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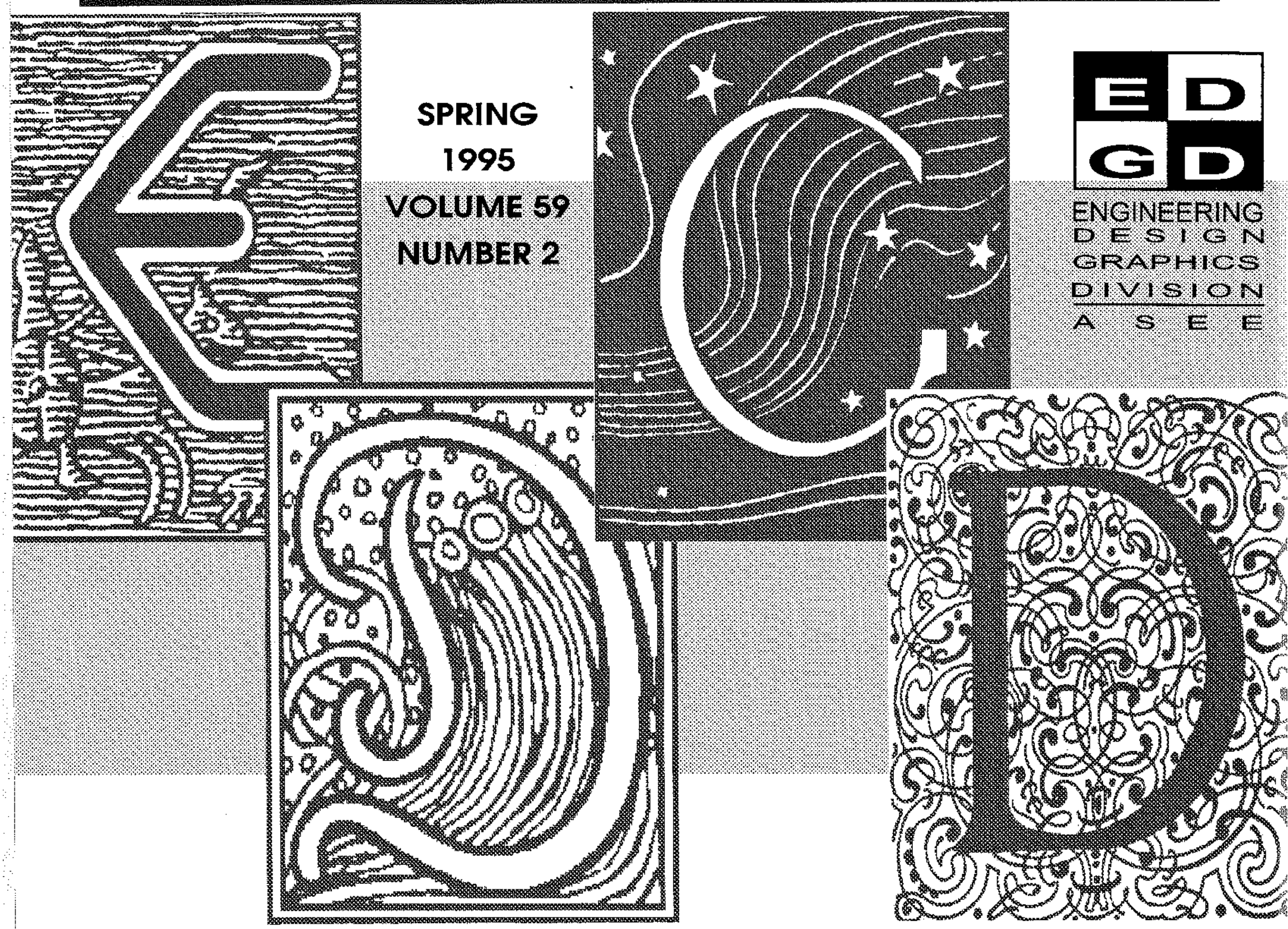

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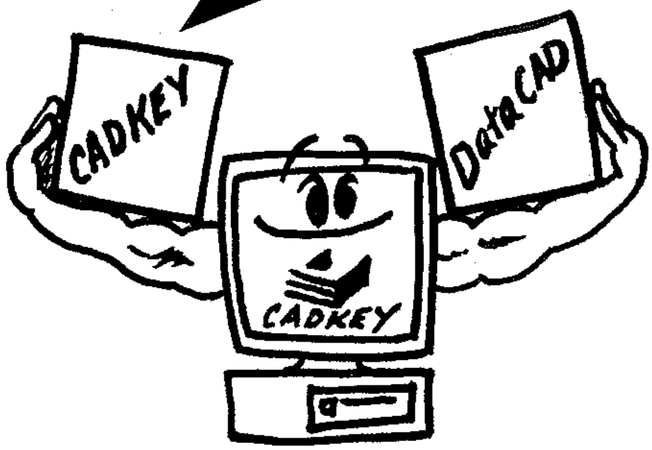

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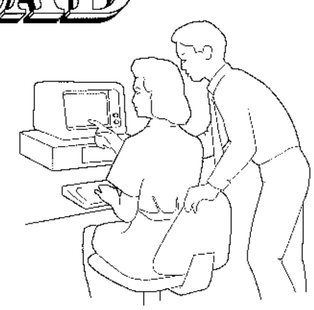

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THE ENGINEERING DESIGN GRAPHICS JOURNAL

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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.

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. . . from the EDGE

All of you should know that former editors do read their Journal. Barry Crittenden, past editor, called to let Bill Ross and myself know that we had posted the correct date for the 50th MidYear Meeing on the call for papers, but had actually used the wrong date in both the letter from the editor (this space) and the Chair's Message on page 36. Just to keep things straight, the 50th Annual MidYear Meeting will be November 5 - 7, 1995 in Ames, Iowa. It promises to be a special meeting so let's try to make plans now to attend. Paul DeJong is attempting to put together a display of items that are of historical interest to the Division (see page 39). If you have something, please let him know. If you are not sure of the significance of your item, give Paul a call or email message and ask.

Summer is by now well under way. In fact, for those of us on the semester system, the summer will be over before you can say August 14. I hope all of you are enjoying a bit of relaxation and great summer weather. This is the second summer that I have not taught or had any official University responsibilities over the summer. I used to be embarressed to tell people that I was taking the summer off. It sounded so unimportant! I've gotten past that attitude and have adopted the attitude of Travis McGee, a character of John D. MacDonald. Whenever Travis makes a bit of money, he goes into early retirement and enjoys life until he finds it necessary to go out and earn a living again. I have decided to look upon my summers as a slice of retirement graciously given to me each year by the administrators at Purdue University. I feel no guilt about golfing, traveling, reading, doing projects that I don't get around to doing during the rest of the year. The only thing that would make this a better situation would be to continue to receive a paycheck during this early retirement. I guess we can't have everything.

I hope you are all having a good summer and are refreshed and ready to begin with vigor this fall.

