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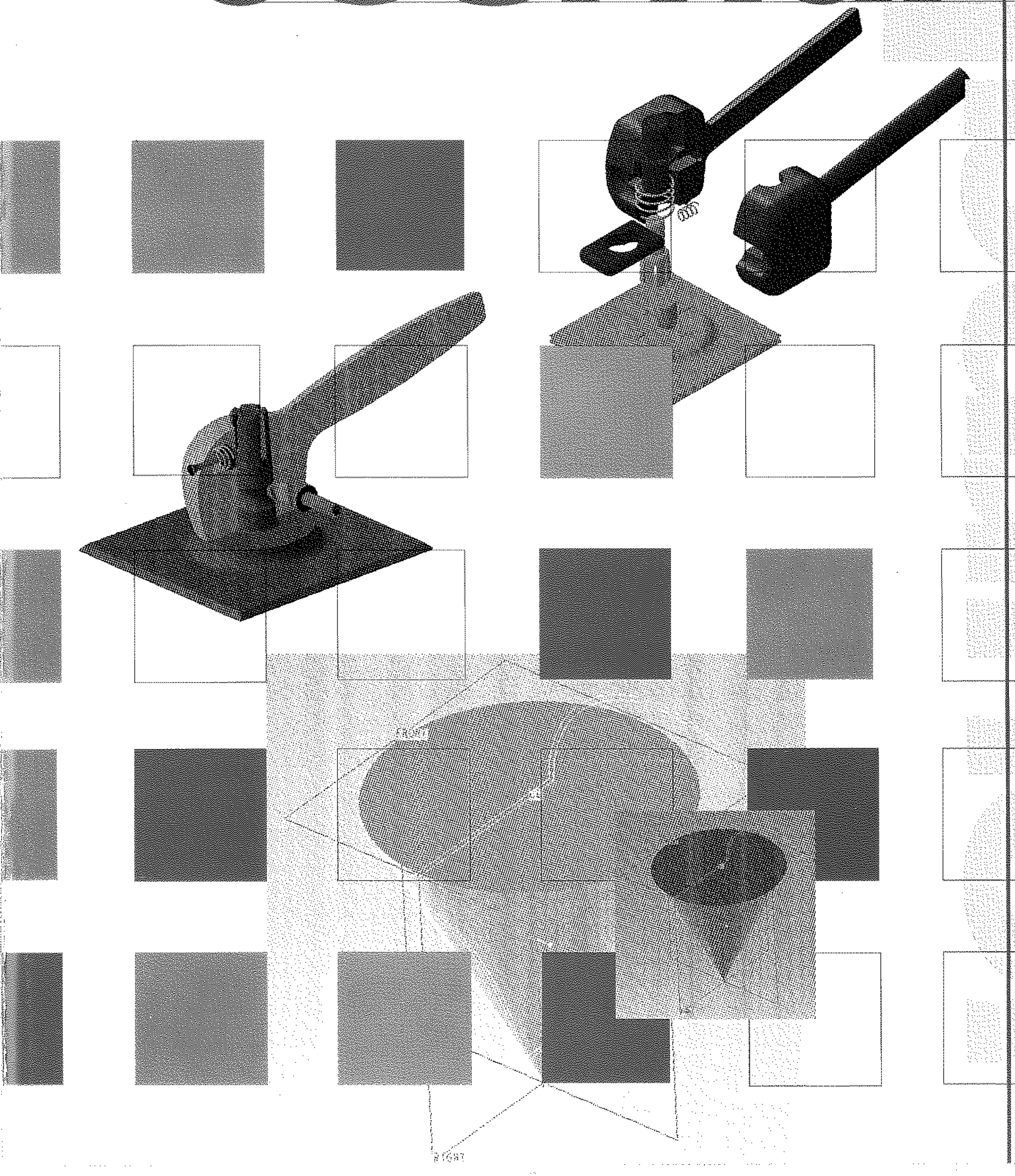
THE ENGINEERING DESIGN GRAPHICS Journal



ENGINEERING DESIGN GRAPHICS DIVISION ASEE

AMERICAN SOCIETY FOR ENGINEERING EDUCATION

THE ENGINEERING DESIGN GRAPHICS
Journal

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The Engineering Design Graphics Journal is the official publication of the Engineering Design Graphics Division of ASEE. The scope of the Journal is devoted to the advancement of engineering design graphics, computer graphics, and subjects related to engineering design graphics in an effort to 1) encourage research, development, and refinement of theory and applications of engineering design graphics for understanding and practice, 2) encourage teachers of engineering design graphics to experiment with and test appropriate teaching techniques and topics to further improve the quality and modernization of instruction and courses, and 3) stimulate the preparation of articles and papers on topics of interest to the membership. Acceptance of submitted papers will depend upon the results of a review process and upon the judgement of the editors as to the importance of the papers to the membership. Papers must be written in a style appropriate for archival purposes.

Cover graphics from the Groendyke and O'Dell article and by Josh Richard, a Computer Graphics student at Purdue Univeristy.

ISSN 0046 - 2012

[From the Editor]

Dear Members:

Membership concerns are still one of the top priorities of the division and Mary Sadowski's article in this issue offers some insights and alternative solutions to this problem. On the other hand, the article by Branoff, Hartman, and Weibe suggest that all engineering graphics programs should be integrating 3D constraint-based modeling technology into the curriculum. Many articles in previous editions of the *Journal* have likewise called for curriculum changes for engineering graphics programs. If engineering graphics courses do not change to reflect the needs of engineering programs and of industry then it might be very hard to recruit members into the Division if our focus is on outdated and historical curricula and courses. Enrollment in elective engineering graphics courses at Purdue University has exploded because students recognize the need to have applied knowledge of 3D constraint-based modeling and downstream applications such as working drawings, assemblies, analysis, simulation, product data management, and web collaboration. This interest has been so strong that a 3D modeling based minor has been developed and successfully implemented to the extend that these courses are being accepted as technical credit by different engineering and technology programs at Purdue University.

Finally, contact Ron Barr if you are interested in contributing to the Oppenheimer Endowment Fund. More information about this endowment can be found on page 4. I would also like to apologize for my absence from the MidYear Meeting in Berkeley. Like most states, Indiana is in the midst of a critical budget crises which resulted in no travel funds for our department. Thanks again for all of the encouragement and support you have provided to me as editor of the *Journal*.

Susan G. Miller

Susan G. Miller

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Message from the Chair

Mike Stewart
Georgia Institute of Technology

With spring come renewal and awakening from the throes of winter. As you read this, hopefully the weather is improving and Spring Break has come or is about to begin. Just as you are anticipating the warmer days of spring, you should also be anticipating the upcoming annual conference in Montreal in June. What a beautiful city to host our annual conference. Our Program Chair Holly Ault has planned a perfect venue for all of us. We will have a full slate of technical sessions as well as some delightful social gatherings and events for all of us to enjoy as we gather once more as friends and colleagues. Please begin making your plans for the annual ASEE conference, June 16-19 at http://ww.asee.org/conferences/annual2002. We hope to see you there.

The networking, contacts and knowledge available through our membership are beyond compare. But as a Division we are not very good at marketing ourselves. We need to sell our Division and ourselves to the educational community much better than we currently are.

Our Mid-year Conference was held at Berkeley, California, Jan. 6-9. Dennis Lieu was Program Chair and did an outstanding job of hosting our Division and provided an excellent program of technical sessions, short courses and local tours of the scenic Bay area. At the Conference it was our Division's pleasure to recognize Mr. Stephen Schroff of the Schroff Development Corporation as the first recipient of the Payne Award, for his support and encouragement to our Division. The Engineering Design Graphics Memorial Award was established in recognition of Rodger Payne who, during his association with our Division, epitomized the best in industrial and educational cooperation, was a strong supporter of graphics education, and became a true friend to each member who knew him. We congratulate Stephen and thank him for his continued support of our Division.

As members of our Division I cannot tell you how much you miss by not attending these annual conferences. Travel funds are often not available for educators to attend our conferences, but this year, Dennis Lieu was able to provide travel scholarships for 4 educators through the financial contributions of Autodesk and Solidworks to attend our conference. We would like to take this opportunity to thank each of our corporate sponsors who supported this year's conference. We hope to be able to continue helping educators in need to attend our conference next year.

Our Division is rich in its history and has many proud traditions, such as our Journal, numerous awards and our Mid-year conference, which we are all very proud, but our

Division is about the members. The graphic education community of men and women who educate a diverse student body in a myriad of educational programs at all levels of higher education. It is these members that the EDGD serves and supports. We need to find additional ways to support the needs of our members.

The networking, contacts and knowledge available through our membership are beyond compare. But as a Division we are not very good at marketing ourselves. We need to sell our Division and ourselves to the educational community much better than we currently are. Increasing our membership remains a major effort and issue that is addressed and discussed at each and every executive meeting. As a Division we need to decide how to expand our name and presence and take on the dominant role in the sphere of influence of graphics that we work and have our being. Membership will not be an issue if we provide the support and services educators in the graphics education community need.

As member of this Division and a people who have a passion for what you do, make known to us how we can move to that goal of dominance and help us take this Division to that level of prominence that we all want it to have.

Have a great spring and I will see all of you in Montreal in June.

