Engineering Graphics And Computer Aided Design: A Foundation To Engineering Design And Analysis

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1.0 Abstract

With the advent of solid modeling, the importance of engineering graphics has been emphasized. Many employers hiring engineers expect their new engineers to have some solid modeling expertise from their academic experience. As with many engineering schools, engineering graphics was greatly curtailed at Rensselaer during the 1980's. When engineering graphics was reintroduced at Rensselaer as a required freshman-engineering course in 1991, there were two major goals. The first was to teach the fundamentals of engineering graphics using solid modeling as opposed to a user course in the specific solid modeling software. The second goal as to provide the students with an opportunity to use solid modeling as an engineering tool for conceptual design, detailed design and engineering analysis.

This paper will present the development of Rensselaer's course, Engineering Design and Computer Aided Design (EG&CAD). The development of the course from a lecture with laboratory using CADAM to a full laboratory course using Pro/ENGINEER will be presented. Pro/ENGINEER training files were written to allow students to have on-line demonstrations of the lecture material. The development of these training files will be presented. By discussing the course development, it will be seen how material from other freshman engineering courses is integrated into the course. Finally, a discussion of the integration of solid modeling into the sophomore, junior, and senior years will be presented. Included in this discussion will be a brief examination of a new follow on solid modeling course designed for sophomore engineers.

2.0 Introduction

The ability to create and document solid models is considered by many companies as an essential skill for their entry-level engineers. Many engineering schools dismantled or greatly curtailed their graphics or mechanical drawing departments during the 1970's and 1980's. Hence, many engineering schools have found it necessary to reinstate their graphics education. Rensselaer Polytechnic Institute faced this problem in 1990 and in 1991 created the course *Engineering Graphics and Computer Aided Design* (EG&CAD) to provide an entry-level course in the fundamentals of solid modeling. Furthermore, solid models and documentation are now required in design courses throughout the engineering curriculum. This combination of a course in solid modeling fundamentals and required solid model creation and documentation for the students' design courses is the solution Rensselaer has created to fulfill the requirements of the firms that employ Rensselaer graduating engineers.

The purpose of this paper is to examine the course EG&CAD in its context as a part of the overall design curriculum. First, an examination of the requirements to provide a solid modeling course will be made. A brief discussion of the hardware and software issues will be presented. The pedagogy of the course will be presented and details of the course will be discussed. A discussion of the four year design curriculum (both required and optional courses) will show how additional solid modeling skills are presented. A brief discussion of a new advanced solid modeling course and its placement in the curriculum will follow. Finally, future work in solid modeling teaching will be discussed.

3.0 Requirements

3.1 Course Objectives

The primary objective of an entry-level course in computer aided design is that the course be both a skills course and more importantly, a technical course. Prior to the creation of EG&CAD, some limited work in technical graphics was part of a sophomore design course, Engineering Modeling and Design (EMAD). In 1990, computer aided design was introduced into EMAD with the two-dimensional software package CADAM. Using CADAM did little more than replace the drawing board with a computer screen. Students were able to make engineering drawings, but no analysis of the parts were performed and students did not see the connection with the computer model to the analysis and design of their product. The instructors of EMAD felt that if the engineering graphics were separated from the design course, the new course should show students how the computer model is created to reinforce their analytic geometry and vector skills in addition to teaching the student how to manipulate a specific computer aided design software package. The greatest concern in developing EG&CAD was that it should not be a simple skills course; the primary objective of EG&CAD is to teach solid modeling using a specific software package, not teach how to use a software package that does solid modeling.

In addition to the technical content, other requirements were considered. The first was that the computer software be a solid modeler; that is, a true three-dimensional modeler that would allow students to perform fundamental analysis such as mass and volume calculations with the software. In addition, it was felt that the creation of a solid would better reinforce the student's visualization abilities by making the students rotate the model from isometric to orthographic views and back. To ensure that companies hiring Rensselaer graduates would appreciate the students' knowledge of solid modeling, it was decided to select a package that was gaining recognition in industry. The software had to be simple enough to learn with a limited amount of lecture time. When the course pedagogy was developed (See 4.1 Engineering Graphics and Computer Aided Design), it was determined that any software package selected must clearly demonstrate the lecture topics.