Mary A. Sadowski

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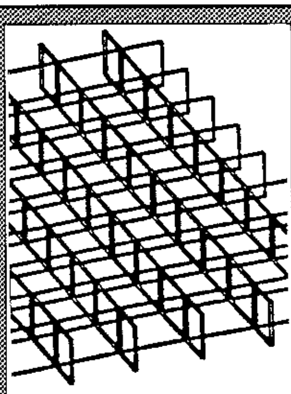

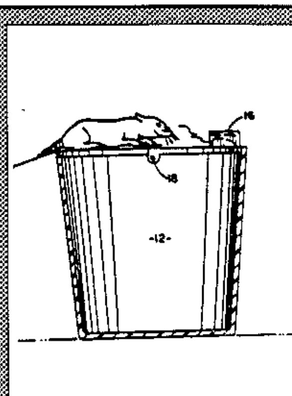

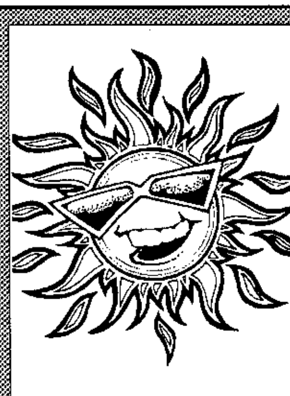

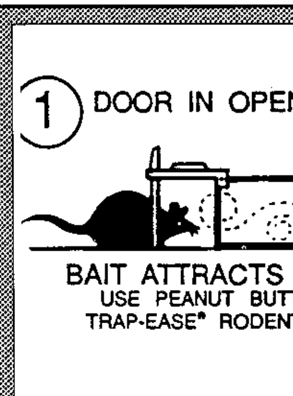

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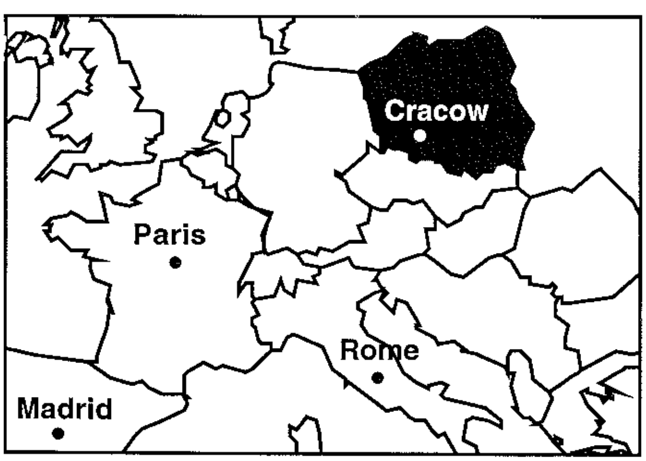

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1. Theoretical graphics and applied geometry; descriptive geometry; kinematic geometry; computational geometry; geometric and solid modeling; geometry in arts and sciences; other applications of geometry,
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3. Graphics education; graphics teaching techniques; computers in engineering graphics education; evaluation of graphics courseware; evaluation of student's spatial abilities; impact of computers on engineering graphics education and society,
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CAD Processes for Rapid Prototyping

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Department of Technology
Southwest Texas State University
San Marcos, TX

Abstract

In less than a decade many rapid prototyping systems have emerged in the market. These systems generate a physical prototype of a part based upon geometric definitions stored in a Computer Aided Design (CAD) file. The rapid prototyping process can cut the prototype development time from weeks or months to a few hours or days. Thus rapid prototyping can facilitate concurrent engineering and shorten the time-to-market lead times of new products. In this paper we will consider certain practical aspects, from an engineering graphics perspective, that are associated with the CAD input file generation needed for rapid prototyping. The paper will deal with geometric modeling for rapid prototyping, selection of appropriate CAD models, CAD file formats for interfacing with rapid prototyping software and using AutoCAD, release 12 with AME, as a front-end for rapid prototyping. This makes it possible to easily include this high technology concurrent engineering tool into the engineering graphics curriculum.

Introduction

With the rapid advancements in technological knowledge and increased global pressure to get products to market first, the concept of concurrent or simultaneous engineering was developed to shorten product development cycles. Concurrent engineering is the process of developing the product, the process, and the related tooling and equipment simultaneously (Jacobs, 1992). Rapid prototyping (RP) can play a critical role in further reducing product lead times by generating a prototype or model of a part directly from a CAD file in a matter of hours or days. This saves considerable time over traditional methods of prototyping, which often took weeks or months. The creation of an accurate prototype is critical in the design process to verify form, fit and function. It allows the engineer to discover any latent flaws that would be costly to correct later. Since producing a RP model often requires less time and expense than conventional prototyping methods, engineers have found it possible to design several versions of the same part for concurrent testing before selecting the final design.

Much information has been written on the rapid prototyping process, the various RP systems, and actual and potential uses of RP in industry. However, very little has been written on how to select the proper CAD model and develop the file format required by various RP systems to actually produce a prototype - information that is important for persons in both industrial and higher education as RP systems become more common and global competition increases.

"Concurrent engineering is the process of developing the product, the process, and the related tooling and equipment simultaneously."

Two rapid prototyping systems will be mentioned in this article. 3D Systems was the first company to enter the RP business, with its first commercial machine introduced in 1987. The 3D Systems Stereolithography process uses an ultraviolet (uv) laser beam to photopolymerize a thin layer of uv curable liquid plastic resin. This process is repeated until the part is formed. To produce the part mentioned in this article, DTM Corporation's Service Center was used. DTM has developed the selective laser sintering process, which differs from the Stereolithography system developed by 3D Systems. In the sintering process, an infrared laser is used to sinter thin layers of powder materials into a solid form. Currently, selected plastics and casting wax are used, with future materials under development including metals, ceramics and composites.

The quality and accuracy of the final prototype is extremely dependent upon the CAD model. A sound background in CAD and engineering graphics is a key ingredient to successful RP applications. By incorporating design projects that involve creating an input CAD file and subsequently developing a rapid prototype, the vital role played by engineering graphics in concurrent engineering can be illustrated for the student.

Geometric Modeling for Rapid Prototyping

One of the preliminary steps in developing a rapid prototype is using a Computer Aided Design (CAD) system to generate a geometric model of the part. RP systems, such as 3D Systems' rapid prototyping machine, produce a part by the photopolymerization of a photoreactive polymer. The part is built in thin layers between .002 - .005 of an inch using an ultraviolet laser beam. A computer directs the laser beam using part geometry information contained in a computer file. Thus, an essential first step in the RP process is the generation of a geometric model using a CAD system.

Geometric modeling may be classified into two categories: I) Two-dimensional modeling or II) Three-dimensional modeling. Three dimensional modeling generates part models in three-dimensional space. By simultaneously defining and displaying a part along the three axes, this scheme facilitates the visualization of the part. Three different three-dimensional modeling schemes exist: I) Wireframe modeling, II) Surface modeling, and III) Solid modeling. Wireframe modelers represent an object as a collection of lines, arcs and circle representing the edges of the object. Wireframe representations are relatively straightforward to use and economical in terms of processing time and memory requirement; however, they suffer the following drawbacks. They are ambiguous in representation and are limited in use for calculating mechanical properties of the model, as well as serving as a basis for manufacturing (McMahon & Brown, 1993).

Surface modeling overcomes some of the drawbacks associated with wireframe modeling. A surface representation may be thought of as a wireframe model that has a thin, flexible rubber sheet-like material pulled over it. Surface models resolve some of the ambiguities associated with the interpretation of a wireframe model and facilitate volume analysis. These models, that can be used to generate complex shapes, are especially useful in automobile, aircraft, mold and die manufacture. However, the models are ambiguous in the sense that viewers would not know if they were looking at a solid or a hollow object.

A solid model can represent both the geometric and physical properties of an object (Rembold, Nnaji, Storr, 1993). These models are unambiguous when compared to surface models. This may best be illustrated by considering the modeling of a solid cube and a hollow cube represented by surface and solid models. In the case of a solid model, upon slicing the model, one would find hollow space in the interior of the hollow cube and material in the solid cube. Surface models, however, represent both cubes with hollow space in the interior. This unambiguity in the case of solid modeling results in its effective applications in mass property analysis, interference checking and visualization of assemblies.

Since many different geometric modeling approaches are available, the next consideration is which of these approaches are best suited for rapid prototyping? Since the prototype produced is a tangible object, three-dimensional CAD models are better choices for rapid prototyping. The next question is which among the three schemes for three-dimensional modeling is the best choice for rapid prototyping? Rapid prototyping software requires that the input CAD data be unambiguous. This necessitates one and only one possible interpretation of the data. Such data can generate closed paths upon slicing the part horizontally, which is required due to nature of part generation in rapid prototyping systems, and to differentiate between the inside and outside of the part. Figure 1 illustrates the concept of a closed path. Consider a box shaped part with a through hole at the center. If a knife were passed horizontally through the part, the resulting cross section would appear as shown in Figure 1. The cross section in this case shows two closed paths. The first is represented by edges of the cross section, which is basically a rectangle, and the second by the edges of the hole, which is basically circular. Problems can occur during prototype generation if the part geometry is not completely closed. Surface normals such as those shown in Figure 2, are used to differentiate between the inside and outside of a part.