Respectfully,

Michael D. Stewart
Chair

Liaison Committee

Pat Devens
Director

Doug Baxter
ASEE Relations Chair

Tom Krueger
Vendors & Publishers Chair

Jennifer Bahnsen
Industry & Manufacturer Chair

Aaron Clark
Professional Societies Chair

Mary Jasper
Membership Chair

Oppenheimer Endowment Fund

Dear EDGD Members:

The Engineering Design Graphics Division of ASEE is establishing an endowment fund for the Oppenheimer Paper Award, which is given each year to the author/presenter of the Best Paper at the annual EDG Midyear meeting. Frank Oppenheimer created the award to improve paper presentations at the EDG Midyear meeting, and he has personally sustained it financially over the last three decades. The purpose of the endowment is to permanently honor him and his contribution to the EDG Division by having a fund to support his award in perpetuity.

Individual EDG member donations are being solicited over the next several months until a target corpus is met. Several donations and pledges in the range of $50-$250 have already been received. If you would like to donate, write your check made out to "ASEE EDG Division," write a note for "Oppenheimer Endowment," and send it to:

Ronald E. Barr
Chair, Oppenheimer Endowment Fund Committee
Mechanical Engineering Department
Mail Code C2200
University of Texas at Austin
Austin, Texas 78712

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

Theodore J. Branoff, Nathan W. Hartman, and Eric N. Wiebe
North Carolina State University

chair's award
ASEE 2001 Annual Conference in Albuquerque, New Mexico

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.

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 (Miller, 1999). 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 (Nasman, 1999).

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 (Clark & Scales, 1999). 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.

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 (1999) 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 (1999) 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 (1999) 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 (Connolly, et. al., 1999). In a project that has national implications, Cumberland (2001) 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.

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.

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 (Sorby, 1999; 2000). 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 (2001) 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.

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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finite element analysis was conducted with ANSYS Design Space, version 6.

Pro/Engineer Modeling Techniques

The straight run (header) and the branch pipe were modeled as two separate cylinders and later assembled. The header is a nominal 12" sch. 40 pipe (12.75" O.D. and 0.375" wall thickness) with a diameter 4-5/8" cut in the top wall to accommodate the branch pipe. The branch is a nominal 4" sch. 40 pipe (4.625" O.D. and 0.280" wall thickness).

The reinforcing pad was modeled by creating a revolved extrusion in the shape of a cone. An extruded cut was then made through the cone in the shape of a thick arc, with the bottom radius of the arc equal to the outer diameter of the 12" nominal pipe and the outer radius .25" greater. The cut area was then flipped so that all material inside of the cut was kept while all material exterior to the cut line was removed. The center hole to allow for the 4" nominal pipe was created as an extruded hole thru the centerline of the pad. The reinforcing pad is modeled with a width of 5.25" and 0.25" thick. The 5.25" width is considerable wider than would be standard industrial practice. In standard practice, the reinforcing pad would probably be no more than 2" wide (one-half branch O.D.). The increased pad width was used in order to exaggerate the pads effect.

The weld around the outer perimeter of the reinforcing pad, which connects the outer edge of the reinforcing pad to the header pipe, is formed by two cones for its inner and outer surfaces, both cones intersecting a cylinder with I.D. equal to the reinforcing pad OD. The inner weld, which connects the inner edge of the reinforcing pad to the branch pipe, is formed by vertical cylinders at both its inner hole and outer circle, intersecting a cylinder with I.D. equal to reinforcing pad O.D. It will be seen that both weld cross sections approximate rectangles rather than geometrically correct triangles. Later, in the stress discussion, it will be shown that this deviation from the theoretical shape is not significant. Figure 2 depicts a cross section of the model showing the various cones and cylinders used to create the reinforcement pad.

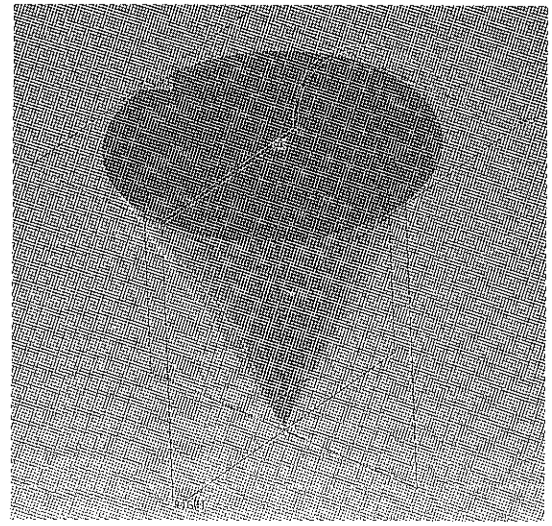

Figure 2 *Modeling of Reinforcement Pad*

The model as created thus consists of five parts-the header pipe, the branch pipe, the reinforcing pad, the reinforcing pad inner weld and the reinforcing pad outer weld. There are then several options in terms of joining the part parts into one model. They can be "merged" into one part. They can be put together as an "assembly" and fixed in proper relationship through the use of various "constraints" from within the finite element program. These techniques will be discussed in the next section.

Modeling for F.E.A.

Design Space is a relatively new offering from ANSYS. It is intended for mechanical designers in evaluating preliminary designs as opposed to the rigorous stress analysis used in the final design phase. Compared to ANSYSís traditional stress analysis program, Design Space is easier to learn how to use, but more limited in applications and user choices.

Design Space starts a new database for analysis from an existing Pro/E geometry model by allowing the user to select an open and active model in a Pro/E session. These models may either be a part or an assembly. Once imported in, the geometry cannot be modified in Design

Space, rather for changes in geometry the user makes the updates in the actual Pro/E model and from Design Space selects update geometry.

Since the Pro/E model becomes the input model for the finite element model, special attention must be paid to how the parts are set up in Pro/E. For a Pro/E part, the user does not have to worry about contacts, as the Design Space will read the file as a single part. For Pro/E assemblies, there are a several schemes of contacts available for finite element analysis.

Our initial concept was to model the part as an assembly and run multiple cases including one in which the assembly model was "merged" into a single part. At the time of this writing we have not succeeded in "meshing" this model in Design Space. Further investigations are needed in order to create a useful finite element model of the "one solid" type.

When a model consists of several components, Design Space provides for four types of interaction between those components that are touching each other. The contact options concern how the surfaces of the parts are permitted to move relative to one another.

The default configuration is "bonded". There is no sliding or separation between surfaces and any gaps are closed. This contact assumption results in a linear solution, because the contact areas cannot change when load is applied.

Another contact option is "no separation". The parts maintain separate identity. No separation is permitted to occur between parts, but relative sliding, without friction, is permitted.

"Frictionless" differs from "no separation" in that separations, or gaps between parts in contact, are allowed to occur, along with sliding, with a coefficient of friction of zero.

"Rough" works like "frictionless" except that the coefficient of friction is infinite. Both "rough" and "frictionless" yield non-linear solutions because the contact area between parts can change, due to relative movement between them.

Finite Element Analysis

In the case considered in this study, the question of interest is whether there are significant differences in calculated stress results based on various contact assumptions.

The two assumptions at opposite extremes whose stress results could be compared are that, on the one hand, all of the parts are "merged" into a single part, or that, on the other hand, the parts are constrained relative to one another only at the three weld lines.

In the case of a header/branch intersection, in the case of piping, or a nozzle on a pressure vessel, the applied loads can in general take the form of internal pressure or vacuum, external pressure or vacuum, or independent forces and moments acting on the intersection. These most typically result from connected piping interactions and thermal expansion, but also arise from wind, earthquakes, etc. In this study we consider internal pressure effects only.

The nature of the construction is such that internal pressure does not cause either separation of, or sliding between the parts. For this reason it has been a common practice to model and analyze these intersections as single, solid models. As stated earlier, we were unable to mesh a solid model, so we used as a substitute an assembly in which all parts are to be considered "bonded".

The next case that we used was to assume the pad was not "bonded" but in a "no separation" state which is similar to the real life application in which the outer and inner weld areas are the only places where the parts are bonded.

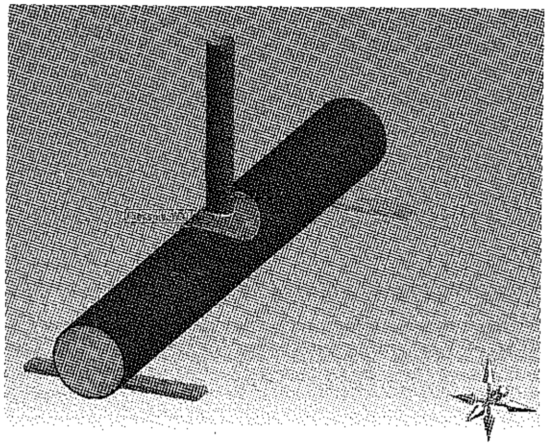

Figure 3 Model Constraints

The final case was an assembly without the reinforcement pad as a baseline case to show the improvement in lowered stress from the pad.

In all three cases the following constraints applied. The assemblies were "fixed" at the bottom surface of the two pipe supports spaced 80 inches apart. A pressure of 600 psi was then applied to all internal surfaces.

