The 3D Model Centered Curriculum: How Do We Prepare Our Students?

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Abstract

Industry leaders have realized the potential of using the 3D model as the center of the design process. Now engineering graphics and technical graphics educators must adjust the curriculum to prepare able practitioners to address industry’s current set of demands. The “drawing” can no longer be the focus of all engineering and technical graphics courses. Students have a desire to leave the university with an education that will prepare them to fill a productive place in society, and industry expects them to be productive members of the corporate environment. Graduates must be well versed in handling digital information, specifically 3D models, and be able to extract documentation; translate, manage, archive, and store data efficiently; and communicate solutions to problems throughout the design process. The Graphic Communications Program at North Carolina State University is exploring ways to better prepare students by examining the content of courses in an effort to determine core concepts that adhere to a 3D modeling-based curriculum. During the spring and summer of 2001, introductory courses were revised to eliminate instrument-drawing concepts and place an emphasis on solid modeling and sketching. The next step is examining faculty philosophies and industry trends as to what should be the product of the curriculum. Several models have been presented over the last 15 years that have recommended a 3D model centered curriculum. Have faculty implemented these models? If not, why? This paper will introduce a rationale for the proposed curriculum; present core concepts of a 3D model centered curriculum; and outline possible courses.

Introduction

Over the last twenty years, engineers, technicians and educators have watched the development of three-dimensional modeling go from wireframe to solid. More recently, constraint-based modelers have replaced constructive solid geometry (CSG) modelers as the tool of choice for many engineering applications. These modelers place the 3D model at the center of the design process database. Over the last several years, engineering graphics educators have been adjusting their curricula to better prepare students to secure employment in environments where constraint-based modelers are used. One of the big concerns in engineering graphics education is the importance of documentation in the curriculum. How much time should be spent covering multiview drawings, standards for dimensioning and tolerancing, sectional views, conventional practices, auxiliary views, or geometric dimensioning and tolerancing? Do employers want students to know these “drawing” practices? Do they want students to be proficient in constraint-based modeling, animation, simulation, and technical data presentation? What should students know when they leave the university and what will they learn on the job?

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The EDGD Curriculum

Members of the Engineering Design Graphics Division of ASEE have been trying to answer some of these questions over the last decade. Curricula have been revised, but because of the diversity of the Division, it is difficult to reach consensus on a common curriculum. There are, however, common themes that seem to surface from most curriculum revisions. Surveying 16 EDG members regarding areas that need to be researched relative to the engineering design graphics curriculum, Barr 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. Ault recommended that new teaching methods be investigated in graphics education since there must be an increased emphasis placed on solid modeling, parametric modeling specifically, and modern graphical analysis within the curriculum. Miller suggests that for students to be successful in a digital world they must have both applied and theoretical knowledge. He recommends including visualization, problem-solving, design-based exercises, engineering graphics standards, sketching, constraint-based solid modeling, and exposure to the latest engineering, computer-based technologies in engineering design graphics curricula. In a survey of 28 companies, Cumberland identified several areas of expertise necessary for the next generation of engineering graphics technologists. The most important areas identified through the industry survey were 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.

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. The program moved from the college of engineering during the late 1970's. There it was housed in the Department of Mechanical and Aerospace Engineering. When the program was moved to the College of Education, it opened the possibility of expanding the curriculum to include courses outside the realm of traditional engineering documentation. Currently, students can receive a Bachelor of Science degree in Technology Education with a concentration in Graphic Communications. The following courses are available in the program:

- GC120 - Foundations of Graphics
- GC250 - Engineering Graphics II
- GC320 - 3D Spatial Relations (descriptive geometry)
- GC350 - Applied CAD & Geometric Controls
- GC410 - Concepts of Desktop Publishing
- GC420 - Visual Thinking
- GC450 - Advanced CAD
- GC496B - Scientific Visualization
- GC496C – Introduction to Technical Illustration
- GC496I - Technical Data Presentation
- GC496M – Web Page Development
- GC496N - Technical Animation

Students are required to take two courses (Foundations of Graphics and Applied CAD & Geometric Controls) and must take four 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 a revised curriculum where each course stresses a concurrent engineering design process with three-dimensional modeling at the center (see Figure 1). This curriculum design reflects the concurrent engineering design model of Barr, Juricic and Krueger while meeting the unique program needs at North Carolina State University and, potentially, future engineering graphics
curricula. While many faculty in engineering and technical graphics agree this type of a model is useful, there still seems to be a strong focus on traditional engineering graphics methods.