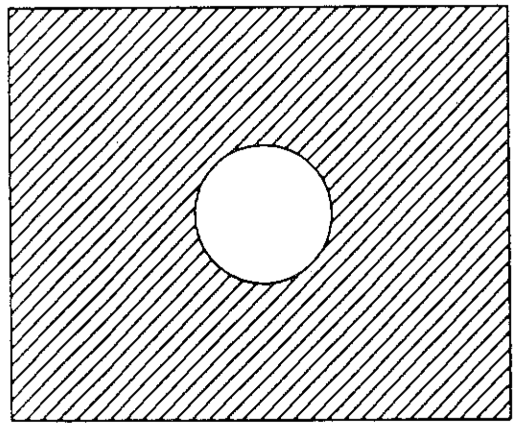


Figure 1. Closed paths

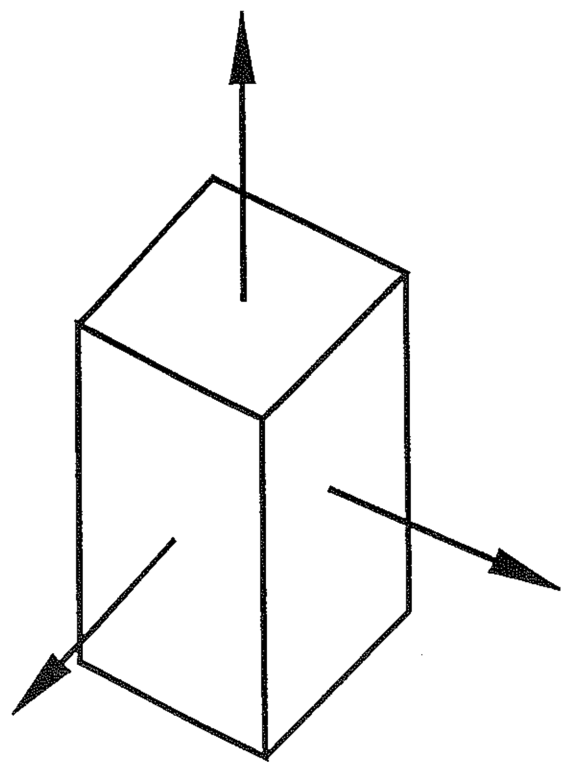


Figure 2. Surface normals

The very nature of solid modeling is such that an unambiguous part geometry is produced. This is due to the fact that, during the creation of a solid model using boolean operations, if any violations in the closed nature of part geometry occurs, the system warns the user. Solid models by definition therefore, satisfy the requirements for rapid prototyping input data (Jacobs, 1992).

When a solid model is built for a rapid prototyping application, the following facts guide the user in deciding part orientation. First, the model should be constructed in the positive X, Y, Z octant. This means that for a part all X, Y, Z coordinates will be positive. Secondly, closer approximations to curved surfaces would be achieved by orienting curved surfaces in the horizontal XY plane. This minimizes stair stepping that results when linear elements approximate curves. Lastly, minimizing the height of the model in the Z axis reduces build time (Jacobs, 1992). Most rapid prototyping systems also accept surface models; however, an important requirement is that the surface models must be closed so that they are "water-tight" (Wohlers, 1992). This is a concern in the case of a surface model, because unambiguity is not a requirement for these models (Jacobs, 1992). Wireframe and less complex models will also work with rapid prototyping systems, but these are tougher and more costly jobs because the RP firm will have to do extra work with these models to make them acceptable for the RP software (Jacobs, 1992).

CAD Software	Rapid Prototyping Companies
CAD Software	3D Systems, Inc.
AutoCAD	DTM Corporation
Bravo Solids	Helisys, Inc.
CADKEY v5	Stratasys, Inc.
Medussa	Cubital, Ltd.
CADMISD	Light Sculpting Incorporated
Silver Screen	Soligen Technologies
Pro Engineer	
CATIA	

Table 1. CAD software and rapid prototyping companies that accept STL files.

CAD - Rapid Prototyping Interface-STL and IGES files

CAD systems use different representation schemes to describe part geometries. Therefore, a need existed to create a standard interface between various CAD systems and rapid prototyping software. The issue of incompatibility between various systems sharing graphical information was approached using a standard neutral format called Initial Graphics Exchange Specification (IGES).

Although the IGES format has been used to facilitate the transfer of two-dimensional and three-dimensional graphical information, this standard currently is unable to completely translate information contained in a three-dimensional solid model. Therefore 3D Systems Inc. developed an interface specification called STL (Stereolithography). The STL format is the most popular file format for rapid prototyping and is becoming a de-facto industry standard. Table 1 lists CAD software and some of the RP companies that accept STL files.

An STL file represents the surface of an object as an array of triangular facets. Four parameters are used to represent each facet. Three of these represent the coordinates of vertices of the triangle and the fourth represents the surface normal of the facet (Wood, 1993). The facets approximate the shape of the part.

At this point it is pertinent to mention three of the problems that are encountered with STL files. First, problems occur due to lack of connectivity in the triangular mesh, rendering the object's representation ambiguous. Such files may result in tiny cracks in the solid models. Secondly, problems arise when adjacent triangles conflict, creating confusion as to upon which side of an object the mass resides. This problem is due to incorrect normal orientation. Some

RP system software such as 3D System's can detect and correct problems in STL files. Third, many of the surface models created are usually not fully closed, and STL files generated from such models can be intractable.

The resolution of the prototype is directly dependent on the resolution of the CAD geometry. Therefore, it is at the CAD geometry creation stage where decisions need to be made that will influence the accuracy of the model. In general, the more facets approximating a surface, the greater the accuracy. However, increasing the number of facets will cause the STL file to be increased in size. Thus a balance has to be struck.

Rapid Prototyping Using AutoCAD

Since AutoCAD is the CAD software used by many universities and industries, it is important to users that this program be able to prepare input files for rapid prototyping use. Most rapid prototyping systems accept CAD files in either the IGES or STL format, or both. AutoCAD release 12 is capable of producing CAD files in both the IGES and STL format.

The first step in the process is generating a three-dimensional part model using AutoCAD. As discussed earlier, a solid model is the better choice; however, certain complex shapes may necessitate the use of surface models. At this point, the user can manipulate the accuracy of the prototype by choosing an appropriate facet density. The AME system variable, SOLWDENS, may be evoked to change the facet density. The larger the value of the variable, the greater the density. Once a drawing file has been created and stored, it is saved with a .DWG extension (in conformance with the DOS format).

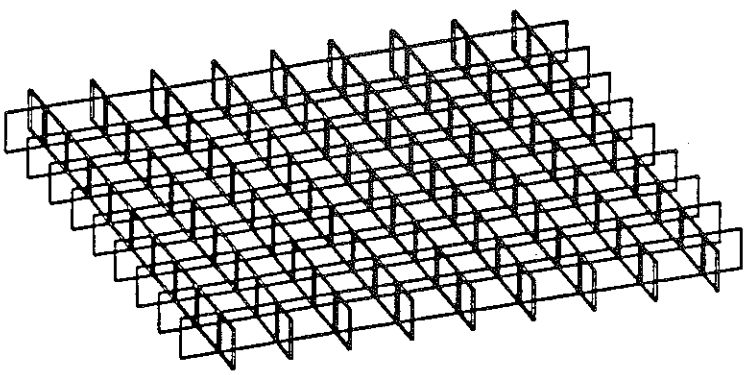
In the case of surface models, an IGES file of the part may be created. IGES files are given an .IGS extension by AutoCAD. However, surface models may not be "watertight". This fact may require the rapid prototyping company to do additional work on the IGES file to "sew" the model and render it "water-tight".

Solid models are created in AutoCAD release12 using the Advanced Modeling Extension (AME) program. After creating a solid model of the part, an STL file of the same may be created using an AME command called SOLSTLOUT. The command sequence that follows upon issuing the SOLSTLOUT command is illustrated in Figure 3. STL files are given an .STL extension in AutoCAD.