ANSYS Design Space in its current form allows the meshing of solid geometry parts using a 10-noded tetrahedral, 20-noded hexahedral, and 15-noded wedge elements. The user can either specify that Design Space optimize these elements or can specify that all tetrahedron elements be used. The user may specify the relevance of certain parts and add refinement controls to mesh critical areas more finely. The choices in this regard are much more limited than in standard ANSYS. For our analysis, we allowed the program to pick the shape and size of the elements. During various refinements, we saw no significant difference in stress results, but did see a significant increase in time to solve in the finer mesh models.

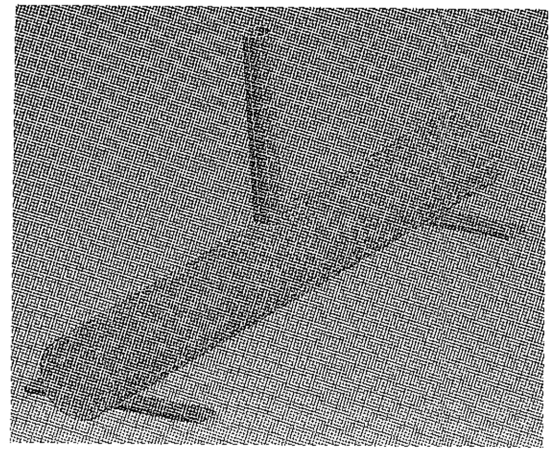

Figure 4 Finite Element Model, Meshed

Conclusions

We encountered the most difficulty performing the finite element analysis on the solid model. Initially, this is the case where we expected the fewest difficulties. We suspect, but have not yet confirmed that these problems are due to using the merge function within Pro/E. ANSYS Design Space was unable to mesh the Pro/E model after it has been merged. For future studies, we must resolve these issues, since merging and meshing solid models will continue to be a fundamental technique.

The stress results for the three different cases are as follows:

1. No reinforcing pad — maximum stress 27,785 psi
2. Reinforcing pad with contact as "bonded"- maximum stress 21,841 psi
3. Reinforcing pad with contact as "no separation" 21,645 psi

As discussed earlier, the weld shape used was not a triangular form, but a rectangular cross section. This was a limitation from the various different attempts to model a 3D object that changes dimension in both X, Y and Z planes as well as changing in angles relative to a curved surface. Attempts were made at using a "sweep" around a datum curve on the 12" pipe, but without success. An approximation of the large weld was done similar to the cre-

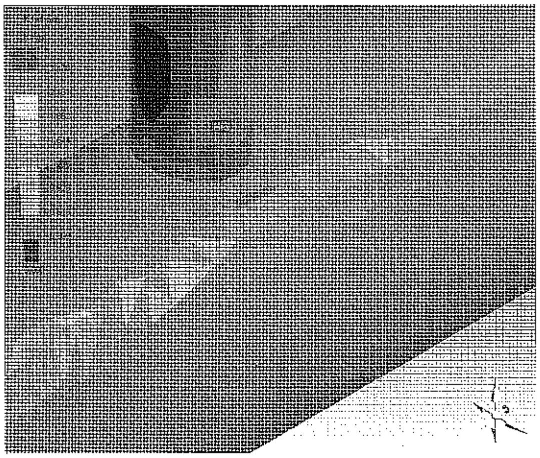

Figure 5 *Pipe Only Results*

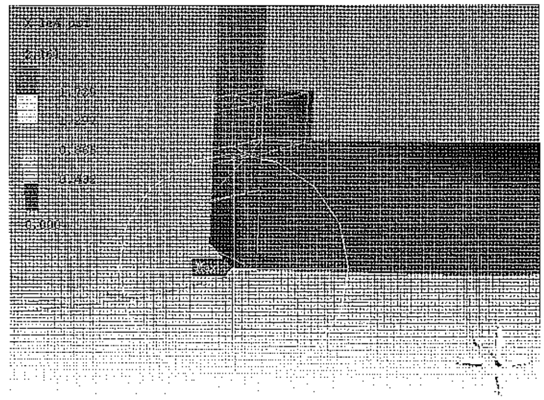

Figure 8 *"Bonded" Contact Cross Section*

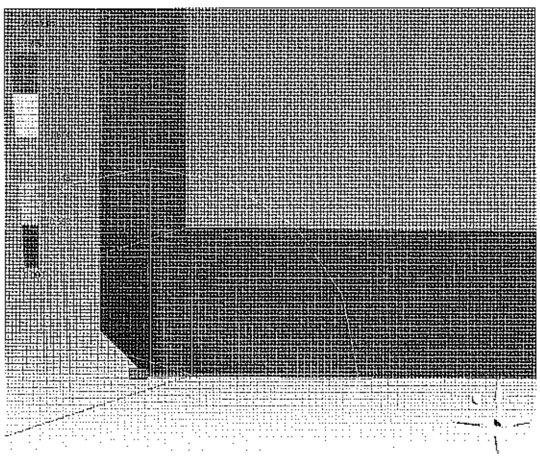

Figure 6 *Pipe Only Cross Section*

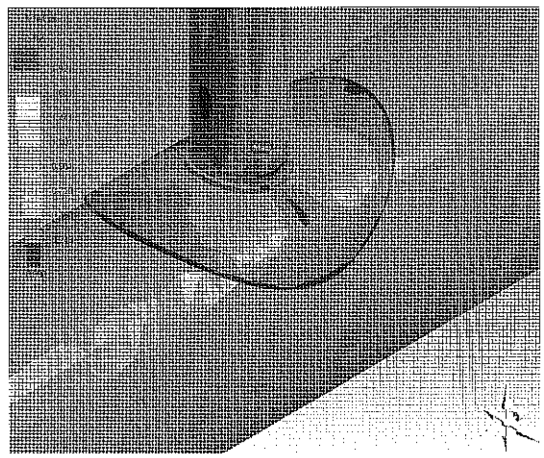

Figure 9 *"No Separation" Contact Results*

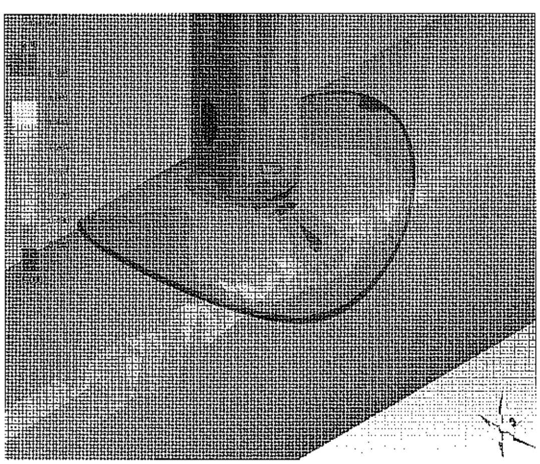

Figure 7 *"Bonded" Contact Results*

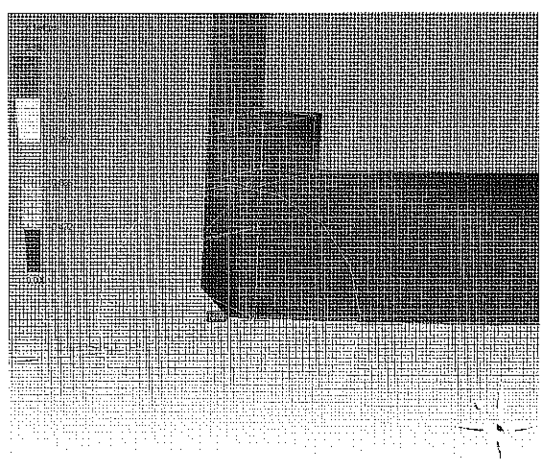

Figure 10 *"No Separation" Contact Cross Section*

ation of the reinforcement pad, as can see in the stress cross section of the parts, the extra material adds nothing of value and can be assumed to give similar results if a true shape can be approximated.

In summary, we consider these results to need of further verification before we consider them conclusive. So far we reach the following "tentative" conclusions:

1. Of the contact mechanisms so far successfully modeled and analyzed, there is not a significant difference in the resulting stress calculation.
2. The reinforcing pad is shown to effectively achieve its purpose, by reducing the maximum stress by about 25%.
3. Integration of Computer Aided Analysis with existing 3D graphical tools as in the case of Design Space and Pro/Engineer makes the evaluation of multiple design cases a relatively easy and quick alternative to traditional prototyping or existing full finite element analysis.

Referenced Software

Design Space) Version 6.0.0 SP2 by ANSYS, Inc.

Pro/ENGINEER) Release 2000i by Parametric Technology Corporation

Ensuring the Viability of the Engineering Design Graphics Division for the next 50 Years: A Brainstorming Activity

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Abstract

Since it was devised in 1940, one method for group creative problem solving has been brainstorming. This paper discusses brainstorming as a general technique and some of the different ways it can be used. The method used at the MidYear meeting in Columbus, Ohio where conference attendees participated in a brainstorming exercise is described. The question they were asked to consider was, "What is at least one thing we can do as a membership to ensure the viability of our Division into the next century?" This paper presents the results of the brainstorming activity conducted at that meeting. Over 60 different suggestions and a variety of comments concerning EDGD viability were collected. After eliminating duplicates and separating into like categories, several themes emerged. These themes are presented as well as some of the actions that are currently being taken by the Division.

Introduction

As an organization the Engineering Design Graphics Division of ASEE has existed for over 50 years and many of us hope that it will survive another 50. Over the past 10 to 15 years we have observed Engineering Design Graphics Departments disappearing from major universities. Some have been dispersed throughout different departments and others have taken up residence in schools of technology. Our membership although steady, has many members who will soon be thinking of retirement. As a Division of ASEE, we need to find ways to attract new members and retain the current membership. The brainstorming activity described in this paper was used as a method for gathering data about this issue.