**Introduction to Solid Modeling**

Branoff, Hartman and Wiebe proposed revisions to the Introduction to Solid Modeling course based on national trends in engineering graphics in both industry and education. The topics included in the revised course included visualization, sketching, solid modeling, constraint-based modeling, geometry, dimensioning, multiviews and pictorials, manufacturing processes, working drawings, sectional views, auxiliary views, and assemblies of solid models. Although some of the contents of the course reflect a "drawing centered" design process, the focus of the course is on model creation and extracting information from the solid model. Emphasis will be placed on the decision-making process involved with creating constraint-based geometry and the development of modeling strategies that incorporate the intentions of the designer. Students will participate in activities that involve their analysis of geometry at a fundamental level, the relationships between geometric elements, and the new mentality of “modify and re-define” rather than “delete and re-create”.

**Surface Modeling**

The surface modeling course builds on the knowledge gained in the Introduction to Solid Modeling course. It uses surfaces to describe critical elements of the part from two different perspectives. A portion of the course will use a NURBS-based modeling tool to describe geometry in a manner that is consistent with industrial design practices. Simple and complex surface geometry will be created from all types of forms (extrude, revolve, loft, and blend) to imitate some of the more stylized products being produced today. Another portion of the course will expose the students to parametric surface modeling techniques similar to those used in a mechanical design environment to describe complex fillets and rounds, parting lines for molded or cast parts, and complex geometry for thin-walled objects. A final segment of the course will consider the differences
between the two modeling strategies and some basic translation techniques with regard to sharing surface geometry between software packages.

Component Interaction

Since most designs do not involve a single part, it is important for students to understand how to work with multiple parts in small and large assemblies. This content has traditionally been addressed in GC250 and GC350 with some focus on constraints between parts. For students to have a real understanding of assemblies, the following topics should be covered in a component interaction course: basic assembly construction, top-down construction, assembly skeletons, assembly layouts, parameters, constraints/mates, and tolerancing issues. Another important consideration for this course will be the treatment of assembly components at an operating-system level and the direct influence of the associative characteristics of a constraint-based modeling tool on the geometry modification process. Students will be asked to model existing objects and to create solutions to unique problems with an understanding that a critical attribute of their solution should be its ability to be modified.

Engineering Documentation

Educators in the EDGD include documentation in their courses because they feel students must be able to at least read drawings and understand standards and conventional practices since many industries still document their designs using traditional means. Some educators feel more of an emphasis needs to be placed on 3D documentation and product design intent. It is difficult to know how to prepare students in the best way since standards change so much slower than industry practices. With this in mind, students should at least be exposed to standards and conventional practices for representing objects (multiview drawings and sectional views), standards for dimensioning and tolerancing (including geometric dimensioning and tolerancing), auxiliary views, threads and fasteners (focusing on dealing with libraries of parts), and drawing templates. One of the objectives of this course will be on the interpretation of 2D documentation rather than the explicit production of engineering drawings. Students will also learn how to create templates and seed files to speed the creation of models, as well as potentially automate many of the mundane tasks involved with 2D documentation. Through the use of a constraint-based modeler, students can investigate how documentation can be added to the three-dimensional model and how traditional documentation can be extracted from the three-dimensional database.

Graphical Analysis

One of the most powerful aspects of maintaining a three-dimensional database is the possibility for graphical analysis. Constraint-based modelers have continued to integrate more analysis capabilities with their traditional model generating tools. They have also continued to add more options for exporting data into multiple formats so models can be analyzed in other programs. The activities of this course will be focused on analyzing the geometry of the design for initial gross errors. When finished with this course, students will not replace a person trained in analysis of systems and who has fifteen years of experience in that area. However, it is a goal that students, as a result of the activities in this course, will be able to make recommendations to a trained analyst after working with information at a basic level. For example, students might be able to interpret fringe plots on a basic level with regard to manufacturing potential of the object, examine assemblies of parts for clearances and interferences using tools resident in the modeling package, and perform basic motion studies with an animation or simulation tool. Students who are majoring in an engineering or technical graphics area need to have experiences with simulation, animation, and technical data presentation if they are going to be leaders in an ever-changing, competitive market place.
**Downstream Applications**

The impact of a 3D modeling-centered design process is most evident in downstream applications. While creating geometry is important, and in many ways crucial to the success of the design process as a whole, using a model for more than just documenting the design is where the true potential of this technology lies. Students with a good understanding of post-3D modeling processes involved in engineering design will be crucial to the success of an engineering design group. Companies spend hundreds of millions of dollars trying to make their process coincide with the whims of a particular software company, while seemingly never achieving a truly profitable or integrated position. Students will be given activities to address this deficiency by using the 3D model to extract vector-imaging data for technical illustrations. Students will also employ basic web creation techniques, both resident in the software and original, to publish information from the design process to internal and external individuals, and they will use the model as a basis for creating colored images to be used in corporate literature. In addition, students will be exposed to prototyping applications for the model and the generation of machining data to be used by other stages of the engineering design process.