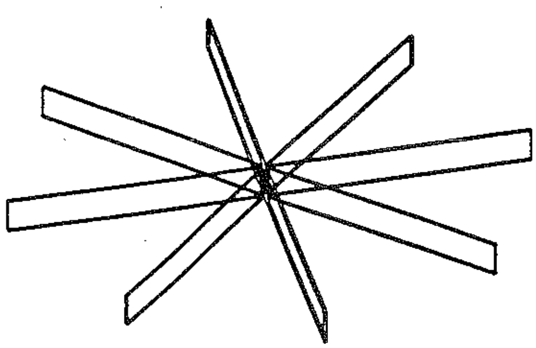
```
Command: solstlout
Select a single solid for STL output:
Select objects: Pick a solid.
Create a binary STL file ?<Y>:N (for ASCII file)
STL filename <name>: Part
231 triangles generated.
```

Figure 3. Creating an STL file using AutoCAD

AutoCAD's AME module allows the user to create structures that are required in the case of some rapid prototyping systems to support the prototype while it is being built. Supports are necessary for some or all of the following reasons: to prevent freshly cured resin from collapsing under its own weight, to make certain that the recoater blade will not strike the platform upon which the part is built, and to permit easy removal of the part from the build platform after part completion. These supports have to be fused with the CAD model during the geometric modeling stage using boolean operations. AutoCAD provides the option of building eggcrate and star support structures, as illustrated in Figure 4. Supports may be built in AUTOCAD using the AME command STLSUP. Figure 5 shows the command sequence that follows upon issuing this command. In case of software that does not provide support generation, the user may use support generating software such as Solid concepts' Bridgeworks or Supslice.



a. Eggcrate structure



b. Star structure

Figure 4. Prototype support structures

Case Study

This section describes steps that were taken in creating a rapid prototype using AME as a front-end to the RP system. The version used was AutoCAD release 12. A solid model (shown in Figure 6) was built using AME release 2.1 of AutoCAD.

```
Command: (load "stlsup")
Command: stlsup
Star/<Eggcrate>: Star
Center point of star:
Diameter/<radius> of star:
Height:
Number of segments <8>:
Web Thickness <0.020>:
```

Figure 5. Support construction using the STLSUP command

The AME portion of AutoCAD allows a user to create solid models. The solid model shown is described in the AutoCAD AME release 2.1 reference manual (Autodesk, 1993). The solid model is essentially a composite part because it was created using simpler geometric solids called primitives. The primitives used were a box, cylinder, extrusion primitive and a swept volume primitive. These primitives were fused to create the composite part using boolean operations such as subtract and union.

Once the solid model was created, it was then stored as a drawing file with .DWG extension. Next the AME command, SOLSTLOUT, was used to create an STL file of the solid model. This command gives the user the option of building either a binary or an ASCII file. ASCII files are easier to interpret manually. However, it is advantageous to choose binary files because they are smaller in size. As the STL file is being created, AutoCAD lets the user know how many triangles were used in approximating the model. A portion of the STL (ASCII) file for the part shown in Figure 6 is shown in

Figure 7. The number of triangles used in this case was 231.

The .STL file was sent to the DTM Corporation in Austin, Texas, which uses the selective laser sintering (SLS) process to build physical models. This process uses a CO_2 laser to selectively sinter layers of plastic or casting wax powder to build the part. The .STL file was used by the SLS process to build a physical prototype (shown in Figure 8) out of polycarbonate material.

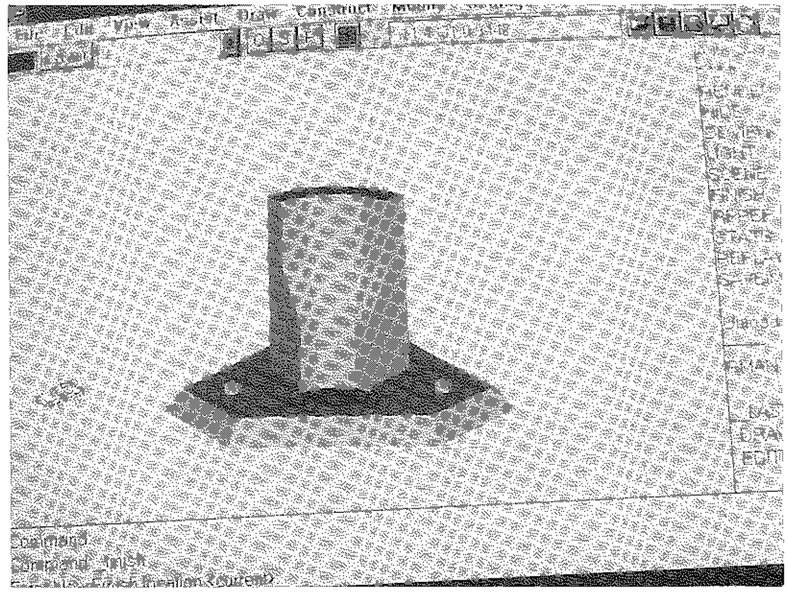


Figure 6. Solid model used in the case study

```
solid AME
   facet normal 9.9254615e-001 -5.2976286e-015 1.2186934e-001
      outer loop
         vertex 4.5458605e+000 5.4725697e+000 4.1986696e+000
         vertex 4.7198758e+000 4.7934926e+000 2.7814282e+000
         vertex 5.0000000e+000 4.0075098e+000 5.0000000e-001
      endloop
   endfacet
   facet normal 9.9254615e-001 -1.3429363e-017 1.2186934e-001
      outer loop
         vertex 5.0000000e+000 4.0075098e+000 5.0000000e-001
         vertex 5.0000000e+000 5.0150197e+000 5.0000000e-001
         vertex 4.5458605e+000 5.4725697e+000 4.1986696e+000
      endloop
   endfacet
   facet normal 9.9254615e-001 5.8255926e-016 1.2186934e-001
      outer loop
         vertex 4.7198758e+000 4.7934926e+000 2.7814282e+000
         vertex 4.8334107e+000 4.1753502e+000 1.8567608e+000
         vertex 5.0000000e+000 4.0075098e+000 5.0000000e-001
      endloop
   endfacet
   facet normal 9.9254615e-001 -1.6817896e-016 1.2186934e-001
      outer loop
         vertex 4.5458605e+000 5.4725697e+000 4.1986696e+000
         vertex 4.5384344e+000 4.9762966e+000 4.2591500e+000
         vertex 4.7198758e+000 4.7934926e+000 2.7814282e+000
      endloop
   endfacet
   facet normal -1.2096095e-001 1.2186934e-001 9.8514786e-001
      outer loop
         vertex 3.1334881e+000 4.8911496e+000 4.0971776e+000
         vertex 3.1491921e+000 4.0572238e+000 4.2022679e+000
         vertex 3.4791551e+000 4.5402315e+000 4.1830310e+000
      endloop
   endfacet
```

Figure 7. Portion of the STL (ASCII) file for the part used in the case study

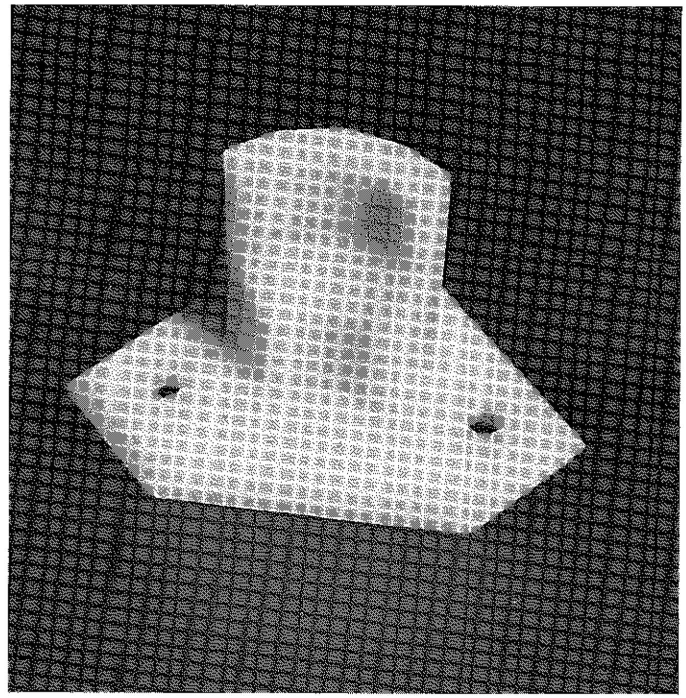


Figure 8. Rapid prototype of the solid model

Conclusions

Some of the basic steps from an engineering graphics perspective that are involved in preparing an input CAD file for rapid prototyping are as follows. The first step in producing a rapid prototype is to prepare a CAD model of the part. Three-dimensional CAD models are more suitable for rapid prototyping applications, because the final result is a three-dimensional part. Solid modeling is the most appropriate three-dimensional modeling scheme to use, because of its unambiguity and integrity.