Brainstorming

Brainstorming is generally considered to be a group approach to creative problem solving. The classic brainstorming method was developed in the 1940's by Alex Osborn and has been widely used throughout many industries when attempting to find new design solutions, create marketing strategies, define product lines, solve space problem etc. Brainstorming is a powerful strategy that taps into important characteristics of group dynamics (Ayan, 1997). It takes advantage of the synergy generated by a group rather than relying on the isolation of the individual designer. Brainstorming can help individuals break out of their own rigid way of thinking and open them to the suggestions and insights of others.

When brainstorming, there are several things the participants should keep in mind. Nierenberg (1982) suggests that there are three rules for brainstorming.

Quantity vs. quality: Generate as many ideas as possible looking for quantity rather than quality. Wild, crazy, oddball ideas are encouraged. It is often these oddball ideas that when refined, become the most original ideas.

Hitchhiking or ping-ponging is encouraged. Participants should be aware that not all ideas have to be completely new. They can build, expand, refine, modify, or combine ideas that have already been presented

Criticism, verbal or non-verbal, is initially not allowed. For brainstorming to be successful, the participants and leaders must remain positive and accepting of all ideas. Humor is accepted, but no ideas are turned down because they are vague, imprecise, considered to be wrong, or too far out.

Methods of Brainstorming

There are a number of different methods for conducting a brainstorming session. Considerations must be given to the size of the group, the problem to be solved, the physical location and expertise of the participants.

The most common method of brainstorming is often referred to as free-wheeling. Everyone in the group is encouraged to toss out ideas while the facilitator writes them down. Although easy to conduct, there can be disadvantages to this method. Although most of the group members will actively participate there will be some individuals who are naturally reticent or who will feel intimidated and not offer their suggestions. Good ideas often come from the quieter members of the group, so they must be given an atmosphere that will encourage their participation. Some control must be maintained so a free-for-all does not emerge.

The Delphi method is considered a form of data gathering or brainstorming technique that is used when the participants are not in the same location. A selected panel of experts participates through a series of mailed questionnaires. More recently electronic Delphi's have emerged as an alternative to traditional mailings. A problem can be posed through email and panel members can respond almost immediately via electronic mail.

When a large group is involved the panel method is sometimes employed. Volunteers from the group are chosen and form a panel. The panel then verbally brainstorms for 10 to 15 minutes while the rest of the group listens and jots down their own ideas. A second and even third panel can then be selected to continue the work of the first panel. In this way the ideas can be refined and everyone gets to participate without the mayhem that sometimes happens when a large group is tossing out ideas at the same time.

While there are other Brainstorming methods including the Pin Card, the Story Board, Round Robin, and the Ringlii Process, (Lumsdaine et. al. 1999) for the EDGD MidYear meeting we utilized a version of the Crawford Slip Writing method. In the Crawford Slip Writing method participants are asked to write as many ideas as they can on individual slips of paper. The slips are collected and a different task force of people who have not participated in the initial data gathering is appointed to evaluate the ideas and arrive at a workable solution.

EDGD MidYear Meeting Brainstorm Session

As an organization we have existed for over 50 years and many of us hope that we will survive another 50 years. At the MidYear Meeting in Columbus, Ohio we took some time at the business luncheon to brainstorm. The brainstorming question was also posted on the EDGD listserve so those who weren't at the MidYear Meeting could also contribute.

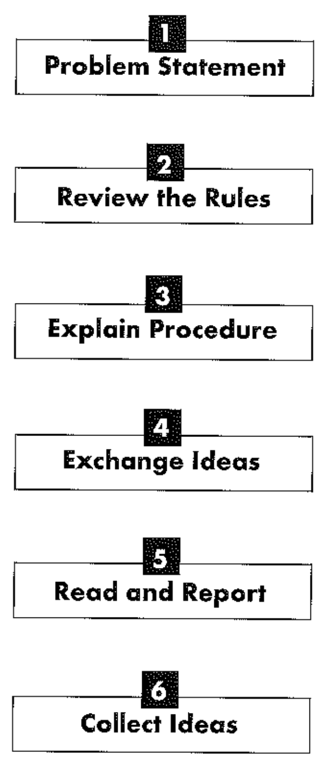

Figure 1 *The Brainstorming Process*

Problem statement

"What is at least one thing we can do as a membership to ensure the viability of our Division into the next century?"

Review the rules for brainstorming

- Quantity vs. quality - Wild ideas are welcome
- Hitchhiking is encouraged.
- Don't criticize

Explain the procedure

- Write your suggestion on the slips of paper provided
- Put your suggestion into one of the balloons
- You may write more than one suggestion, there are plenty of balloons.

Exchange ideas

- Blow up the balloon, tie it, and toss it into the air
- Keep all of the balloons in the air until time is called (Figure 2)

Read, modify, select and report

- Catch a balloon, pop it and read the idea written on the slip
- Return to your pre-assigned small group
- Read, discuss, refine, and modify your ideas
- Write your best ideas on a new slip of paper and then read your best ideas to the entire assembly. (Figure 3)

Results

There were 63 different suggestions along with several pages of comments. Because of the brainstorming format, all comments were anonymous. The suggestions are varied, but some of the more thought provoking ideas include suggestions to expand the mission of the Division, expand our horizons to include new technologies, and even to change the name of the Division. Notice that while there is some repetition in the suggestions each offers a unique perspective or solution. All of the suggestions were listed and arranged into like categories until several major categories emerged. These included some suggestions and actions for change.

Categories

Expand

Mission: Who we are and what we do
Membership: Expand the membership
Relationships: Cultivate our relationship with community colleges

Training and education for current members

Promote the organization - get the word out

Collaborate

Make changes:

Divisional Changes
MidYear Meeting Changes

Figure 2 *Writing suggesting and putting them in balloons*

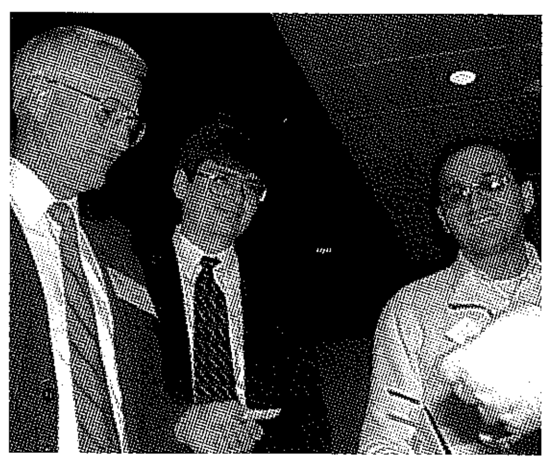

Figure 3 *Reading the best ideas to the group*

Mission: Expand who we are and what we do

- Expand our horizons to include "new" technology i.e. multimedia, web, etc
- Broaden the focus of papers in the Journal and papers presented at the MidYear and Annual Meetings
- Embrace and encourage web-based sharing and teaching
- Broaden the role that graphics, particularly the ever-expanding capabilities of computer graphics, plays in engineering education.
- Emphasize the expectation that students will use a much broader variety of graphic imagery in all phases of their engineering careers
- Broaden the mission of the Division in promoting graphic communication for engineers through any and every technical means available
- Diversify in membership as well as in content
- Expand into the areas of web and multimedia

Membership: Expand who we recruit and how to retain members

- Recruit new members from schools that aren't participating in ASEE/EDGD
- Ask each member to recruit 5 new members
- Invite members from related fields, i.e. animators who have their own societies
- Offer a free trip to either the MidYear or the Annual meeting for new members. Once they see how good the conference is they will come back
- Develop ways of attracting young faculty into the program
- Solicit new faces for leadership positions in the Division
- Offer "distinguished members" paid dues
- Involve designers from industry
- Invite a stranger to a MidYear meeting
- Offer a one-year free membership to "new" members of EDGD
- Increase our visibility, seek participation from other divisions
- Actively recruit EVERYONE, including DEED and other divisions, interested in the implications of graphic communications in engineering education.
- Recruit two-year CAD/ drafting and multimedia computer graphics teachers
- Maintain the people we already have. Don't let anyone get away. If someone doesn't renew their membership, we need to find out why and encourage them to come back.
- WIIFM (what's in it for me). We have to discover and then continue meeting the needs of all members and potential members. The more needs we can meet, the more we should be able to retain members, the key to the viability of the EDGD.

Expand our relationship with community colleges

- Make a greater effort to involve community colleges
- Go after junior and community college faculty
- Provide information to high school and community college instructors though A.V.A. and other vocational organizations
- Target other areas that use the same visual techniques we deem important, just not traditional engineering graphics (i.e. scientific visualization)
- Compile a valid list of Community Colleges which offer drafting and other graphics programs with the name of the person in charge of that program. These people must be kept informed of EDG activities, whether they are members or not.

