the whole curriculum. The current systems are just virtual classrooms. How attractive a curriculum can be purely depends on the design of the teaching materials (e.g. slides). Bringing the fun element into the virtual classroom will make the online packages more attractive, especially to the younger generation.

An Interactive Roadmap Approach using Treasure Maps

This paper proposes an Interactive Roadmap approach for the design of an online curriculum. The approach uses a "treasure map" concept to include the fun element of simulation games into the overall curriculum design. The main concept is to use the treasure map to layout the multi-dimensional links between subtopics, i.e. learning modules, which impose the critical precedence among some modules while having the flexibility of choosing different paths. Therefore, the learners can explore the whole package by developing their own learning path under certain constraints.

The interactive roadmap approach consists of three major components: the Treasure Map Model, Learning Modules, and Performance Evaluation Modules. These components are explained further as follows.

1) Treasure Map Model

A treasure map is developed to be the backbone of the curriculum. It maps out the precedence relations among topics as shown in Figure 2. The term "treasure map" is used in this paper because it represents a structured map with guidelines. Unlike a simple roadmap, a treasure map teaches the users how to move toward the destination and to collect the valuables (i.e. knowledge in our case) along the way.

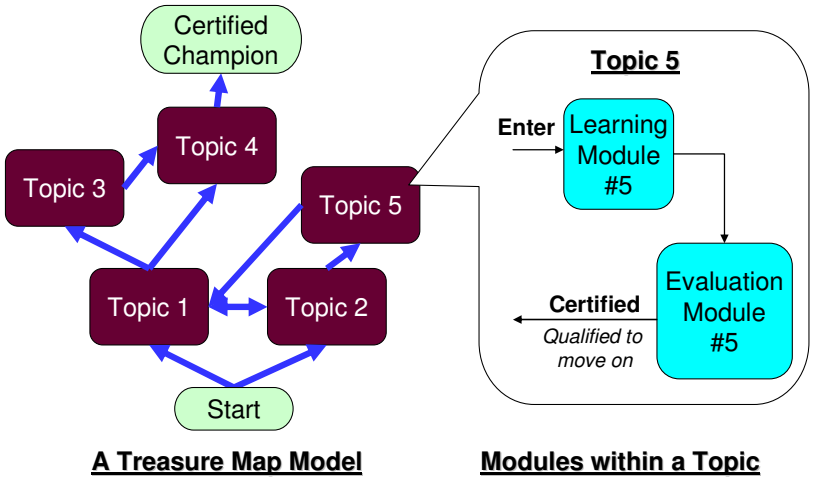

Figure 2. The Interactive Roadmap approach and the components

Upon entering the system, the learner will see different choices to browse through the topics. Some topics have prerequisites while the others do not. Each topic contains a learning module and an evaluation module. Once a learner finished learning and passed the evaluation criteria, he is then allowed to move on to the next topic that he chooses. With more topics being cleared, the learner will see more available choices to move ahead. Once the learner passes the evaluation criteria of all topics, he will be granted as a certified champion in this subject, the final trophy.

2) Learning Modules

Each topic in the treasure map contains a learning module and a corresponding evaluation module. The learning module conveys knowledge to the learners through a variety of methods. Using a web-based program, the learning module can easily incorporate lecture notes, presentation slides, photographs, and audio and video clips. More importantly, interactive programs, such as online games, can be developed to facilitate hands-on practices. The interactive programs can be the aforementioned simulation games or the virtual experiments as shown in Figure 1. The interactive programs can be developed using HTML, Java script, Flash, Flex, or other web-based programming platforms. These multimedia contents and simulation games would facilitate an interactive learning experience that attracts young students.

3) Performance Evaluation Modules

The evaluation modules certify the knowledge level of the learner to be qualified to move on. Quizzes corresponding to the learning modules are used to evaluate the performance. The learner who passes a quiz will receive a trophy of that topic which serves as a key to move on to the higher level topics. Therefore, the learner must collect enough trophies to be qualified for a certain higher-level topic. The last topic in the subject should be a comprehensive review of the whole curriculum. The learner must pass the comprehensive evaluation module to receive a final trophy, i.e. the certification of champion in this subject.

