Automating an Introductory Computer Aided Design Course to Improve Student Evaluation

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Introduction

All engineering students at Rensselaer Polytechnic Institute are required to take a one-credit course in solid modeling. This course, Engineering Graphics and Computer Aided Design (EG&CAD) teaches the skills of using a solid modeling system to create parts, small assemblies, and documentation. More importantly, EG&CAD also emphasizes the use of vectors in creating solid models and thereby provides students reinforcement of their linear algebra knowledge. The students normally take EG&CAD during their freshman year and then have the opportunity to use solid modeling in their sophomore and senior design projects as well as some special topic electives. In addition, several other courses are now using solid models as a way to demonstrate fundamental principles[1]. With an increasing dependence on solid modeling skills required, it is imperative that the course content in EG&CAD be effectively delivered and evaluated.

Finding the teaching staff to run EG&CAD for 750-800 students/year has always been a challenge. EG&CAD runs twelve to twenty sections each semester; concerns about equality of instruction and evaluation between the sections always existed. Over the last ten years, several methods of instruction and teaching material have been developed to help ensure the uniformity of the learning experience for the students[2][3][4][5][6][7]. In the last year, the focus of the course development has been on providing intervention to students who struggle in the early lessons[2]. In this paper, the software implementation developed to provide students with immediate feedback to their laboratory work is discussed. By writing macro programs in Visual Basic and taking advantage of the Advanced Programming Interface (API) available in the software tools used in EG&CAD, the student will be able to submit their computer work (such as parts, assemblies or engineering drawings) to a database for evaluation. In addition, if students are struggling with certain key concepts in the course, then the software can flag their instructor to provide intervention.

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Course Pedagogy and Implementation

EG&CAD is taught with a series of twelve one hour lectures over a fourteen week semester[3][5][6]. The first eight weeks are spent creating parts and documentation. Two weeks are spent on assembly of parts and the remaining time is spent on special topics such as surface modeling and sheet metal design. Students also create hand sketches of parts creating both isometric and orthographic projections. An additional textbook[8] is used to supplement the hand-sketching portion of the course. The last two weeks of the semester are dedicated to work on a final project. The final project consists of a small assembly that students create as a solid model and then document with a collection of engineering drawings. Each of the twelve lectures has an associated laboratory session where students work problems based on the lecture material. As EG&CAD is a one credit course, no additional work is assigned outside the laboratory; the goal of the lecture and laboratory is to contain the course to three hours each week; one hour for lecture and a two hour laboratory session each week.

EG&CAD is taught using laptop computers required for all RPI students. The present software consists of:

1. SolidWorks – Computer Aided Design Software
2. PDMWorks – Data Base Manager
3. Windows Media Player – Used to view online lectures
4. WebCT- Internet course management tool containing section syllabi and general student information
5. 3 CDs containing video lectures, SolidWorks data, and other course material for EG&CAD. These CDs come bundled with the textbook[1]

Laboratory sessions are held in "laptop rooms" which consist of tables with Ethernet connections for the students and an instructor station with an overhead projection system. During this session, students use their laptops and work on problems previously assigned by their instructor. There is no actual lecture period; rather, students watch video lectures on their laptops. The video lectures (an example is shown in Figure 1) consist of 10-15 minute segments with four to five segments to watch per week. This format allows students to watch the segments at their convenience. The video lectures can be watched individually or incorporated in WebCT (as shown in Figure 1) with the SolidWorks data shown in a separate window.

The goal of the course is for all students to finish their laboratory work during the laboratory session. However, this is not always possible so office hours are held by some of the graduate students throughout the week to give students more contact hours. In addition, the SolidWorks software contains an online meeting capability that is coupled with Microsoft's NetMeeting. This allows data, voice and visual (if the computers are equipped with cameras) communication between two computers. In the EG&CAD course, experimentation with the "virtual office hours" has been done with mixed success.

