Constraint-Based, Three-Dimensional Solid Modeling in an Introductory Engineering Graphics Course: Re-examining the Curriculum

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Abstract

The content of engineering graphics courses has remained the same for many decades. When three-dimensional modeling became available, many educators considered the new technology a novelty. Industry, however, realized the potential of using the 3D model as the center of the design process, deriving from it drawings, documentation, and other technical information instead of seeing it as an end in and of itself. If educators are to prepare able practitioners to accompany this change in industry, the current curriculum content must be re-evaluated. The Graphic Communications Program at North Carolina State University is exploring ways to better prepare students by examining the content of the introductory courses in an effort to determine core concepts that adhere to a solid modeling-based curriculum. During the spring 2001 semester, a pilot study was conducted in an introductory engineering graphics course using a proposed alternative curriculum focused on constraint-based, 3D solid modeling. This paper will introduce a rationale for the proposed curriculum, and outline the main topics of the curriculum.

I. Introduction

The engineering design graphics curriculum is at a crossroads. Computer technology is enabling engineers and technicians to design and manufacture parts without relying on two-dimensional drawings. The curricula at many universities and community colleges still spend a great deal of time focusing on 2D documentation drawings. This is even truer at the high school level. There are several possible reasons why some programs have not changed to a curriculum that focuses on constraint-based, three-dimensional solids modeling. One obstacle to this type of change has been the cost of hardware and software. Some constraint-based programs can cost tens of thousands of dollars and cannot realistically be purchased by small education departments. Within the last several years, however, the cost of these types of programs has come down [1]. Since some 3D modeling programs are as low as $150 and student editions of constraint-based modelers can be purchased for as little as $300, cost can no longer be an excuse for not including 3D modeling into introductory courses [2].

Another excuse for not revising the curriculum has been that students must understand 2D

geometry before entering a 3D environment. A recent survey of NAITTE, CTTE and EDGD members indicated approximately 57% of faculty still use manual drafting equipment in their curricula, most of which is focused in the freshman year [3]. Although many faculty might argue that swinging a compass is necessary to understand tangent geometry, no studies have been conducted to suggest that this is true.

Tradition may be the most prominent excuse for not revising the engineering graphics curriculum. The core of the curriculum, which has mainly focused on engineering drawings, has not changed much over the last 50 years. Computer-aided design has changed the way documentation drawings are produced, but many engineering graphics programs have not critically examined the way computer technology has influenced the design and manufacturing processes. Where in the past drawings were critical components of the design process, today they tend to be ancillary documents.

II. What Should the Curriculum Include?

The Engineering Design Graphics Division of ASEE is a diverse group including faculty from many engineering disciplines as well as several technology programs. Curriculum revision activities are underway at both national and program levels. Because the faculty and programs are so diverse, curriculum revision must fit within a large framework while also meeting the needs of the local program.

At the national level, several formal and informal curriculum revision activities are taking place. Barr [4] conducted a survey of 16 EDG members regarding the types of activities that need to be researched relative to the engineering design graphics curriculum. He reported that the most important topics were considered to be developing 3D visualization skills, parametric modeling, 3D solid modeling, manual sketching, and a new generation of teaching materials. Items considered of least importance were lettering, manual construction using instruments, virtual reality, descriptive geometry, and computational geometry. In a review of 3D modeling programs, Ault [5] concluded that there must be an increased emphasis on solid modeling, parametrics and modern graphical analysis within the engineering graphics curriculum. She also recommended that new teaching methods be investigated to ensure the effectiveness of graphics education. In a review of new technologies for engineering graphics, Miller [6] lists several topics that every program should emphasize – visualization, problem-solving, design-based exercises, engineering graphics standards, sketching, constraint-based solid modeling, and exposure to the latest engineering, computer-based technologies. He encourages the development of students who have both applied and theoretical knowledge, and suggests that this is necessary for their success in a digital world.