Training and education for current members

- Offer "basic" and/or advanced graphics theory training sessions for members
- Provide EDGD subsidized multiple-day workshops
- Prepare people to teach Engineering Graphics through a wide variety of offerings
- Offer travel grants for attendance at MidYear and Annual conferences

Promote the organization - get the word out

- Presentations to commercial and industrial organizations
- Mail brochure to teachers of graphics across nation
- Advise community colleges of our organization

- Publicize the fact that the Journal is peer reviewed
- Make advertising videos (cd-roms) to give to schools
- Increase web-based information on EDGD interests and activities
- Create a more active web site
- Place papers on web for distribution and broader dissemination
- Provide as many links as possible to our site on the web

Collaborate

- Advertise/ encourage presentations from other related ASEE division members
- Think outside the box, get more universities involved
- Encourage paper collaboration between faculty from two or three universities.
- Collaborate with colleagues teaching in related areas
- Develop joint NSF proposals
- Make links with other universities to do graphics research, visualization and curriculum
- Tie in relationships with other divisions of ASEE and other related organizations

Changes in the Division

- A more representative name for the Division that includes new technologies
- Start a student organization or make it part of the Annual and MidYear meetings
- Graduate programs to prepare engineer graphics educators
- Establish a graduate curriculum in engineering graphics
- Excite students about graphics
- Simplify and promote the design project competition requirements
- Create a new need and awareness of the need of these skills to engineers
- Develop a better way of communicating between members (directory, e-mail)
- Concentrate more on helping non-participating members get involved
- Divisional name change to Graphic Communication for Engineering
- Be creative, take a chance in the classroom

Changes at the MidYear Meeting

- More discussions at meetings
- Workshops on new technologies
- Less quantity at meetings more focus on topics with discussions

Discussion from the EDGD Listserve

While most of the ideas suggested through the listserve have been incorporated into the list above, included here are some of the comments made by members that give support and expand on some of the ideas. As in any brainstorming activity, all comments and suggestions were anonymous. Several participants suggested that we consider actively broadening the mission of the Division in promoting graphic communication for engineers through any and every technical means available. Within the broader context, (perhaps a Divisional name change to *Graphic Communication for Engineering*) the role of the Division would be to greatly expand its development into the visual communication realm. This could certainly be used to attract a broader base of professionals into the field. If we're going to be successful at this, we must actively recruit EVERYONE, including DEED and other members from other ASEE divisions interested in the implications of graphic communications in engineering education.

Two target markets for membership are community college instructors and other areas that use the same visual techniques we deem important, not just traditional engineering graphics. The Division's future needs to include diversity in membership (community colleges) and content (Scientific visualization, multimedia, world wide web, animation).

The tables of contents in the 54th and 55th EDGD MidYear Meeting Proceedings show that several of the papers presented at these meetings veer away from the traditional Engineering Graphics topics. Topics have included papers on PDF technology, where GIS fits into the graphics curriculum, web-based interactive programs, interdisciplinary design topics, graduate teacher education programs, and preparation of images for distribution. This variety of topics supports the suggestion that we are broadening the definition of graphics as it pertains to the Engineering Design Graphics. As noted by the same conference proceedings, CAD and computer graphics with its ever-expanding capabilities continue to play a large role in engineering education. Although many of our members are involved in the teaching of CAD, modeling, object visualization and engineering design, the acceptance of this wide range of graphic topics at our meetings might suggest an expectation that students will be learning about and using a variety of graphic technologies and imageries.

At least one person expressed concern about the demise of the traditional engineering graphics programs by commenting that while some engineering graphics departments have survived there seems to be a trend to dissolve engineering graphics departments. A random sampling of the EDGD membership shows individuals in Civil Engineering, Mechanical Engineering, Industrial Technology, Computer Graphics Technology, Information and Management Technology, Engineering Technology, Ag Engineering, and Math Science and Technology Education. In at least one university graphics is taught within the Division of Engineering Fundamentals.

There were also comments that are not new to the EDG Division, a) we need to have a body of research, b) that research must be rigorous, and c) we need graphics degree programs.

Discussion of the Gathered Information

To make sense of all this information and look at the whole rather than all of the individual statements, we must condense even further. Several themes that emerge include: Expand, collaborate, change, include, promote, and train.

We must expand our own vision of who we are and what we do. We must be more than CAD and descriptive geometry. We must develop and encourage an interest in a more encompassing view of graphics. The job description of engineers has changed vastly over the past 50 years and so must the description of engineering graphics. This change will be difficult for some, but it will be beneficial for individuals as well as the organization as a whole.

We must promote the Division to other divisions within ASEE as well as people who have not been members before. We need to make industry aware that we are graphics and we must include them and get them involved in Division activities.

We must continue our efforts to maintain, expand, and diversify our membership. With the expansion should be the inclusion of a diverse population of graphicians and educators whose interests might include multimedia, World Wide Web, Distance Learning, Animation, even print. Gone are the days when ASEE had a quota on the number of non-engineers who were accepted as members. We must not be arrogant in our consideration of who might be valuable members of the Division and who will have important things to offer. We must look beyond traditional engineering graphics to community colleges, schools of technology, and other ASEE divisions.

Collaboration should be something we all consider. We can collaborate on papers, projects, programs, and grants within our own university or with other universities. Many granting agencies look favorably on proposals that show collaboration between institutions.

Some of the suggestions are already underway

- Jim Leach has been actively seeking new ways to add interested parties to the membership, and Mary Jasper has continued her efforts to entice community college instructors into our ranks. His efforts have resulted in 31 new EDGD members.
- The EDGD Brochure has been printed and can used to tell non-members who we are and what we do.

- Jon Duff has accepted the role as the Webmaster for the Division and has begun the process of updating and adding information.
- North Carolina State, Arizona State and Purdue Universities, have established graduate programs in graphics.
- Dennis Lieu introduced a keynote speaker at the 56th Annual MidYear Meeting in Berkeley.

What Can You Do?

Read through the list and see what you can do as an individual. Do you know someone you can encourage to join the Division? Will you volunteer to chair a committee and then actually set goals and achieve them? Can you collaborate on a paper with someone who isn't a member and get him or her to attend an EDGD MidYear Meeting? Are there community colleges in your state that you could contact and encourage their graphics faculty to join?

Conclusion

Brainstorming used as a method for group creative problem solving was shown to be effective in eliciting responses from the Engineering Design Graphics Division members. The question, "What can we do to ensure the viability of out Division into the next century?" elicited a wide variety of responses. Review of the many different ideas resulted in five areas of suggested changes in the Division or ways to increase its membership. It is up to the leadership as well as individual members to act upon these suggestions and continue the efforts to keep the Engineering Design Graphics Divisions viable and healthy through its second 50 years.

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volume 66 number 1

Internet-based Distributed Collaborative Geometric Modeling

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Abstract

This paper proposes a real-time collaborative framework for geometric modeling. Different from conventional collaborative design environments, the proposed framework adopts a strategy in which a server manages the communication between team members and stores data while client-side applications have full geometric modeling capabilities. The modeling commands instead of the generated geometric models are transmitted to the client-side applications. This strategy minimizes network traffic by eliminating the need to download geometric data after each operation. The prototype environment developed for this research includes a general-purpose 2D drawing tool, a 3D modeling tool that supports extrusion and revolution operations, and a 3D rendering tool. Geographically dispersed users can work together to build the same geometric model collaboratively. Real-time information sharing was implemented. When one user initializes a rotation, other remote users can see the action on their computers. A chat room was used to help communicate among the users. The effectiveness of the collaborative environment was evaluated statistically. The assessment results show that the collaborative environment was useful in design education. Numerous Internet technologies, such as Java, Java 3D, Shockwave, and CGI, were employed to develop the environment due to their flexibility and low cost. The environment is open to the public at www.vcity.ou.edu.

Introduction

As engineering design becomes increasingly complex and international competition grows, both concurrent engineering and collaborative engineering are adopted by industry to coordinate product development (Prasad, 1996; Mills, 1998). This requires the involvement of designers from different departments in the same company, as well as from different companies. However, designers and experts are often geographically separated and it is expensive and difficult to move them all to the same working location. The ubiquity of the Internet however has opened a new window to develop unprecedented engineering design tools and thus provided a solution to these types of problems (Sun & Gramoll, 2001).

To use the power of the Internet for engineering design, this paper proposes a collaborative design framework that allows dispersed users to perform geometric modeling jointly over the Internet. Internet technologies, such as Shockwave, Java, and Java 3D, were employed to develop the environment due to their flexibility and low cost. The concept of distributed collaboration was also extended to engineering analysis, which was discussed in a second paper (Sun & Gramoll, 2001).

Researchers have investigated other distributed collaborative examples and addressed related issues from various angles. Kim, Lee, and Han proposed a prototype called Process-centric Engineering Design WorkSpace (PEDWorks) for distributed collaborative design (Kim et al, 1999). PEDWorks deals with the collaboration of multidisciplinary design teams who are geographically dispersed. No real-time manipulation of the same geometric model was supported in PEDWorks. Lee, Kim, and Han also proposed a prototype to implement web-enabled feature-based modeling in a distributed environment (Lee et al, 1999). They adopted a server/client model, in which a powerful solid modeling kernel runs on the server and a client works as an interface to issue modeling requests. Their prototype did not use synchronous collaboration among users. Sieve is a Java-based collaborative environment to construct visualization interactively (Isenhour et al, 1997), which allows multiple users to manipulate a data-flow network in real-time. The function of Sieve however was simple, and the user could not build geometric models dynamically. Senin, Pahang, and Wallace (1997, 1998) proposed a distributed object-based modeling and evaluation framework for product design. Its basic goal was to link distributed design modules and seek optimal design. Similarly, no real-time collaboration was implemented with this framework. Alibre Design investigates the possibilities of using the Web as a collaborative tool in the product design (King, 2000). The Alibre Design system must be installed directly in the client computer. To share CAD information seamlessly among design departments, non-design departments, and partners, major CAD suppliers introduced a software system called product development management, such as Windchill from PTC (2001) and MetaVPDM from SDRC (2001). This software system currently, however, centers on asynchronous collaboration.