In order to create the type of course and provide the necessary reinforcement in using the software in all of the design courses, it was decided to create a freshman level course instead of a sophomore level course. By introducing solid modeling in the freshman year, the connection with vector analysis is easily made with another required freshman course entitled *Introduction to Engineering Analysis* (IEA). Furthermore, it was decided to make the course a one-credit course with a final assembly project instead of a final exam. This final project serves as a small detailed design project in that students must create the piece parts of the assembly, create the assembly, and create all the documentation for the piece parts (detailed dimensioned drawings) and the assembly (assembly drawings with callouts and bill of materials). This final project provides the students with an opportunity to properly document a design and to time manage a five-week project. These additional skills better prepare the students for their sophomore design course and allows for further solid modeling skills to be developed.

3.2 System Requirements

During the evaluation of software packages, it was quickly determined that considerable effort had to be devoted to the requirements the software package would impose on the campus computer system. Rensselaer's computing system was collection workstations tied to several mainframe computers running AFS over UNIX. While slower than UNIX, AFS allows students to log on to any terminal and access their files. This system has been expanding and now includes many Windows 95 and Windows NT 4.0 platforms as well as several Macintosh systems. The goal of Rensselaer's computing services has been to supply software tools that will run on many platforms and be compatible among the different platforms. Help should be available on-line and the software must be installed and maintained by Rensselaer computing staff. The software should interface with other software on campus and should be usable in a variety of courses and curriculum.

Based on all of the requirements, Pro/ENGINEER from Parametric Technology Corporation (PTC) was chosen. In 1991, Rensselaer started using Pro/ENGINEER version 7 and is presently using version 18. The license with PTC gives Rensselaer all of the software PTC offers on all available platforms. In 1991, Pro/ENGINEER was installed on UNIX, today it is installed on UNIX and Windows 95 and Windows NT 4.0. The complete package with help files requires just over one gigabytes of storage. Help is available within the package and is stored as local Internet pages. Questions and problems with Pro/ENGINEER are first handled by local staff who will pass problems they can not solve along to PTC; this is done to ease the number of calls to PTC. A student version of the software PTModeler is available to students who want solid modeling capability on their PC; PTModeler runs on Windows 95 or Windows NT 4.0. PTModeler files can upload to Pro/ENGINEER but Pro/ENGINEER data can not be loaded into PTModeler.

4.0 Course Description

4.1 Engineering Graphics and Computer Aided Design

The course outline for EG&CAD is shown in Table 1: Course Pedagogy For Engineering Graphics & Computer Aided Design. The course meets for three hours, once a week. The first forty five to fifty minutes are devoted to lecture and the remaining time the students work on problems based on the lecture material. The course meets in a computer terminal room with either IBM workstations or Unigraph workstations. During the laboratory session there are the instructor and two teaching assistants (usually one graduate student and undergraduate student) providing an eight to one teaching ratio. The lectures and assigned problems are contained in [3.] and stored as training files. There are a total of twelve lectures that take the student through the process of creating modifying and documenting engineering piece parts and assemblies. The remaining two class periods are devoted to a small final project which consists of a small (five to seven piece) assembly that must be created and documented on-line. Students have the option of submitting their own final project with approval from their instructor. One self-directed final project is chosen by the EG&CAD staff for the MacFarlane Prize as the best graphics project of the freshman class. Several of these projects from the past five years may be viewed in [4.].

Table 1: Course Pedagogy For Engineering Graphics & Computer Aided Design

Session	Topics
1	Pictorial and orthographic representation, base features, dimensioning, use of sketcher
2	Part mode-base features, creation of solids by extrusion and revolution
3	Part mode-base features, creation of solids by sweeps and blends
4	Modifying base features using placement and sketching planes to remove or add material
5	Modifying base features using datum planes as sketching or reference planes
6	Creating patterns and establishing relations
7	Freehand sketching isometric to orthographic straight lines, Pro/ENGINEER drawing mode
8	Freehand sketching isometric to orthographic arcs and curves, Pro/ENGINEER geometric construction and dimensioned drawings
9	Freehand sketching orthographic to isometric straight lines, Multiview drawings
10	Freehand sketching orthographic to isometric with arcs and circles, Auxiliary view drawings
11	Sectional views, full sections, half sections and revolved sections
12	Assemblies, assembly drawings, parts lists, balloon callouts
13	Course or Self-directed final project
14	Complete final project and course folder