Using the interactive roadmap approach, the learners can go through the topics one by one and gain the knowledge through an enjoyable way of interaction. The game-like environment is expected to be more attractive to young students, and the "treasure hunt" approach would provide additional joy of achievement.

Prototype: CAD-RP System Curriculum

In this research, a prototype software program has been developed to demonstrate the proposed approach. The program is developed using PHP+MySQL as the programming platform. A PHP program is a server-executed scripting program that facilitates interactive contents of web pages. MySQL is the web-based database to support the needs of data storage and retrieval in the interactive program. In addition, some Flash programs are underdevelopment to serve as the enhanced interactive contents in the learning and evaluation modules.

The subject chosen for the prototype program is a computer integrated manufacturing system consisting of Computer Aided Design (CAD) and Rapid Prototyping (RP). The goal is to develop a self-learning package for high school and middle school students in the area of manufacturing engineering. CAD is the front-end activity of all manufacturing systems. Through the CAD training, students will learn how to develop their own design to be manufactured. On the manufacturing side, the RP technology, also known as 3-D Printing, is selected in this research due to some of its superior characteristics. Comparing to traditional manufacturing processes, such as milling, turning, casting, welding, etc., the RP technology is easier to understand, has less constraints, and is easy to operate in most cases. An RP machine "grows" a work piece layer by layer from the bottom to the top. In other words, it "prints" three dimensional objects. There is very little limitation (if there is any) on the shape of the three dimensional design that an RP machine can make. Therefore, the RP process is also known as free-form manufacturing process. Unlike milling or turning, an RP process does not require

process planning or tool path generation. Some recent models of RP machines require little setup and operate similarly to a desktop printer. Due to the simplicity, it is a perfect manufacturing process for younger students to learn and practice if they do not have much background knowledge about machining processes. As a result, the integrated CAD and RP system represents a compact and self-contained computer integrated manufacturing system, or a "mini-factory," for the young students to explore.

Due to the availability of software and equipment, the prototype program has been developed based on *SolidWorks 2007* for the CAD learning modules and *Dimension SST 768* for the RP learning modules. The program is developed mainly for high school and middle school students. Therefore, only basic contents are included in the learning modules. Figure 3 shows the roadmap of the prototype package. The learners can start with the CAD track or the RP track in the roadmap and switch to the other track any time. However, if a block is not cleared, the following stops on that track cannot be entered.