Although work has been done on distributed collaborative design, few environments have implemented real-time collaboration. Conventional server/client models are usually adopted, in which the server is a powerful kernel while the client has limited capabilities. This paper proposed and implemented a different model with synchronous collaboration, in which the client has full geometric modeling capabilities while the server only takes care of communication and storage of data. While not tested, the system can also be used for synchronous education as part of a distance learning environment over the Internet. The client runs within the browser, and no installation is needed because it is completely web-based.

Overview of the Environment

In general, the collaborative geometric modeling environment presented here is a simple CAD program that provides a general-purpose 2D drawing tool, and 3D operations such as extrusion and revolution, as well as a rendering tool. However, it is different from traditional tools, because its internal design supports multi-user capabilities. Users within the same team can work on the same geometric model when they are geographically dispersed. Real-time information sharing and real-time manipulation of the same design object were implemented. Because it is difficult to implement natural communication features such as video over the current Internet due to the bandwidth limitation, only a real-time text-based chat room was developed to support communication with this basic prototype.

The collaborative geometric modeling environment works as follows. Assume there are three designers in a design team. Designer A is in California; Designer B is in Oklahoma; Designer C is in Michigan (Figure 1). First, Designer A and B log in the design environment. Designer A draws a line and Designer B sees it immediately; Designer B draws another line and thinks the location of first line is not good enough and moves the first line; then Designer A sees changes designer B has made. Designer C then logs into the design environment, and joins the work of the other two. Designer C immediately sees the work-in-progress from the other two designers. The main idea is that only one copy of the file is kept and the designers share the same design object. If Designer A disagrees with Designer C, Designer A can communicate with Designer C through a chat room. After the cross section is finished, it can be extruded to obtain a 3D object. Then Designer C feels that it is difficult to produce this part and wants to discuss it with other designers. Design C rotates the object and the peer designers immediately see the part rotation on their own computers. Then they can discuss the production problem while viewing the object from the same point of view.

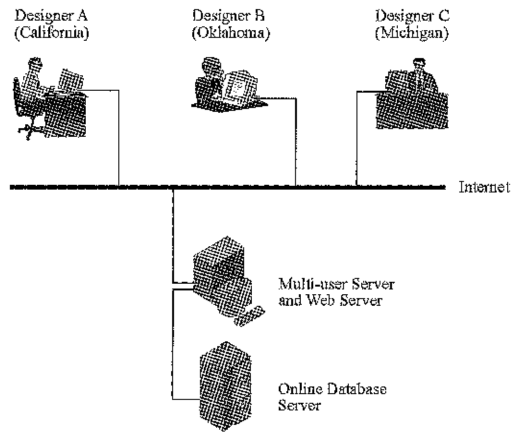

***Figure 1** Distributed Collaborative Design*

Design of the Environment

The geometric modeling environment is one such prototype that internally supports collaboration of remote users. It consists of two components: a client-side geometric modeling application, and a server-side application. The client-side application performs geometric modeling while the server-side application manages communication and storage of data. Two technologies, Java and Macromedia's Director Shockwave, were chosen to implement the environment due to their advantages of low cost, convenience, and collaboration. Java is a general-purpose programming language with high-level support of networking. Director Shockwave is a technology for web-based interactive graphic-oriented simulations. Director Shockwave technology was used for its ease of development and wide acceptance. However, due to its lack of 3D rendering engine at the time this research was started, Java was used to shade the wireframe geometric models generated by the Shockwave applet. It should be noted that just recently Macromedia has released version 8.5 of Director that included a robust 3D modeling and rendering engine.

Server-side Application

A server-side application is used in the geometric modeling environment to route messages to interested client-side applications and to avoid difficulties associated with direct communications. Direction communications require knowing each other's Internet Protocol (IP) addresses in advance. This is particularly inconvenient when a client computer is configured to obtain a dynamic IP address.

The server-side application used in the research contains numerous CGI programs and a multi-user application. The CGI programs were employed to save generated geometric data on the server and present the data to the user. The multi-user application includes two programs: a Director Shockwave multi-user server and a Java multi-user server. Both are capable of receiving and delivering packets to client-side applications. The reason for two multi-user servers is that the geometric modeling environment employed two different technologies: Shockwave and Java. Shockwave applications, developed by using Director, can only communicate with the Shockwave multi-user server while Java applets can be easily programmed to talk with the Java multi-user server.

The Shockwave multi-user server is a standard extension of Macromedia's Director program. There was no need to develop a new one for the Shockwave application. However, no standard Java multi-user server was available. Java was used to design a Java multi-user server for distributed collaboration. Socket implementation was chosen, because it is widely accepted in the networking world.

In a collaborative environment, discussion of design ideas before taking actions is encouraged. A chat room, therefore, was designed to allow the users to exchange ideas. When multiple participants are working on the same design object, they are strongly encouraged to coordinate their actions. This is because design is a constructive activity and makes sense for participants to communicate with each other in a collaborative environment.

Client-side Application

Similar to the server-side application, the client-side geometric modeling application also consists of two programs: a Shockwave application and a Java applet. The Shockwave

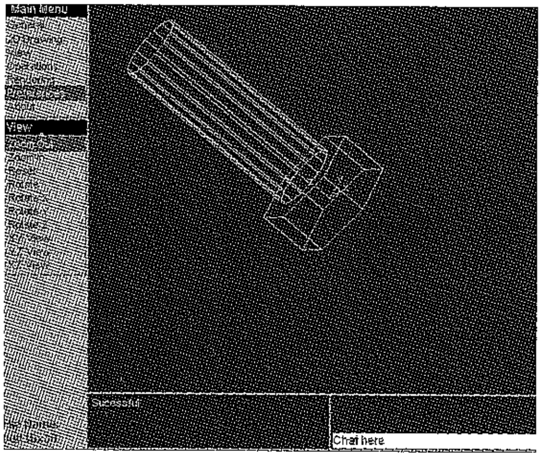

Figure 2 *Bolt in Wireframe*

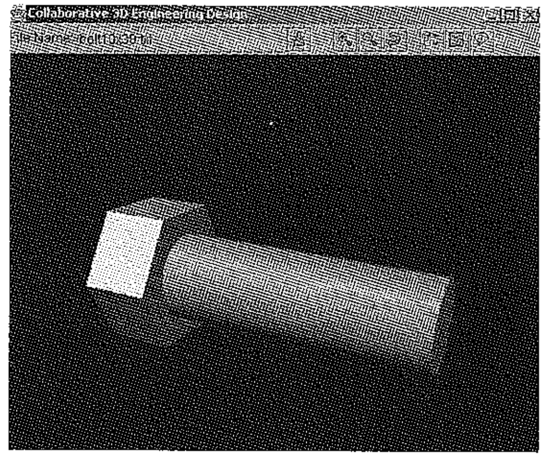

Figure 3 *Shaded Bolt*

application is used to generate 3D wireframe models (Figure 2) while the Java applet is employed to shade them (Figure 3). The Director Shockwave was used because it is easier and less time-consuming to develop the geometric modeling application than using Java. Director Shockwave technology is also widely accepted as a standard method to enhance the web with interactivity. The Java applet was developed using Java 1.3 and Java 3D 1.2.1.

The general procedure of building a geometric model involves a number of steps. First the user creates a 3D wireframe model, assigns it a name, and saves it on the server. The user then starts the applet, and selects the same name given to the wireframe model. The applet loads the geometric model data generated by the Shockwave application from the server, renders it, and displays it. Both work simultaneously to display the same model. If the user makes any change to the 3D wireframe model, the change will be propagated to the model automatically in the applet because they both share the same model name. As discussed previously, the Shockwave application talks to the Shockwave multi-user server while the applet communicates with the Java multi-user server. Both are real-time collaborative applications.

To develop the client-side modeling application, multiple data structures are employed. Among them, the B-Rep data structure and stack data structure are of particular importance. The B-Rep data structure stores the basic elements composing the boundary of a solid: the vertices, edges, and faces. Due to its simplicity, it is easy to program the B-Rep data structure to represent geometric models.

The stack data structure was adopted to program the Shockwave geometric modeling application when using Macromedia's Director. To display visual entities on the stage in Director, the entities must be placed in different channels. The channel is a container to store visual entities in Director. Because all of the line entities are dynamically created and may be deleted after creation, the stack data structure can be used to manage free channels. Director does not support a built-in stack data structure; however, it provides a list data structure that can be used to simulate the stack data structure. The concept of the stack data structure can then be used to manage the free channels efficiently (Figure 4). Free channels are pushed into a stack when the application starts. A channel is popped out from the stack when the application needs it. If a line on that channel is deleted, that channel is free again and pushed back into the stack for later use. Using a stack, the problem of keeping track of the free channels in Director was efficiently solved.