CAD part files have to be converted into a suitable format for input to the rapid prototyping software. The de-facto industry standard today is the STL files. The AME module of AutoCAD release 12 supports the generation of STL files. Also, some RP service bureaus have produced RP prototypes from files submitted at little or no cost for educational institutions. This capability adds meaning to student engineering graphics design projects since a RP prototype can be built and used to verify the form, fit and function of the design. This capability will help the freshmen engineering and technology students realize the important role played by engineering graphics in the product development process and in concurrent engineering.

Acknowledgements

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Principles of Design and Communication

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The art of civilization is the act of drawing lines.

Oliver Wendell Holmes

Abstract

This paper introduces a principle-based approach for improving engineering design and design communication education. The approach consists of developing "systematic generalizable knowledge" for the field. However, this requires a paradigm shift from the present "standards & tools" approach to a universal "principle-based" approach. The development of guiding principles is essential to the establishment of any formal intellectual discipline.

Importance of Principles

Although design communication is among the oldest of human endeavors, the field is still governed by standards, experience, intuition, and tools, rather than by a universal set of guiding principles. Suh (1990) points out that if our goal as educators "is to transmit systematic and generalizable knowledge, rather than experience, to those uninitiated in the art and science, design has not yet made the grade as an intellectual discipline, for few schools teach the subject with systematically generalizable knowledge." This paper is an attempt to articulate the fundamental design communication principles, as well as discussing their importance and interrelationships.

What is a principle? The *Oxford American Dictionary* defines *principle* as "a basic truth or a general law or doctrine that is used as a basis of reasoning or a guide to action or behavior." Covey (1989) states that principles are "self-evident and can easily be validated by any individual." However, the design communication field has yet to validate a universal set of principles and to document its knowledge in a systematic generalizable way.

Several colleagues at Purdue and Ohio State, among others, have advocated the need for a *paradigm shift* in the EDG field. The term paradigm shift was introduced by Thomas Kuhn in his landmark book The *Structure of Scientific Revolutions*; as cited by Covey (1989): "Kuhn shows how almost every significant breakthrough in the field of scientific endeavor is first a break with tradition, with old ways of thinking, with old paradigms." This paper advocates the shift from the "old ways" of training students in 'standards and tools' to 'principle-based' education that builds-on generalizable engineering design and design communication precepts.

The importance of design and communication principles, is illustrated by Oliver Wendell Holmes' famous quote: "The art of civilization is the act of drawing lines," as quoted in Kidder (1985). Holmes' assertion summarizes one of the most obvious principles in the engineering design and design communication field, that is: In order to create something significant, we must first communicate the idea to ourselves and to others. This important **Communication Principle** can be stated as:

Communication precedes implementation

Of course, "what to communicate" is even more important, and that requires an understanding of design and its processes and principles.

Design: Processes and Principles

What is "design"? How are engineers involved with design, and what exactly do they do when they design something? Basically, engineers and designers apply scientific and practical knowledge to analyze problems and develop efficient ways of using resources, such as people, money, materials and machines, to solve the problems. The byproduct of this activity may be a device, a system, or a process - for example, a mechanical pencil, a laptop computer, a bridge, a software system, a building layout, a chemical process (Rodriguez, 1992).

The art of design is to take a bright idea and with adequate resources (and the proper regard for the environment) design and produce something the public wants at a price it can afford. Of course, the original bright idea rarely springs forth complete, polished, and ready to go. Realizing the idea - turning it into a manufacturable product - requires development, that is, it requires trying this configuration, these circuits, that arrangement, or some other form, shape, or size until a satisfactory solution is found (Walker, 1989). Such experimentation can be done mentally, on paper, with the use of scale models or computer-generated models, or even – as the Wright Brothers did – by building full-size structures. However, only rarely is the result of the first development efforts completely satisfactory; perhaps the product will be too difficult to build, too big, too noisy, or too costly to maintain. So, once again the idea goes into the cycle of developing, testing, redeveloping, constructing, and retesting (Walker, 1989). The methodological approach to this cycle is called the design process.

All through history, engineers, architects, scientists, and designers have attempted to approach problems in a methodological fashion. The design process is basically a methodological avenue to reach the best solution to a design problem. First, the designer defines the requirements and the constraints for the problem; then the designer creates alternative design solutions, and models and evaluates a number of those solutions; finally the designer selects the solution that most likely would result in the desired finished product. In short, the design process is basically the combination of imagination and conceptualization (ideation); and modeling and analysis (simulation); and building and testing (implementation); that is:

Design Process =
Ideation + Simulation
+ Implementation

Engineers encounter extremely intricate problems. However, no matter how complicated the problems may be, engineers follow some form of "design process." Be it sequential or concurrent, the design process is interactive and iterative in nature. This means that a person must provide input to the process and also respond to it (interact with it) and that the process does not follows a predetermined sequence of steps - indeed, it can become repetitive (iterative). It is difficult to know when one phase finishes and the other starts; that is, the process phases can overlap with one another. If the design process is concurrent (simultaneous), then, engineers have the opportunity of designing both the product and the procedure by which it is to be built (manufactured or implemented) at the same time. This can be expressed as the **Concurrent Principle**:

Design the product
and the process by which the
product is going to be built,
concurrently

The stages (or sub-processes, if you will) of each phase of a concurrent design process model –as it appeared in Rodríguez (1990) and also in Barr and Juricic (1992)– are discussed briefly here.

Many successful engineering designers and entrepreneurs possess great powers of imagination and creativity, which are essential to ideation – the first phase of the design process. Ideation is the ability to identify a problem and imagine ways to solve it. The "idea person," or designer, is the first person to conceive of a product that will be later developed and manufactured. This person may not necessarily be an engineer – it may be an industrial product designer, architect or inventor. However, an engineer would always be employed to develop the design idea into a manufacturable (hence, engineered) device or a constructable system (for example, a structure).

Ideation is the conceptualization phase of the design process. We may start the ideation phase by doing *market research.* Simply, we need to find out what people want or need. This research is done by surveying the market to determine consumers' trends and demands. We may also observe existing devices, systems, or processes to determine deficiencies or possible improvements. Of course, the ideation process may also begin with an opportunity to explore a market opportunity, or by organizing a group brainstorm session to identify customer's needs. Once we identify the need or want, we need to define the problem. The *problem definition* stage consists of writing a clear statement of the customer's need and the functional design requirements (FDRs) for the problem at hand. The statement is rewritten as many times as necessary - in a concise and comprehensive way - so that it does not favor a preconceived solution. Concurrently, we need to determine the FDRs of the problem.

The late President's initials F. D. R. provide a good mnemonic for the FDR Principle:

Meet customer's
Functional **D**esign **R**equirements
(FDR)

For example, let's say there is a need for a better mouse trap that uses no poisons, glue, or springs. The FDRs may be stated as:

FDR1: Provide an enclosure to trap a mouse.
FDR2: Minimize the pain caused to the mouse.
FDR3: Make it aesthetically pleasing (tasteful) and safe (child-proof).

In addition, one must state the limitations or constrains of the problem - for instance, in the previous example, one most indicate that the trap needs to be disposable and inexpensive. The designer defines these design guidelines based on the customer's needs.