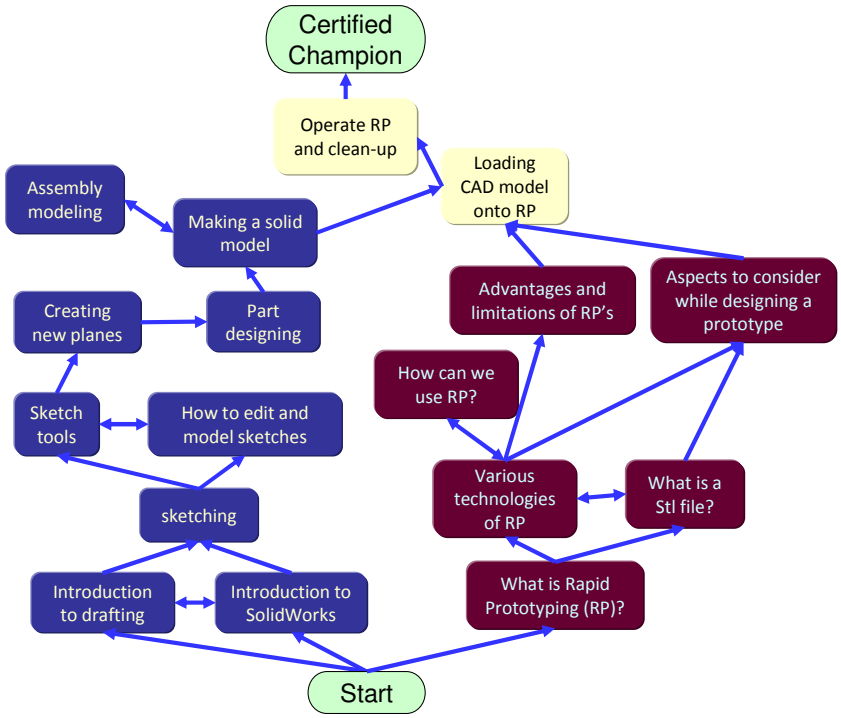

Figure 3. The treasure map of CAD-RP curriculum

The learning and evaluation modules are linked according to the roadmap shown in Figure 3. Students logged into the system will enter the Navigation System page (Figure 4). In this page, the students can see the open links and blocked links. If there is a blocked link, the students need to find out which "key" to the door is missing according to the roadmap. A few screen shots of the learning modules of the prototype program are shown in Figure 5 and 6. Currently, most of the contents in the learning modules are presentation slides. More multimedia files will be included continuously to enhance the content of the modules.

Although the graphical user interface of the prototype program has not reached the professional level, it demonstrates the concept and basic functionality of the proposed interactive roadmap approach. The programming tasks are carried out continually. The research team is developing Flash-based simulation games and virtual experiments to enrich the graphical presentations. An enhanced version will be used in a scheduled summer research program for high school students.