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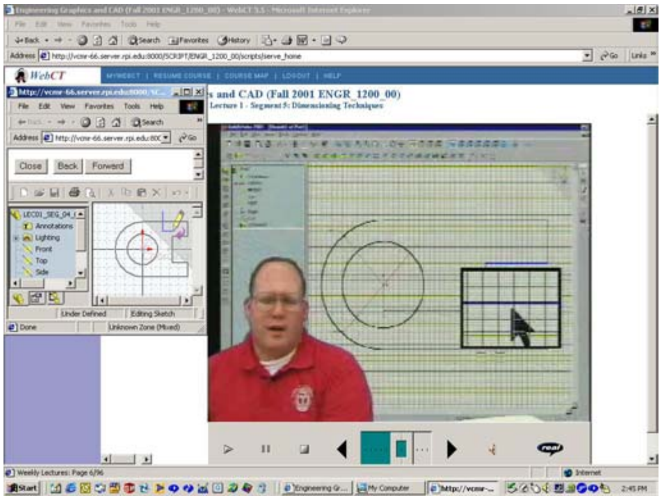
Figure 1: EG&CAD Video Lecture (Running in WebCT).

Evaluation of Student Performance

To evaluate the students, several techniques are used. Lecture effectiveness is measured with quizzes given during the 3rd, 6th, 9th, and 12th sessions. The problems on the quizzes are similar to in class exercises. The major difference is students do not receive assistance from the teaching assistants while taking the quiz. Points are awarded for model accuracy and orientation (was the proper sketching plane selected etc.). Quiz scores correlate with final project scores[2].

In addition to the four quizzes, a 50 question quiz[9] developed by Dr. Sheryl Sorby is used to determine overall course effectiveness. This quiz is administered through WebCT and is given at the beginning and end of the course. Final averages are examined between semesters and between the beginning and end of each semester. Rensselaer students typically average between 35-40 when they first take the quiz and average 70-75 at the end of the semester. While the final scores appear low, they are acceptable as the quiz examines topics not directly covered in class (specifically, the use of engineering scales and reading architectural drawings).

The key change made to EG&CAD in 2001 was the addition of highly specific grading criteria for each laboratory problem[2]. Figure 2 shows an example problem for a simple single feature part created with two cross sections (loft). The five grading criteria are listed on the problem page so the student knows what is expected of them for the particular assignment. The grading criteria focus on three fundamental aspects taught in the course: visualization, engineering relations, and design intent. In the example shown in Figure 2, the first and fifth criteria are the visualization criteria, the third criteria is the engineering relations criteria (in this example dimensioning aids) and the remaining criteria are the design intent problem (additional constraints placed on the design by the engineer).