4.1.1 EG&CAD Lectures with Pro/ENGINEER Training Files

In Figure 1 , a page from the manual describing the creation of a swept solid is shown. The student has this command structure for reference in their manual, but in addition, this slide is also created on-line via the training files. The training files are not interactive; the student can step through the programmed sequence at the pace set by the instructor. The training files are created in advance by building the lesson on-line. Pro/ENGINEER saves all commands during a session as an ASCII file. This ASCII file, a trail file, is normally discarded. However, it is possible to rename the trail file to a training file and modify it by inserting pauses, breaks, and explanatory notes. The training files and associated parts and drawings are stored in directories that may be accessed by the students. When the training files are run, the students will see the commands in Pro/ENGINEER activated with appropriate pauses and breaks. When the training file ends, full control of the Pro/ENGINEER session is returned to the student. The student can then immediately begin the laboratory assignment.

When teaching with the training files, it has been helpful to have a second person (normally a graduate teaching assistant) with the instructor to handle problems students may encounter. When teaching on the computer with students who often never used UNIX or a system as large as Rensselaer's, problems with loading the software, or memory often occur. While it is possible for students to share a workstation during lecture, students need their own workstation during the laboratory assignment. Having a person who can handle the problems that arise during lecture keeps the lecture on schedule and allows for all the students to have the full laboratory time available for their assignments.

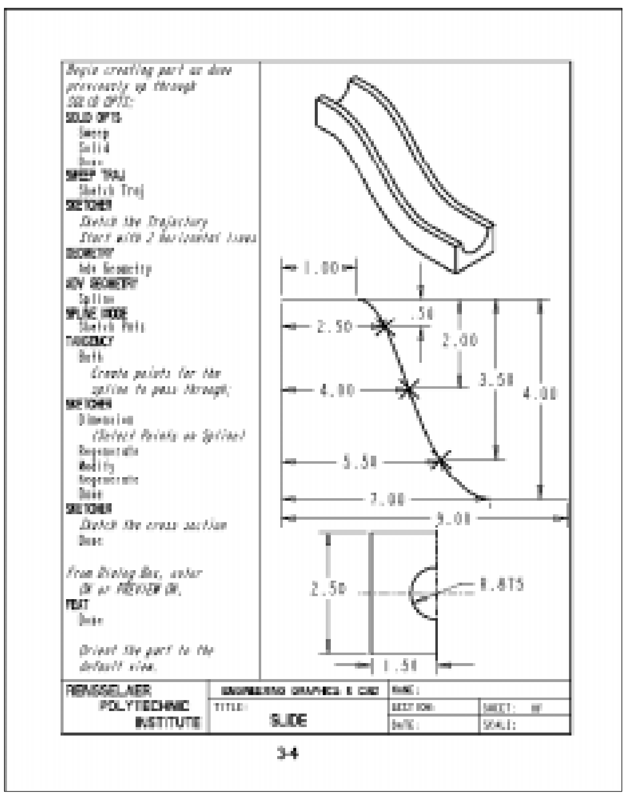

Figure 1: Text from EG&CAD Manual detailing the creation of a swept solid

4.1.2 EG&CAD Laboratory Assignments

Laboratory assignments are based on the lecture materials with either two assignments using the computer or one computer assignment and one hand sketch. A full list of the assignments can be found in [4.]. For many of the sessions, a variety of problems have been assembled to provide the instructors a choice of problems. Generally, students who finish the assigned problems prior to the end of class are encouraged to work on other problems in the session. Any opportunity for students to reinforce the lecture with laboratory assignments is encouraged. Given the amount of material presented in twelve hours, the lack of reinforcement through examples is the greatest weakness of the course in its present format. When students are capable of finishing their assignments early, additional work is available for them to further improve their skills. These students often are the design leaders for the CAD work in their design courses; any effort that can be made in EG&CAD to help these students is vigorously pursued.