**Data Integration**

Building on the ideas suggested in the previous course, students in the data integration course will examine the underlying constraints that typically impede the concurrent engineering design process. It is no secret that software companies tend to be very tight-lipped when it comes to sharing information about how their products operate with regard to their competitors' products. Given that all CAD software packages do not include all necessary elements to design and produce a product, it will be necessary to move design data between software packages. This has led to many stressful situations and countless monetary expenditures on the part of companies who use the software as they try to get their products to market. Students that understand different file types and translation utilities will be valuable assets. It will also be important that students understand the different database structures and modeling kernels used by these tools, as these are the things typically at odds during the data translation and integration process. Finally, students must have an understanding of the importance of having “good geometry” to start with. Geometry that is not created in an efficient and mathematically valid manner will wreak havoc in an unsuspecting downstream process. It is then critical that students be able to evaluate model geometry, based on agreed-upon modeling techniques, using manual as well as electronic “checking” utilities. The activities presented in this course will represent the aforementioned methods and ideas.

**Data Management**

Corporations around the world are always looking for an edge in the design of their products or their bottom line. One of the critical areas that was typically neglected until a few years ago was the wealth of data and knowledge that was contained in corporate engineering records. As companies transitioned from file cabinets to electronic databases, this information became more widespread throughout the company and less secure as a result. To fix this problem, companies looked to elaborate product data management (PDM) systems to address this problem; however, results were mixed. Initially the data was protected, but, in many cases, the authority and management of this utility passed to the IT department which typically did not have the ability or general awareness to deal with an engineering group. This has lead to engineering departments being constrained by the feudal policies of the IT group, and therefore, they are not able to manipulate their data as freely as needed. While the students in the data management course will not become certified IT professionals, they will have an understanding of a client/server environment and its implications on the privileges of the users. Students will also learn about different vaulting and security procedures involved with maintaining engineering data and sharing it across the enterprise. The activities in this course will be directed at basic hardware and software installation, configuration and management of databases, and a thorough understanding of the engineering lifecycle. This course will typically be taken during the latter portion of the curriculum, but everyone in engineering graphics courses could definitely feel its effects. As an
ongoing activity for this course, students will create and manage a data management, client/server environment with which all other courses will interact. Students in other courses will be submitting and withdrawing files based on their course needs, and the students in the Data Management course will be responsible (at least partially) for the operation of this environment. By using this scenario, everyone can see the importance and far-reaching effects of data management.

Conclusions

As engineering and technical graphics educators prepare for the future, it is vital that industry trends, as well as national and international standards, be examined in order to design curricula that best prepares students to enter the workforce. At this time, developing curricula around a concurrent engineering design process, based on a 3D model, is the only acceptable method for ensuring our existence. Industry is screaming at the top of its collective lungs for us to give them people that understand the concurrent engineering design process and the ability to move data throughout an enterprise. What we consider as new, industry considers a basic assumption – that the 3D model is the driving force behind all engineering information. Some educators have advocated that industry cannot determine its needs in regard to this issue, but it is obvious that they have. Three-dimensional modeling has become a mature, saturated market with only the top corporations surviving. In many ways, it has become a commodity, and education is very good at addressing “commodities”. We need to move past the point where we continue to question the viability and the effectiveness of the 3D model. Pick up any trade journal, and note the proliferation of articles, opinions, and editorials that comment on topics covered in the more advanced courses prescribed in the aforementioned curriculum. Three-dimensional modeling in many cases is covered in product reviews and case studies that appear, not as featured articles, but as general information. Industry has acknowledged the position and criticality of 3D modeling as the center of the process to such a degree that is considered a given. As educators preparing the next generation of engineers and technologists, it is our responsibility to put aside our misgivings, fears, and prejudices, and give our students the education that they need and deserve.

References


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