The third ideation stage consists of generating *preliminary ideas*. The designer or design team brainstorm for alternative solutions to the problem without ruling out "illogical" solutions. The brainstorming session is simply a meeting where willing people identify or propose alternative solutions to a given problem or actually think of possible problems to solve. The objective is to generate a large number of ideas or market needs. Therefore all proposed ideas are accepted. Criticism or ridicule is not permitted. After forming the group, a leader is selected to encourage comments and responses to the questions posed. For example, the leader could pose a question like this: "What are the main needs of society, community, school, home, or dormitory?, or How do we propose to solve this problem?" Someone in the group is usually in-charge of writing down (or sketching) the collective statements (or proposed solutions.) All responses are written (or sketched) on the board or overhead projector, visible to every group member. We should emphasize that the design team must record their ideas on paper or computer, since some of these ideas may need to be refined later in the process.

In addition, some designers perform a patent search, which consists of looking up similar products that may have been registered in the government's patent office. Many college libraries and public libraries have computer-based patent information available on CD-ROM (Compact Disk - Read Only Memory) disks. Other designers may also read certain magazines or visit retail shops to find ways in which other people have attempted to solve similar problems.

The final stage of the ideation phase is to make a *preliminary decision* of the best design solutions. To make a logical design decision, we need to determine the relevant factors, such as weight, cost, durability, esthetics, and ethics and assess their relative importance in attaining the specified design (functional) requirements of the problem. Selecting the best idea(s) to be modeled and evaluated (analyzed) and then choosing the best design in an objective way are two of the most challenging tasks that a designer faces. A table called a decision matrix is used to compare the various design alternatives. In this table, numerical values are assigned to each specific design factor, according to the importance of the factors. The design with the greatest cumulative value is the "winner."

The intermediate or maturation process is called simulation, and involves modeling and analyzing the object. Computer-generated models are constructed based on the original ideation sketches. The model is analyzed to see how well it behaves under stress, temperature, wind, and other physical factors. Engineers may create computer animations to simulate the product's performance.

Simulation represents the design maturation phase. One often begins this phase by performing *spatial geometry analysis*, which consists in part of determining the product's shape and size - the configuration and the proportions of the product. In some cases, the designer may also need to perform certain spatial geometry operations such as finding true size, true shape, area, auxiliary views, intersections, and developments (unfolding the surface). And they need to determine any other visual information required to build the product's model(s).

Before the product is modeled in the computer system, the part's coordinates and strategic points need to be determined. This is the beginning of the *geometric modeling* stage. One may construct geometric models such as wireframes (showing only the edges of the object) or solid models (showing the surface of the object). These geometric models are constructed using CAD (Computer-Aided Design) and geometric modeling systems. Some systems use simple geometric shapes called primitives, as well as boolean algebra (math operations like subtraction and addition) to create the models. Other computer graphics software systems may also be used to model the product - such as feature-based modelers, which use manufacturing/construction terminology, and virtual-reality modelers, which create an electronic "reality" within which the user can manipulate the object's model.

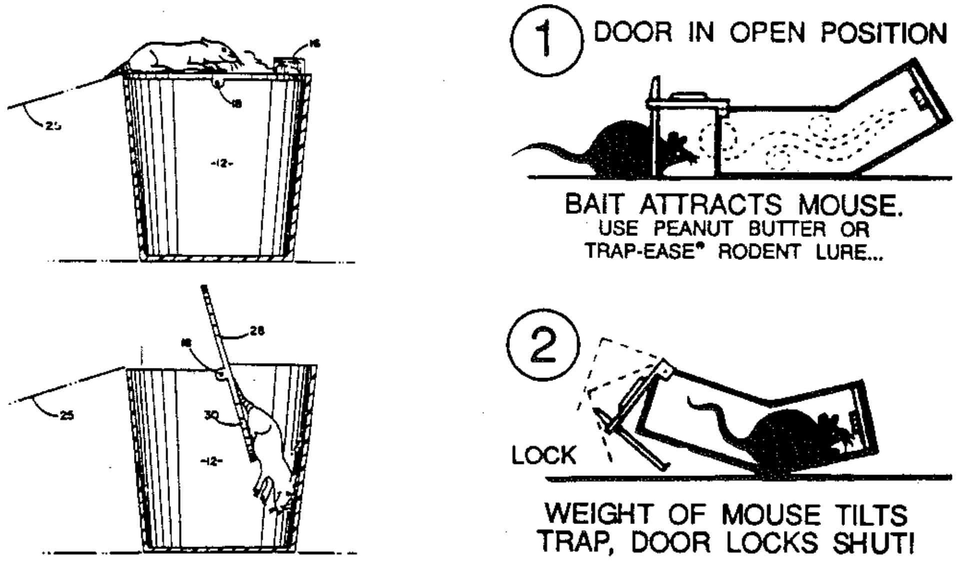
Geometric modeling is followed by the *engineering analysis* stage, which consists of determining mass properties, generating stress (due to forces and deformations), and creating fluid (water, air) flow and/or thermal (heat) simulations from which the engineer can visually inspect the effects of those factors on the device or structure being studied. If the computer system is powerful, designers may proceed to perform visual simulation or *animation* to determine part clearance, interference, collision detection, and so on. They evaluate and improve the product based on the simulation results - always seeking to optimize the product's shape, materials and so forth.

The "final" phase of the design process, implementation, refers to building, manufacturing, testing, and documenting the product. *Prototyping and testing* is the first stage; it consists of building a real model, or prototype, of the product. The *prototype* is tested under real loads, heat, flow, and stresses, and is evaluated for its market appeal and "feel."

A design, or technical, *report* is usually prepared. This is done by organizing product presentation materials. Graphs, charts, and other visual information are usually included to support the design solution. Multimedia (audiovisual) presentations using transparencies, slides, sound, and/or animation sequences may also be conducted.

The design must also be documented. This *design documentation* stage consists of extracting detailed-drawing (including dimensions and geometric tolerances) from the geometric models previously created. This phase also includes the development of material specifications to support the drawings. Designers may also write patent-pending requests and other documents needed for legal or record-keeping purposes.

The "final" stage is *production.* Production involves realization, manufacturing, construction, and/or processing of the product. It consists, in part, of planning and scheduling, that is, determining the time and the resources needed to manufacture and distribute the product. *Marketing* and distribution to the consumer, although normally a management activity, should also be regarded as part of the design process. This process never ends: Feedback and continuous improvement of the product is required to remain competitive in today's world economy. Sometimes production is canceled, as was the case of the patented mouse trap in Figure 1a, because the product did not meet the customer's FDRs. In this case, the design process begins all over again, re-engineering or re-designing the whole concept to implementation process. The designers might have to look back at the market, do additional surveys, brainstorm, redefine the problem and FDRs, or by going to any other design phase, as necessary.



(a) Doesn't Satisfy FDR3 (b) Satisfies All FDRs

Figure 1. Principle-based 'Mouse Trap'

FDR1: Provide an enclosure to trap a mouse.
FDR2: Minimize the pain caused to the mouse.
FDR3: Make it aesthetically pleasing and safe.

Applying Fundamental Principles

To minimize design communication and design implementation (production) problems, and to reduce the number of iterations or cycles in the design process and subprocesses, it is necessary to apply several additional design-related principles.

Design and communication are the two central activities of the engineering field. As any other engineering or scientific endeavor, design and communication, shall be based on sound principles. However, the design ideation process has been significantly subjective. It has depended to a great extend on the designer's creativity, past experiences, standards, and know-how (familiarity with the problem); which are important, but not sufficient to be an effective designer and communicator.

A good designer should be skillful in both analytical thinking and visual thinking. Both mental processes are required for the integration of his/her creativity, knowledge, and experiences into the desired design solution. Creativity alone is not enough to solve the problem. It is necessary to use reasoning powers to define and satisfy the functional design requirements (FDRs) of a particular design problem. In the same way that there are laws of nature like gravitation, there are acceptable principles of good design practice and decision making. Sound design principles help us to conceptualize and choose the best design solution to a problem. Let's discuss some fundamental design principles.