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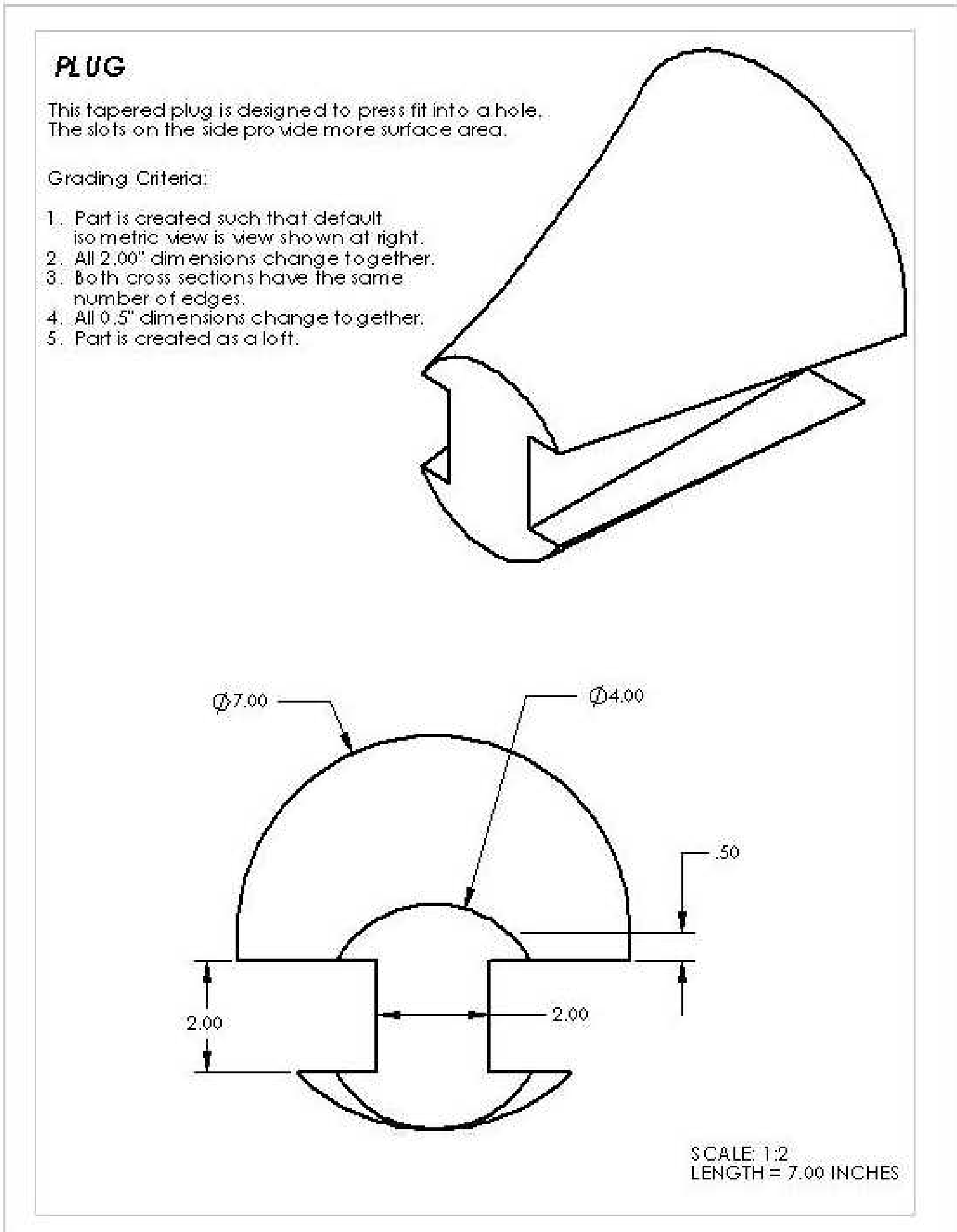

Figure 2: Example of the Grading Criteria for a Single Feature Part

The use of grading criteria in the course has produced several immediate benefits. The first is that the students have a far better understanding of what is expected of them. Many students enter EG&CAD thinking the goal of the course is to produce a nice looking picture. Forcing the students to apply their visualization skills and engineering skills to the laboratory problems helps dispel this myth. Likewise, the instructors also have a better understanding of what they should look for in grading the part. The instructors have also found that the grading of the part is quick as these criteria can be easily examined in the laboratory session. Finally, the grading between sections is now more uniform due to the rigid constraints placed on grading the parts.

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Automation of the Grading Process

With the addition of the grading criteria, and the use of macros with advanced program interface (API) commands, it is possible to develop an automatic grading system for any data created in SolidWorks (parts, assemblies and drawings). API commands allow different software packages to communicate with each other via macro codes (usually written in Visual C++ or Visual Basic). SolidWorks contains an extensive API library and with the 2003 version of PDMWorks, an API is also available. The API commands allow data to be queried, moved and edited all from another program. The goal of the automated grading process is to have students submit work to the database manager (PDMWorks) which in turn via the API triggers a grading program that will compare key data from the student submission with a correct SolidWorks entity. The macro can then determine which criteria have been satisfied, then inform the student of their score and if any of the criteria are not met, then inform the student as to which criteria must still be satisfied. In addition, the grading macro can then enter the grade for the submission (each criteria is listed separately) along with the number of submissions the student makes (students are permitted to submit their work any number of times prior to the due date of the assignment. After the due date, a late penalty is assigned).