4.2 Advanced Topics in Solid Modeling

In 1997, a new one-credit course in solid modeling was added to provide students with an opportunity to enhance their solid modeling skills. The course outline is shown in Table 2: Course Pedagogy for Advanced Topics In Solid Modeling (ATSM). This course is more of a skill course as it concentrates on using the advanced modeling features of Pro/ENGINEER. For ATSM, an assembly of the author's 125HP outboard engine was created in Pro/ENGINEER. The assembly is used to demonstrate the lecture topics. As with EG&CAD, training files are used during the lecture.

Table 2: Course Pedagogy for Advanced Topics In Solid Modeling

Session	Topics
1	Creation of parts and assemblies by datums and coordinate systems, assembly structures
2	Advanced sketching, splines, tangent conditions, reading ASCII data for points, curves, etc.
3	Advanced part creation, swept blends, multi-trajectory sweeps, general blends.
4	Surfaces by extrusion, revolution, sweep, and blend
5	Advanced surfaces, creation of parts from surfaces, quilts
6	User defined features, simplified parts and assemblies
7	Sheet metal design
8	Design project, motor crank arm, conceptual design
9	Design project, motor crank arm, animation modeling, determination of forces, velocities and accelerations
10	Design project, motor crank arm, finite element modeling
11	Design project, motor crank arm, finished design and detailing
12	Design project, motor crank arm, manufacturing
13	Course or Self-directed final project
14	Complete final project

The laboratory assignments are all based on a Blackhawk helicopter. The goal is to have student's work on one assembly throughout the semester to see how all of the topics of the lectures are contained in one assembly. Working on one assembly also has the advantage of introducing assembly management throughout the course. Students can not build the entire helicopter assembly in twelve laboratory sessions. At present, students have twenty-four laboratory assignments, which cover ten to fifteen percent of the total assembly. The students have the remainder of the assembly available to them to create the full assembly if they desire although that is not required. Further details on ATSM and some examples of former students' work can be found in [5.]

5.0 Future Work

Three items are being considered to improve EG&CAD. The first is to add more laboratory assignments to each session. The goal is to have three or four possible assignments for each assigned laboratory problem. Students have asked for additional problems to work on outside of class; additional problems in each session will provide them this opportunity. The second item is to consider using the one assembly approach in ATSM in EG&CAD. Students that have taken ATSM have commented that using one assembly to teach the material and one for students to work on in their laboratory assignments was very helpful in learning the material. The continuity of using one assembly appealed to the students. The goal for this item is to have a trial section of EG&CAD for the summer of 1998 where all laboratory assignments are based on a stapler assembly. In addition, for ATSM, additional problems can be created for the Blackhawk helicopter to allow students to work as design teams throughout the semester; that is, groups of four to six students could work together to create the helicopter assembly. This should enhance the assembly management skills of the students. The third item is to teach EG&CAD and ATSM on Windows 95 and Windows NT platforms. As students have Windows versions of the software available to them, it was felt that teaching on the Windows platforms is desirable. In addition, the cost of a UNIX workstation as compared to a Windows is much higher thus there is a possible cost advantage providing no loss of function is encountered using a Windows based system. The plan is to teach a trial section of EG&CAD on a Windows 95 system for the summer of 1998.

6.0 References

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3. Bunk, Donald S. and Baxter, Douglas H., *Engineering Graphics and Computer Aided Design (20-1200) Course Notes, 4th Edition For Pro-Engineer Version 18,* Rensselaer Polytechnic Institute, Troy, New York, 1997.
4. *Engineering Graphics and Computer Aided Design at Rensselaer* Internet homepage: http://www.rpi.edu/locker/85/000685/public_html/
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7.0 Biographical Information

Douglas H. Baxter is presently the course coordinator for Engineering Graphics and Computer Aided Design at Rensselaer Polytechnic Institute. He is presently completing his doctoral studies. Prior to teaching, he worked as a heat transfer engineer and finite element analyst for International Business Machine Corporation.