It is axiomatic that the most important phase of the design process is ideation. The influence of ideation over the entire design process is profound. For example, the first meeting with a client to define the customers' FDRs, may greatly limit other design decisions that follow. In fact, early decisions in the design process affect the final design solutions in ways hard to imagine by a young designer. Early design criteria selection of constraints and limitations consequentially affect all other stages and can have the greatest impact in the final outcome of the design. This is a widely accepted principle in the design community, although it may not have been implicitly stated as such. We shall refer to this principle as the **Early-Decision Principle**:

Early decisions greatly affect the final outcome

The application of this principle makes the young designer aware of the importance and consequences of his/her initial problem definition statement and FDRs -as developed during the ideation phase. For example, if we state that a mouse trap is to be made out of wood and springs we would probably end up with a conventional mouse trap solution (one that harms the mouse and produces an unsanitary mess —Freddy Kruguer style!); we would have unnecessarily limited other possible solutions. To be sure, even the improved mouse trap (Figure 1a) which meets FDR1 and FDR2, does not satisfy FDR3. However, the better mouse trap shown in Figure 1b, meets all three FDRs, as defined by the customers (see previous section). This mouse trap came as a result of the successful application of the 'Early-Decision,' the 'Concurrent,' and 'FDR' principles.

It may be useful, at this point, to present the application of two general design axioms that were developed by Suh (1990): the Independence Axiom and the Information Axiom. The first states that the problem's design requirements must be independently satisfied. The second states that designers should minimize the information content.

The following example -adapted from Dr. Suh's book (1990) - will serve to illustrate these two principles:

People utilize refrigerators to conserve their food cold and to retard food spoilage. They have to open their refrigerator door various times during the day. In doing so, the cold air escapes (warm air gets in) forcing the refrigerator's compressor to work more and, consequently, precious energy is wasted. In this case, the FDRs may be defined as follows:

FDR1: Facilitate access to the food in the refrigerator.
FDR2: Minimize energy loss by providing an insulated enclosure.

As solution, we may think of the commercial vertical hung door design found in our kitchen's refrigerator. However: Do these doors satisfy both FDRs? Certainly not. When the vertical hung door is opened to satisfy FDR1 (access to food), it results in a violation of FDR2 (energy loss.) A better design solution consist of a horizontally hinged and vertically opening door. This is the type of doors used in chest-type freezers. When this vertical door is opened to take out what is inside, the cold air does not escape because cold air is heavier than the warmer outside air in the room. Therefore, the vertical door will satisfy both FDRs. In addition, the vertical door solution has very little information content, that is, the relevant knowledge needed to produce it. After all, these doors are easy to manufacture.

Of course, we should realize that this vertical door solution may not be yet the best solution for example, it is inconvenient for the customer to retrieve food from this position, and so on so forth.) In addition, notice that the FDRs have been satisfied to certain extend, that is, when the door is opened some energy would be lost by convection (by removing the food from the refrigerator). However, if we specify a design constrain like "energy loss is to be less than 15 calories," then FR2 would be satisfied. Notice that both FDRs have been independently satisfied. We may paraphrase the **Independence Principle** as:

> Functional Design Requirements most be independently satisfied

A designer using this principle would attempt to keep each design requirement, in the problem definition, autonomous from the other. And would separate aspects or parts that are joined if necessary to maintain their independence. However, if it is possible to integrate the design features, and at the same time satisfy the independence principle, the designer should do so. It is also a good idea to reduce the number of design requirements and constrains. An unwild number of FDRs and limitations would complicate the problem unnecessarily.

Another design consideration is to provide for efficient assemblage, construction or manufacturing. This can be expressed as the **Implementation Principle**:

> Minimize the implementation process iterations

Make it easy to build and assemble. As is the case of the better mouse trap in Figure 1b, where only three parts are required to assemble it, we should design products in an effort to reduce the number of iterations required in the implementation process (for instance, the product's assembly). Eight ways to accomplish this have been suggested by Stoll (1986):

1. Reduce the total number of parts
2. Use modular design
3. Use standard components
4. Use interchangeable parts
5. Avoid separate fasteners
6. Reduce assembly directions
7. Reduce the material handling activities required to produce the part
8. Design products that are multifunctional and multiusable

Finally, we can draw from Deming's (1993) and Juran's (1993) Total Quality Management (TQM)'s philosophy a very useful **Design-Management Principle**:

> Improve the design and implementation processes, continuously

Communication and its Principles

The previous sections focused on the design processes and some fundamental design principles. We discussed that an effective design process is concurrent, and involves conceptualization (ideation), modeling (simulation), and manufacturing (implementation). However, these processes requires a person with a great capacity to ideate, and to form mental images of unique designs. It also requires a person capable of clearly conveying a design's visual information to others. For an engineer to be able to conceive imaginative solutions - and to understand the ideas presented by other members of the design team - he or she needs to possess outstanding visual thinking and design modeling abilities. Luckily, we all possess certain visualization abilities that can be greatly enhanced through theory and practice.

Visualization is the creative ability to form mental images which plays a far more important role in our lives than most of us realize. This ability belongs not only to artists, writers, and poets; in fact, engineers, designers, inventors, and scientists continuously use their visual thinking powers to create or modify devices and systems. This unique human ability allows us to think in terms of one, two, three, and four dimensions (lines, planes, pictorials, and animations, respectively.)

In the context of the design and communication process, visualization refers to the visual thinking and design modeling processes that involves perception, imagination, and communication. These three processes work in unison and can be express as:

Visualization = Perception + Imagination + Communication

More simply stated, we see (perceive), imagine, and draw (model). Visualization involves wonderful visual thinking and modeling mechanisms that are not yet fully understood. However, it is fairly obvious that visual thinking uses three kinds of visual imagery:

(1) the kind we actually see,
(2) the kind we imagine (visualize) in our mind's eye, as when we dream, and
(3) the kind we draw or model (to help others visualize our ideas).

Although visual thinking can occur primarily as one kind - that is, only in the context of actually seeing, only in the imagination, or only modeling, for example, expert visual thinkers use all kinds of imagery. They find that seeing, imagining, and drawing (modeling) are interactive and iterative (McKim, 1980); that is, the order in which the visualization's components are arranged vary depending on one's point of view. Am I the designer conveying information to others (communication, perception, imagination)? Am I the client to whom a designer is trying to convey an idea (perception, imagination, communication)? Am I drawing or modeling an object based on something I am looking at (perception, imagination, communication)? Or am I conceiving the idea (imagination, perception, communication to self)?

In artistic activity, perceiving and visual thinking are indivisibly intertwined. For example, a person who paints, writes, composes, or dances "thinks" with his/her senses (Arnheim, 1969). Your ability to visualize creative design ideas will depend on how good you are at perceiving the world around you. Developing your visual thinking and design modeling abilities involves developing both visual perception (observation), and analytical (geometry) skills. When you perceive, or "see," an object (that is, its lines, edges, shadows, movement, and so on), you are able to imagine it, and perhaps you can even draw (model) it if you have the necessary knowledge and skills. This discussion leads us to the **Visualization Principle**:

Visualization leads design communication

History provides the framework for this principle. Visualizing, drawing, and designing are among the oldest and most creative endeavors. Leonardo da Vinci (1452-1519) sketched most of his ideas by using pictorials or drawings showing three faces of the object before attempting to built them. He developed his talent by observing and studying (perceiving) nature. Leonardo's sketches include brilliant studies of the human body and of natural objects. He used visual annotations to enhance his memory and prepare to create his famous paintings the *Mona Lisa* and *The Last Supper*. He was also a great "design engineer." In *The Codex Antlanticus* he sketched maps, refrigeration systems, printing devices, military artifacts, and aeronautical machines. Because of the technological (physics and engineering) limitations of the period, none of these inventions became a reality during da

Vinci's lifetime. However, his idea-sketches anticipated modern inventions like the refrigerator, the airplane, and military tanks. The quickest way to visualize and remember design ideas is by sketching freehand on a piece of paper. This visual annotation technique was employed by da Vinci more than 400 hundred years ago. Quick annotations allow us to record our short-term visual memories for later referral and elaboration.