Such a grading system should also communicate with the instructors and the students. It is expected to allow students to query their grade throughout the semester and a macro can display their grades to date and show them how their point total compares to the maximum point total available at the time of the query. Students should also be able to query individual assignment grades to see where points have been deducted. The system can also be used to inform the instructors about students who continually miss basic types of criteria (such as visualization). Thus, students who miss a design intent criteria on two or three consecutive assignments can be flagged to their instructor who can then invite the student to attend office hours or some other form of extra help. Finally, the system can be used to track the laboratory problem and its effectiveness. Data such as the number of students who are unable to meet a given criteria or require multiple submissions to do so can be easily flagged to the course coordinator. This will allow the course coordinator to better understand if the assignment needs modification.

To have such a grading system, it will be necessary to "teach" the macro how to evaluate the SolidWorks entity. Thus, a user interface to add problems to the database is also being developed. This interface will be used by the course coordinator to create and modify course problems. It is not expected to be used by anyone other than the course coordinator. In addition, it will be necessary to have "overrides" in the system to allow for accepting late work (such as a sports or medical absence). The system should also be able to accept data from the registrar to update spreadsheets and the database manager. A flow chart of the proposed system is shown in Figure 3.

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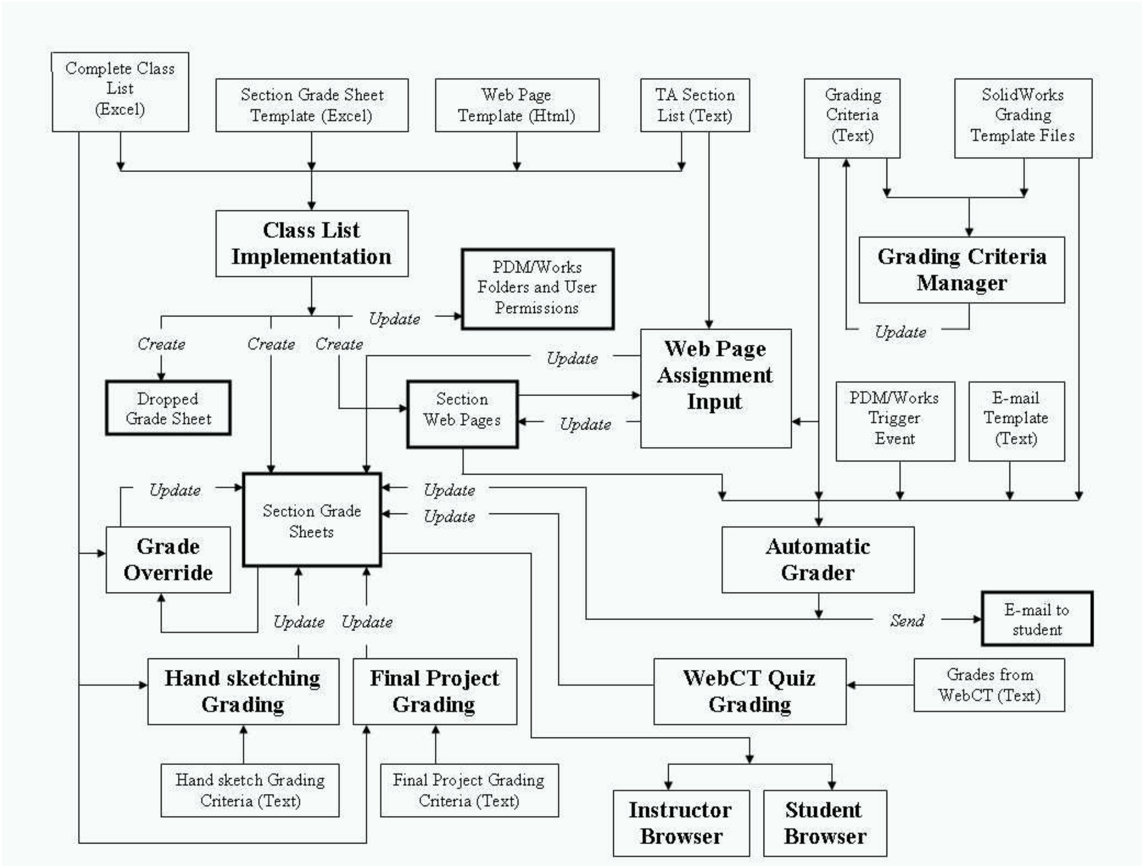