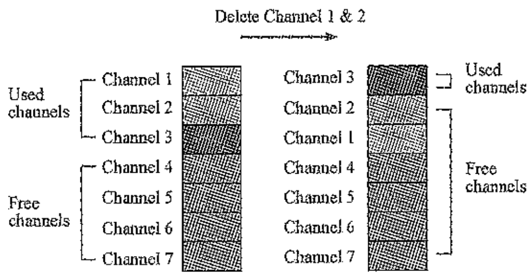

Figure 4 *Stack Data Structure*

Functions of the Client-side Application

The Shockwave application is a simple geometric modeling tool that allows the user to draw any 2D section, extrude it, modify it, save it on the server, and retrieve it from the server. The Shockwave application Interface contains three areas: the menu area for displaying menus, the working area for displaying geometric models, and the message area for displaying input and output messages as well as a chat room. The menu is designed with two levels. The main menu window is always visible while the sub-level menu windows become visible only when the user clicks on the corresponding main menu items (Figure 5). There are seven menu items in the main menu window: 'General', '2D drawing', 'View', 'Operation', 'Rendering', 'Preference', and 'About'. Among them, only the first four main menu items have corresponding sub-level menu windows. Because all of the menu-driven operations propagate automatically among shared users, the shared users can construct the same geometric model simultaneously in different locations. The user can also design buildings and deposit them in the 3D virtual world (Figure 6). The virtual world is an Internet-based virtual city whose structures are built by the use of various multimedia modules (Sun & Gramoll, 2001). One of its purposes is to provide the "big picture" of the generated structures.

Rendering is performed by the Java applet (Figure 3) because when the work was done Shockwave did not support the shading of 3D objects. The user selects the desired shared file name. The applet then downloads the data file from the server and displays it in a true 3D perspective. Geometric data is converted into an internal representation of Java 3D for rendering. The Shockwave application continuously updates the geometric data file on the server. The applet monitors any change made to the file. If a change occurs, the applet automatically downloads the modified data file and redisplays it in the applet. A corresponding Java multi-user server works simultaneously with the applet. If one user rotates the model, other users can see the action and simultaneously obtain the same view of the model. The color of the displayed geometric model can be modified, and any change to the color propagates to other users' applets.

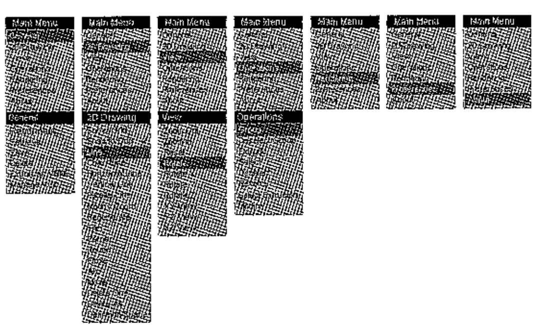

Figure 5 *Menu Levels of the Shockwave Application*

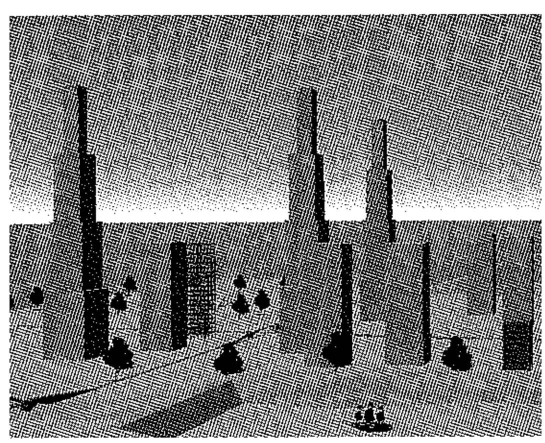

Figure 6 *Buildings Designed by the Geometric Modeling Application*

Assessment

One of the goals of the collaborative environment presented in this paper is for engineering education. Like industry, academic institutions need tools to help remote students collaborate on design objects when they take distance-learning courses. To better understand the usefulness of this program, an assessment was conducted at the University of Oklahoma in the spring of 2001. The design class, Introduction to Computer Aided Design (CAD), with seventeen senior and graduate students was selected because the students were also introduced to general-purpose and non-Internet-based CAD programs.

The survey was conducted in a number of steps. First, a class presentation was given discussing the purposes of the modules and showing the steps of how to use them. Second, an assignment and a survey form were distributed to the students along with help documents. The students were required to form multiple teams. Team members were required to work jointly on the assignment. Each team needed to submit only one copy of the solution. The assignment was graded satisfactory or unsatisfactory. Team members were required to submit the surveying form individually. The survey questions and their answers are presented in Table 1.

Surveying Questions and Results

Questions	Strongly disagree	Disagree	No opinion	Agree	Strongly agree
1. It is helpful if geographically distributed engineers can work in a well-designed collaborative design environment.	0	0	1	9	7
2. The Internet should be used for collaborating engineering design and analysis.	0	1	1	9	6
3. A collaborative design environment encourages spirit of teamwork when it is used to complete homework jointly.	0	1	3	8	5
4. A collaborative design environment encourages collaborative learning of remote users.	0	2	3	9	3
5. Internet-based engineering education with capabilities of 3D engineering design and analysis will be popular in five years.	0	2	6	5	4
6. It helped to collaborate online using the design environment for the homework.	0	4	6	5	2
7. It was easy to use the distributed collaborative design environment.	1	9	2	5	0

The total number of students that responded was 17.

Table 1

3D CAD Analysis of Space Trusses Based on Parallelepiped Method

Daniel M. Chen
Central Michigan University

Abstract

As low-cost, high-speed computing surges, the solid-based design tools are becoming more popular in engineering design. Many construction processes in descriptive geometry can be easily carried out on a 3D CAD system with high accuracy and speed. This paper describes the development of new approaches for the analysis of space trusses using 3D CAD. Various 3D CAD approaches were developed based on the parallelepiped method for the analysis of single-joint space trusses. One of these was further utilized in the analysis of multiple-joint space trusses.

Introduction

In engineering practice, it is often necessary to resolve a known vector into concurrent non-coplanar vector components. This is usually handled with the addition of cartesian vectors in statics of engineering mechanics (Hibbeler, 1986; McGill and King, 1995; & Soutas-Little and Inman, 1999). This can also be handled with graphical construction via the edge-view method or the parallelepiped method in descriptive geometry (Earle, 1984 & Pare, Loving, Hill, and Pare, 1997). The edge-view method uses an auxiliary view showing the plane of the two components in edge view. With this method, the number of unknown vectors would be reduced to only two and, thus, become solvable with vector polygons in both orthographic and auxiliary views. The parallelepiped method utilizes a prism with parallel lines in orthographic views, and the magnitude of components determined by either revolution or auxiliary projection.

Both methods require a series of geometric manipulations with scaled orthographic and auxiliary views. Although this time consuming and less accurate graphical construction on a 2D paper is manageable when dealing with a single-joint space truss, it is extremely difficult to manage for a multiple-joint space truss due to its much more complex geometry. Today, CAD systems with solid modeling capabilities are becoming more popular in engineering design. They allow the user to create 3D models from which the orthographic and auxiliary views can be easily captured. The purpose of this study is to investigate how 3D CAD can be utilized in solving space truss problems. Since the 3D CAD approach had already been developed based on the edge-view method in a previous study for the analysis of a single-joint truss (Chen, 2000), the focus of this study is, therefore, solely based on the parallelepiped method. Various 3D CAD approaches were successfully developed based on the parallelepiped method, which is much more efficient than the one developed from edge-view method. One of these 3D CAD approaches was applied further for the analysis of a multiple-joint truss. The software utilized was I-DEAS.

Parallelepiped Method

Figures 1, 2 and 3 are utilized to demonstrate how a parallelepiped is constructed. Figure 1 illustrates a simple tripod with non-coplanar members. A force of 60 N is exerted at the point of application, 0. Figure 2 shows the isometric view of this tripod. Since the exerted load, 0E, is a compressive force, it must be placed downward from point 0 to point E. Plane EST is made parallel to plane 012 with lines ES and ET parallel to members 01 and 02, respectively. Points S and T are arbitrarily located along the lines. Point c is at the intersection of member 03 and plane EST. Thus,