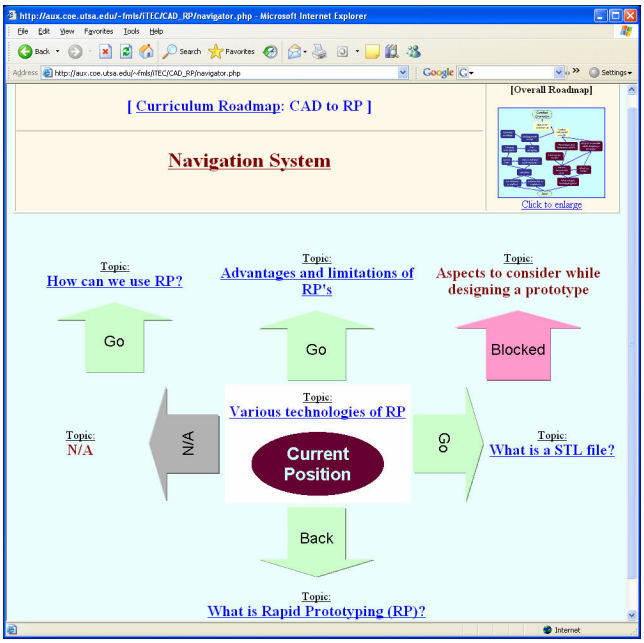

Figure 4. The navigation page of the CAD-RP curriculum

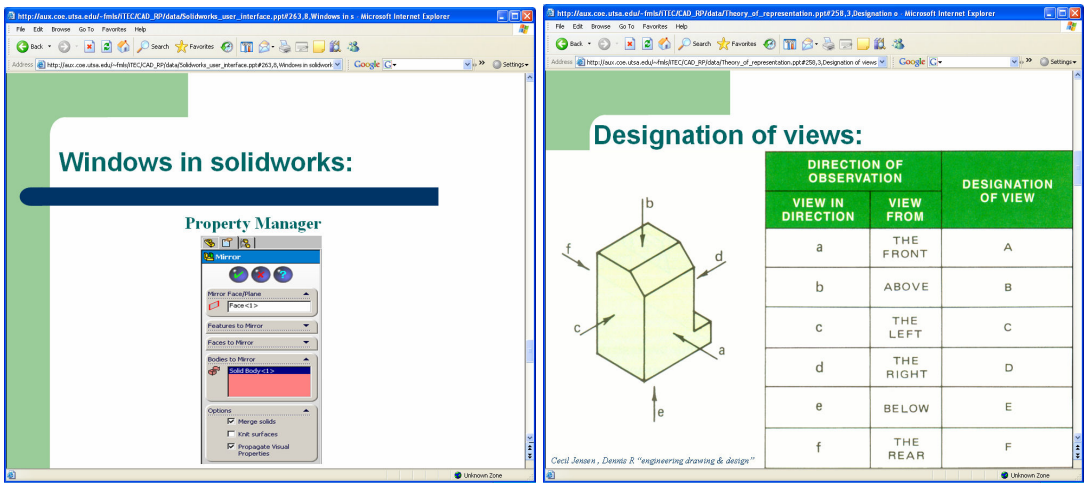

Figure 5. Learning module examples of the CAD curriculum

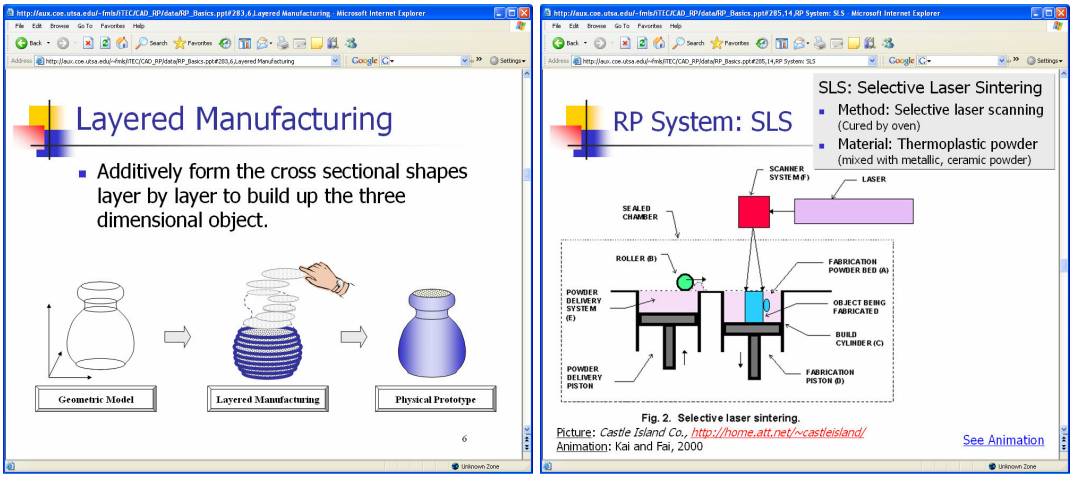

Figure 6. Learning module examples of the Rapid Prototyping curriculum

Summary and Conclusion

In this paper, a new method of designing online learning curriculum is proposed. The interactive roadmap approach graphically shows the relations of various subtopics under a subject. The roadmap defines the prerequisite requirements of the topics and meanwhile shows various available routes for the users to explore the whole curriculum. As a result, learners using this program will learn the subject in a structured way while having the flexibility to create his/her own path of exploration within the constraints.

The goal of this research is to develop an attractive online learning package for high school and middle school students who are interested in the area of manufacturing engineering. CAD and RP are selected to be programmed in the experimental prototype package in order to present a computer integrated manufacturing system as a mini-factory. One of the research objectives is to make the program joyful and attractive to young students. Therefore, a “treasure hunt” component is included in the interactive roadmap to accommodate the fun elements. Users of this system will navigate through the curriculum using a treasure map and collect the trophies from each stop (i.e. learning modules) by clearing the quizzes corresponding to the topics. Users passing all modules will receive the final trophy as the certified champion in that subject. Along the learning journey, interactive and multimedia learning contents are embedded to enhance the attraction to young students.

A prototype program with basic functionality has been developed to demonstrate the new approach. An enhanced version is expected to be finished soon and will be used by a summer research program for high school students. The web-based program with PHP+MySQL platform provides easy access to internet users. No set-up or installation is needed for running the program, and the standard web-browser operations are easy to understand.

In continuing the research, the graphical user interface will be further enhanced. More interactive contents will be added using Flash or Flex programs. Although the prototype program aimed for self-learning in the area of manufacturing engineering, the platform can also be applied to other areas. The research team will continue to explore the applications on other engineering subjects.

Another research direction is to develop a more flexible infrastructure for the instructors to easily modify the contents of the curriculum. Ultimately, the authors hope that more students of the younger generation will be inspired by the interesting curriculum design and decide to pursue higher education in engineering.

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