Figure 3: Proposed Data Flow of Automatic Grading System

The boxes in Figure 3 in bold print are the macros that need to be written, the remaining boxes indicate input into the system. Many of the inputs have already been created. The top row of boxes in Figure 3 have existed for some time. The automatic grading system is meant to compliment previous work, not replace it. Thus, the number of inputs seems severe, but in reality, will be simplified by the automatic grading system as these input files will no longer be modified by multiple people.

The first stage of the programming will be the class list implementation. This program will automatically program the section spreadsheets and the database manager. As new class listings are available from the registrar, these databases will be updated automatically. At present, it takes about 40 minutes per section to program the spreadsheets and database manager. By having these simple tasks automated, an immediate benefit will be gained in the Spring 2003 semester. In addition, the class list implementation is critical for the rest of the programs as it provides the basic data flow for the entire system. With this program, the Web Page Assignment Input will also be written. This small macro will update the EG&CAD web pages (http://www.rpi.edu/locker/85/000685/public_html) to keep the instructor list and assignments current. This portion of the software was completed on 1 February, 2003. Testing with the current EG&CAD grade lists shows that twelve sections (with up to thirty students in each section) can be analyzed and have spread sheets generated in under

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ten minutes using a 1.6 GHz Pentium IV processor. Section changes (students adding and dropping sections) can be analyzed in less time.

With the class list implementation, the user input programs (Grade Override and Web Page Assignment Input) will follow to allow for modification of the assorted databases. This system can take advantage of the existing security systems to ensure that the databases are not compromised. At present, spreadsheets are stored in a secure UNIX folder that can only be accessed by the instructors and the course coordinator. The new system will further restrict the access of each spreadsheet to the course coordinator and the instructor for that section.

The remaining portion of the system is scheduled for testing in early April of 2003. The system will work as follows. The section instructor assigns problems for each laboratory session. The system determines which students are in that section and creates a spreadsheet with their information. In addition, a locker is created for them in PDMWorks. As the semester progresses, names and lockers may be added or dropped or moved between sections. Students create their assignments with a unique name which will consist of the entity name and their Rensselaer user id.[1] Students submit their work to the database manager, PDMWorks. Using the PDMWorks API, a trigger starts the grading macro which will then compare the student data to the solution. A one or a zero is determined for each criteria and the information is sent back to the student and placed in the spreadsheet (with the appropriate checks to ensure that only one program is accessing the spreadsheet or database manager at any time). If the SolidWorks entity is submitted late, then the system will consider the submission the last allowable submission (as per present course guidelines) and grade the data with the appropriate penalty. If the student had previously submitted the part, only those criteria that moved from a zero to a one would have the late penalty applied (again, as per present course guidelines).

Future Work

The entire system will be beta tested during the Summer 2003 semester with a first phase implementation expected in the Fall 2003 semester. Guidelines for flagging the instructor about students have yet to be fully determined. The PDMWorks API is new and has not yet been fully tested at Rensselaer. These issues are expected to be examined during the beta testing. By writing the macros with programmable inputs, these variables can be changed after the software is written.

It is already clear that the grading of engineering drawings will be difficult. While it is simple enough to detect if dimensions and views (as well as view types) are present, it is not obvious how to automatically check for placement of these objects. It is felt that the implementation of a fully automatic drawing grading routine may require several further studies and should be implemented in stages. For the present, it has been decided to grade as much of the drawing as can be accomplished under the current study and leave the rest to manual grading. To aid in the manual grading, a picture of the drawing will be

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[1] This convention is used by many courses at Rensselaer that require electronic submission.

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created and sent to the grader. This will decrease the amount of data flow and still allow for accurate grading.

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