Several significant activities are also happening at the program level. The faculty at Purdue University has recently revised their curriculum in applied computer graphics. One of their concerns was that students be exposed to a wide range of 3D computer graphics areas at the

freshman level, so students will be able to make informed decisions about future careers. With this in mind, one of the introductory courses was revised to include the following: 3D modeling, visualization, 3D coordinate systems, geometric entities, isometric sketching, solid modeling, surface modeling, multiview sketching, the design process, sections, creativity, and lettering [7]. In a project that has national implications, Cumberland [8] surveyed 28 companies to identify areas of expertise necessary for the next generation of engineering graphics technicians. Based on the survey data, he concluded that engineering graphics programs should include the following: macro programming, data translation, file and data management, CAD standards, constraint-based solid modeling, web technologies, simulation and animation, internships, collaboration, and a study of current trends and issues.

III. Engineering Graphics at North Carolina State University

At North Carolina State University, engineering graphics is taught within the Graphic Communications Program, which is part of the Department of Mathematics, Science and Technology Education. Currently, students can receive a Bachelor of Science degree in Technology Education with a concentration in Graphic Communications. The curriculum includes the following courses:

- Foundations of Graphics
- Engineering Graphics II
- 3D Spatial Relations (descriptive geometry)
- Applied CAD & Geometric Controls
- Visual Thinking
- Advanced CAD
- Scientific Visualization
- Technical Data Presentation
- Concepts of Desktop Publishing

Students are required to take two courses (Foundations of Graphics and Applied CAD & Geometric Controls) and must take 4 other Graphic Communications courses. This allows some flexibility in their area of expertise. In addition to students majoring in our program, approximately 300 students take an introductory course in Graphic Communications each semester. Most of these are engineering students who are required to take the class. Others take the course to satisfy a general education requirement.

The focus of this paper is to examine the content of the Foundations of Graphics course. This course currently includes the following topics:

- Lettering
- Tools and line symbols
- Geometric constructions
- Multiview & pictorial sketching
- Multiview & pictorial drawing

• Design and manufacturing processes
• Dimensioning, sectional views
• Auxiliary views
• Working drawings

Homework assignments are completed via sketching, instruments, and computer-aided design. CAD assignments are integrated throughout the course and range from 2D geometric constructions to 3D solid modeling activities. Students also complete a final project, which typically consists of modeling a machine part and producing a detail drawing of the design.

IV. Revisions to the Introductory Course

The proposed revision of the introductory course is based on national trends in engineering graphics in both industry and education. Although some of the topics look similar to what is currently taught, the material in the revised course will be presented with the idea that the 3D model is the center of the design process. The proposed topics are as follows:

• Visualization
• Sketching
• Solid modeling
• Constraint-based modeling
• Geometry
• Dimensioning
• Multiviews and pictorials
• Manufacturing processes
• Working drawings
• Sectional views
• Auxiliary views
• Assemblies

Visualization

The development of students' visualization skills has been a priority for engineering graphics educators for many years. Three-dimensional modeling programs require students to be able to manipulate objects and workplanes in 3D space. In the past, educators have focused on developing students' spatial skills, but have not spent much time discussing with students how these skills are developed. The visualization component of the revised course will be woven throughout the semester. At the beginning of the semester, one class will be dedicated to administering a standard spatial visualization test and discussing research and educational methodology related to visualization.

Sketching

Being able to quickly communicate ideas is vital to many engineering professions. Sketching not only is a means of communicating ideas, but some educators have shown that it is one of the best

activities for developing visualization skills [9, 10]. Engineering graphics educators must continue to emphasize the importance of sketching and help students develop their abilities in this area. Sketching has always been a component of the introductory courses at North Carolina State University. Most sketching assignments are related to multiviews and pictorials (given these three views, sketch this pictorial). In the revised course students will be asked to keep a sketch notebook during the semester. Each week students will be given a sketching assignment. It may involve traditional sketching activities, but students will also be asked to sketch objects not typically addressed in engineering graphics classrooms.

Constraint-Based Modeling

In a survey of 28 companies, Cumberland [11] reported that constraint-based or parametric modeling tools are used more frequently than static solid modeling or surface modeling software. Sixty-eight percent of the respondents used constraint-based or parametric modelers as their primary source for creating new designs. Static solid modeling tools were used by 15% of the respondents for creating new designs. Although industry seems to be using constraint-based modelers, cost and ease of use have been reasons why some educators have not made the switch to this type of software. At North Carolina State University, AutoCAD® has been used in the introductory courses for the last 5 years. Students complete 2D geometric construction exercises before moving on to 3D solid modeling activities approximately halfway through the semester. During the spring of 2001, all laboratory activities will be completed using SolidWorks® 2000. Where in the past many of the CAD exercises have focused on creating documentation drawings, CAD exercises in the revised course will emphasize modeling concepts. One of the goals of the course is have students understand the importance of having the 3D computer model as the focal point of the design and manufacturing processes.