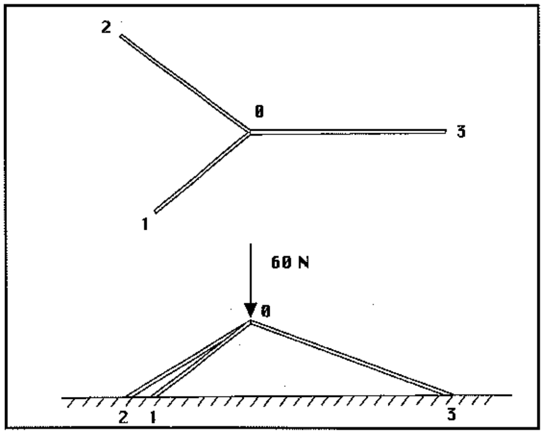

Figure 1 *A tripod with non-coplanar members*

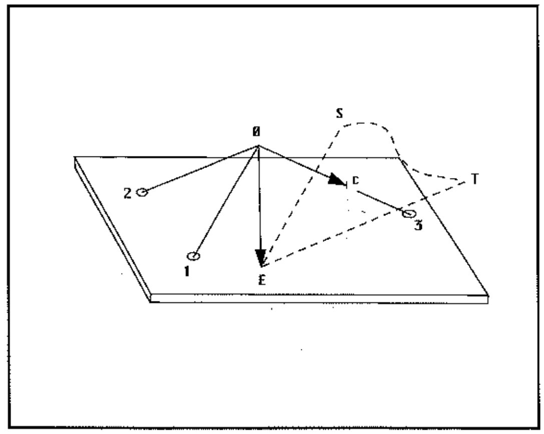

Figure 2 *Plane EST parallel to members 01 and 02 of the tripod*

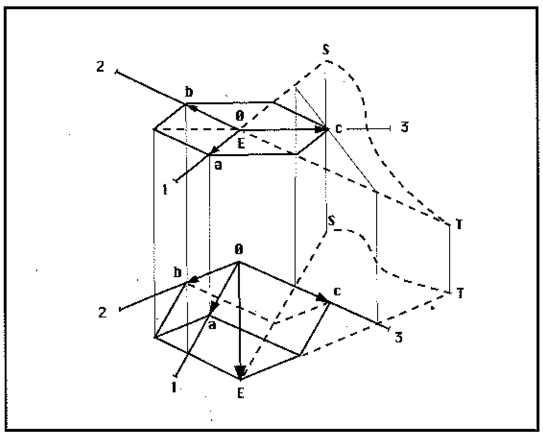

Figure 3 *The construction of parallelepiped*

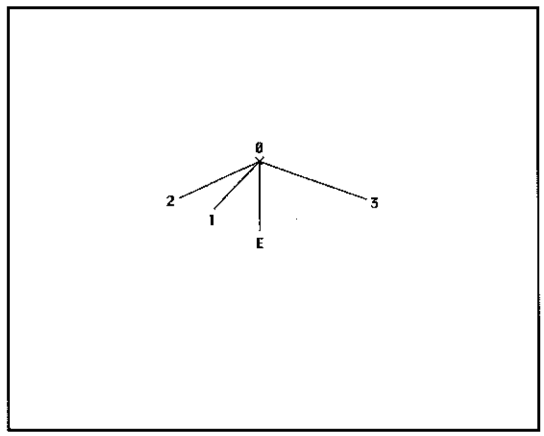

Figure 4 *The tripod and external load 0E in isometric*

the line from point 0 to point c represents the magnitude of the force in member 03. Figure 3 illustrates the orthographic views of the parallelepiped constructed. The construction process begins with determining the location of point c. From there the top view of the parallelepiped is completed with the edges coincide with the legs of tripod. The front view of the parallelepiped can be completed with the external load of 60 N as the diagonal (0E) of the parallelepiped. The magnitude of force in each member, which is the same as the length of its corresponding edge of the parallelepiped, is then determined with revolution or auxiliary views.

3D CAD Approach for A Single-Joint Space Truss

In order to demonstrate how a single-joint space truss can be analyzed using 3D CAD, the same tripod as illustrated in Figure 1 is also used here.

Original Approach

The 3D CAD approach is based on the assumption that if the force in one of the three members is determined, the force vectors in the last two members can then be laid on the same plane. The force in the first member is determined according to what described in the first half of the parallelepiped method. The required procedure is as follows:

- Set up the space diagram of the tripod first as shown in Figure 4. This can be done via drawing lines 01, 02, and 03 for three members using the CAD command of "3D line" (Lawry, 1999). Then, set up another "3D line" 0E equal to the vertical external load of 60 N based on a scale of 1 mm = 1 N.

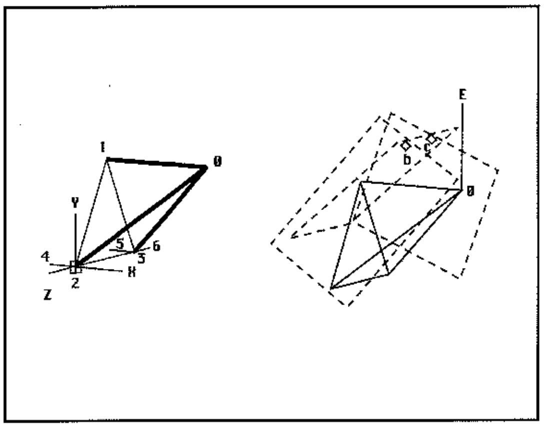

Figure 11 *Analysis of joint 0*

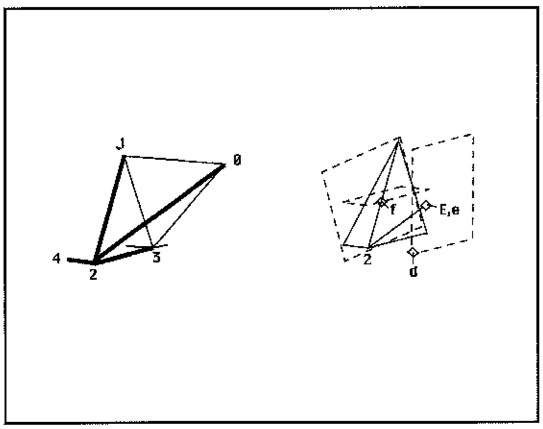

Figure 12 *Analysis of joint 2*

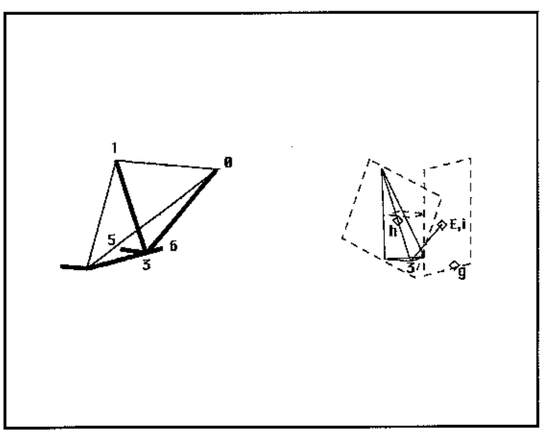

Figure 13 *Analysis of joint 3*

with the same alternative approach. The forces in members 12 and 24 are, therefore, equal to the distances from point E to reference points d and f, respectively. It is noted that point e overlaps with point E in this case. This implies that the force in member 23 is zero. Figure 13 depicts how joint 3 is analyzed. The force in member 03, which has already been determined, is used to set up line 3E. The forces in members 13 and 35 are, thus, equal to the distances from point E to reference points g and h, respectively. The overlapping of points i and E implies that the force in member 36 is zero.

Discussion

The first problem presented in this study demonstrates that one can use either the original or the alternative approach to analyze a single-joint truss with the same level of effectiveness. As to which approach one should select, it depends on one's training in 3D CAD and the spatial reasoning in descriptive geometry. In either approach, it shows that the CAD process is less time-consuming and more accurate, because it just requires the application of proper CAD commands instead of the manual construction of orthographic and auxiliary views. The second problem presented in this study is to demonstrate how a multiple-joint truss can be analyzed. The alternative approach is selected for this purpose because it allows one to repeat the simplified CAD process (of creating multiple planes at the same point), and thus, minimize chance of making mistakes.

Both truss problems were solved utilizing I-DEAS, a design-oriented software, on the Unix-based Sun workstation. They can also be solved as effectively using any CAD software package on a PC, as long as the software is solid-based. Today, it is common to see one of these solid-based CAD software incorporated in the freshman-level class of engineering design graphics. It is a logical step to see students applying their CAD skills further in higher-level classes, such as descriptive geometry and engineering mechanics, for solving this type of problems.

Conclusion

The purpose of the 3D CAD approach as developed in this study is not to replace the analysis approach for this class of problems. Though the 3D CAD approach is effective in dealing with the simpler multiple-joint truss as presented in this paper, it is not feasible for a more complex truss that has a large number of joints. A more complex space truss problem needs to be solved using an analysis program for greater speed. With an analysis program, the load in each member of a space truss is available as soon as its resultant geometry is imported for solution. Students can follow the method outlined in this study to solve for a simpler problem before they proceed to the use of analysis programs.

The goal of the 3D CAD approach is to help students grasp the mechanics of the geometrical approach without involving time consuming and less accurate 2D graphical construction. Various 3D CAD approaches can be developed for the solutions of not only space truss problems, but also other problems that require geometrical approaches in descriptive geometry. Students should be encouraged to use the geometrical approach before they move into the analysis approach. With the geometrical approach that emphasizes spatial reasoning, students will have a better visual understanding of the physical significance of the problem.

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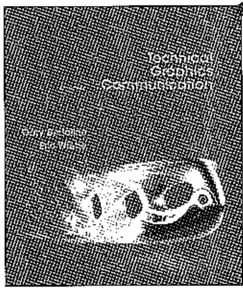

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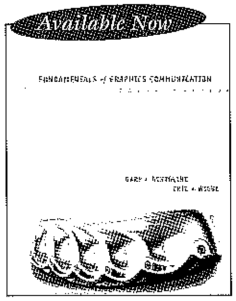

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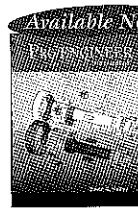

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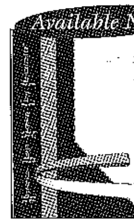

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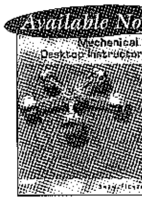

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