Geometry

As stated earlier, many faculty believe that using instruments to complete geometric construction problems is necessary for students to understand concepts such as tangency or locus of centers. This has been the main reason instrument work has been included in the introductory courses up to this point. Although geometry concepts will be covered in the revised course, no instrument work will be required of the students. Instead these concepts will be explained through manual sketching activities and profile sketching activities within SolidWorks® 2000. In addition to the 2D concepts associated with geometric constructions, students will examine 3D concepts as they relate to modeling primitives and complex solid shapes (sweeps and blends).

Dimensioning

Dimensioning activities in the introductory courses at North Carolina State University have focused mainly on aspects of documentation drawings. The faculty has emphasized correct dimensioning technique and providing necessary information to manufacture parts. Since detail drawings will not be the focus of the revised course, dimensioning concepts will relate to the information necessary for properly constraining 3D models and incorporating design intent into the models.

Multiviews & Pictorials
Since the main emphasis in the introductory courses has been correctly describing the size, shape, and manufacturing information of single machine parts, multiview drawings and pictorials have been the primary means for accomplishing this. Educators also use these topics in hopes of increasing students' spatial visualization skills. Traditional activities include constructing a multiview drawing given a pictorial, constructing a pictorial given a multiview, and adding missing views or missing lines to an incomplete multiview drawing. The intention in the revised course is to use multiviews and pictorials as a means for describing the shape of objects in a conventional manner and for a means for improving visualization skills.

Manufacturing Processes
A discussion of manufacturing processes has been included in the introductory courses to give students an understanding of the main methods for creating parts. Also included were the conventional ways of representing these processes within a detail drawing. With an understanding of basic manufacturing processes and dimensioning constraints, it is the intent that students will be able to model objects in such a fashion to reflect potential design changes.

Working Drawings, Sectional Views, Auxiliary Views
Typically working drawings have been the focus in introductory engineering graphics courses. Sectional views and auxiliary views have been presented as standard and conventional ways for representing objects on drawings. Although these topics will be covered in the revised course, the focus will be on using them to enhance model creation and comprehension. Students will examine these topics based on modeling strategies and not based on documentation requirements.

Assemblies
Currently, only a discussion of assemblies occurs in the introductory courses. Final projects involve modeling and creating a detail drawing of a single part. One of the problems that occurs when working with a single part is students do not get a complete understanding of how that part interacts with the other parts in the assembly. Final projects in the revised course will consist of modeling all parts in a simple assembly (3-5 parts), putting the parts together in an assembly, and creating a detail drawing of one of the parts. By completing an assembly, students will not only have to consider modeling strategies for a specific part, but also how a specific part interacts with other parts in the assembly.

V. Conclusion
As with all courses at university campuses, it is vital that faculty keep up with changes in technology. For many years engineering graphics concepts had not changed because technology was not advancing at a rapid pace. Over the last 10 years, however, educators have discovered that old standards, conventional practices, and teaching methods for engineering graphics no longer make sense when working with new technologies. Courses & curricula based solely on traditional engineering graphics standards and conventional practices will no longer meet the needs of students and their future employers.

The philosophy of the new introductory course at North Carolina State University relates to the importance of dynamic 3D models rather than static documentation drawings. Documentation is now a byproduct of the 3D modeling processes emphasizing the 3D model as a dynamic entity with drawings representing a 'snapshot' of the model at a point in time. Geometry and geometric constructions are understood through 3D-model construction. Dimensioning is seen as a means not of documenting a static representation, but 'driving' feature definition. Both dimensioning and geometric relations are seen as tools for embedding the design intent within a 3D model. View selection is driven by a goal of clear, unambiguous feature description. Pictorials, sectioning and auxiliary views are no longer techniques removed from the larger communication goal. With these changes, students should have a better understanding of current technologies as they relate to 3D modeling, engineering design, and manufacturing.

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