Visual images were also one of Albert Einstein's most useful tools. The famous scientist said, "Imagination is more important than knowledge, for knowledge is limited, whereas imagination embraces the entire world stimulating progress or giving birth to evolution" (Earle, 1990). In fact,the graphic communication process was one of Einstein's favorite tools. When asked about what kind of internal world he made use of, Einstein responded: "The words or the language, as they are written or spoken, do not seem to play any role in my mechanism of thought. The psychical entities which serve as elements in thought are certain signs and more or less clear images which can be voluntarily reproduced and combined" (Hadamard, 1945).

In the same way that Albert Einstein was able to conceptualize his mathematical ideas, we can conceptualize our design ideas, develop new engineering devices, and visualize (simulate) the behavior of materials and processes.

For thousands of years, engineers have used design communication techniques; particularly, drawings to document and manufacture/build their products. In fact, engineers still use working drawing, where numbers and symbols designate the dimensions (size) and tolerances (acceptable margin of error). Manufacturers rely on such design information to determine the size and shape of the product they are going to make. Drawings are also used to illustrate how a part's components should be put together (assembly drawings) and to show the floor, elevations (architectural plans), and structural details (structural plans) of a building.

As stated earlier, the design communication field is among the oldest of human endeavors. In fact, the first known working drawing is the plan (top view) of a fortress that was recorded on a stone tablet by Chaldean engineer Gudea (c. 4000 B.C.). Engineers have pointed out "how similar this plan is to those made by architects today, although `drawn' thousands of years before paper was invented" (Giesecke et al., 1990).

As early as 2600-1200 B.C., the Egyptians were using drawings made on papyrus (paper made from a reed-like plant) to design their projects. They used drawings to trace and record land boundaries, because the Nile River overflowed its banks each year (Steidel & Henderson, 1983). They also used drawings to show, for example, the stages in an excavation operation and the side views of a shrine or sanctuary (Dobrovolny & O'Bryant, 1984).

Roman architect/engineer Vitruvius (30 B.C.), in *De Architectura*, explains various drawing and construction procedures. His treatise could be considered the first design communication book.

Pierro della Francesca (1500 A.D.), during the Renaissance period in Italy, first used drawings showing various views of an object. The use of these interrelated views in a working drawing was a cornerstone in the attempts to visually represent an idea for a project (Juricic & Barr, 1987).

Gaspard Monge (1746-1818), a French mathematician, is regarded as the founder of descriptive geometry. Descriptive geometry involves the construction of precise drawings. Such drawings provide two-dimensional (2-D) descriptions of and information about 3-D objects. Monge developed geometry techniques mainly to solve problems in the design of fortifications. He was the first to propose simple geometric techniques to previously complex mathematical methods. Using simple drawing instruments like triangles, compasses, and dividers - and Monge's descriptive geometry principles - we are able to determine true shapes and angles of oblique surfaces, and to draw the unfolded shape (development) of physical objects. Descriptive geometry, drafting (drawing with instruments such as T-squares and triangles), and design methodology concepts were introduced in the U.S. engineering curriculum during the 20th century under various course titles, for example, descriptive geometry, engineering drawing, engineering graphics, engineering design graphics, visual communication, and design communication.

In the last few decades, computer graphics tools such as CAD (computer-aided design), solid modeling, stereographics (illusion of real 3-D), and animation have been introduced as a replacement for drafting instruments. Ivan Sutherland is considered to be the father of computer graphics. In 1961, while a doctoral student at the Massachusetts Institute of Technology, Sutherland developed a computer drawing program called *Sketchpad*. "The name was derived from the proclivity of engineers to rough out an idea on a scrap of paper, then gradually refine it by making innumerable revisions" (*Computer Images*, 1986). This computer program allowed simple geometric construction of lines and arcs on the monitor's screen. Dr. Sutherland was able to generate lines by using a series of push-buttons, a light pen, and a cross on the screen. By moving the light pen from one position to another, a line would follow much like rubberband, with one end tacked to the center of the cross and the other end attached to the light pen. He "sketched" circular arcs by indicating the center of the arc with a push-button, then moving the pen to another position to define the length of the radius. Dr. Sutherland's work marks the progress of computer graphics visualization from the laboratory into industry. Nowadays the ability to create geometry using computer graphics visualization tools, is regarded as a necessary skill for the engineering designer.

Scientists also use visualization. They regard visualization as a method that "transforms the symbolic into the geometric, enabling researchers to *observe* their simulations and computations. Visualization offers a method for seeing the unseen. It enriches the process of scientific discovery and fosters profound and unexpected insights. In many fields it is already revolutionizing the way scientists do science (and the way engineers design and manufacture devices.) Visualization is a tool for interpreting image data fed into a computer, and for generating images from complex multi- dimensional data sets. It studies those mechanisms in humans and computers which allow them in concert to perceive, use and communicate visual information" (McCormick et al., 1987).

Indeed, scientists have coined the term scientific visualization. *Scientific visualization* involves developing computer software and hardware tools to facilitate the interpretation of scientific data and to better understand physical and chemical behavior in materials or processes. Visualization is emerging as a "major computer-based field, with a body of problems, a commonality of tools and terminology, boundaries, and cohort of trained personnel. As a tool for applying computers to science, it offers a way to see the unseen" (McCormick et al., 1987). Visualization through computing can increase productivity and the potential for major scientific breakthroughs, as well as bring advanced methods into technologically intensive industries and promote the effectiveness of the scientific and engineering communities.

In design, visualization is the overall imaging and visual thinking process involved in conceiving, developing, modeling, simulating, testing, documenting, and marketing a device or a system. It also involves analyzing the device being designed, and predicting and seeing the response of the device to actual operating conditions (visual simulation). Computer graphics software can be used in the visualization process to build computer models and simulate the behavior of those models under certain design conditions. The designer begins by logging into a computer system and constructing one or more solid models as necessary from sketches and/or coordinate geometric data on the product being designed. The geometric model of, say, a product can be exploded to show how its components fit together. After executing certain commands, the software then generates solid sections that help the engineer visualize the interior of the product. The program can also generate working drawings and details from the model. To analyze the physical effect of factors such as forces and temperature, the program generates a finite-element mesh - that is, a set of wire-like elements connected together in a grid. Results of thermal (heat) and stress (force) analyses can be visualized easily by executing the finite-element analysis (FEA) capabilities of the software. For example, a cross-section image can be used to illustrate the stresses generated by the fuel pressure in a valve's inlet, and a scale can be used to indicate the stress in pounds per square inch (psi). When the visual simulation phase of the design is finished, the engineer may prepare the tapes needed by a numerically controlled (NC) machine-tool cutter for machining the products' parts. NC tapes can be used to set up the data for the cutter to machine the product from a real piece of, say, plexiglass.

As you can imagine, with computer graphics visualization tools we are now able to model and simulate the product being designed before building the first physical prototype. Two of the most useful computer-based visualization tools are geometric modeling and computer-aided design (CAD) - software programs that use the designer's input to generate an electronic 3-D graphic model on the computer screen. The model created by a geometric modeler or a CAD package represents a database. The database is a collection of data - such as the X, Y, and Z coordinates of the products' parts - having organization and structure. If the same database is shared with the manufacturing or building engineers, the process is called CAD/CAM, or computer-aided design and computer-aided manufacturing. Sharing a database involves hooking up computers (networking) in different departments. In fact, sharing the same electronically stored data files facilitates the design communication process. This can be expressed as the **Effectiveness Principle**:

Shared 3D database minimizes design communication problems

The benefits of sharing a 3-D CAD/CAM database include the following:

(1) Better product quality (since the manufacturing process is easier to control);
(2) Greater accuracy (by specifying an acceptable margin of error or tolerance);
(3) Shorter design time (since designers and manufacturers use the same data);
(4) Reduced prototyping cost (real model generated directly by a machine);
(5) Faster analysis (by using same computer model from an earlier design stage);
(6) Added manufacturing flexibility (by being able to change the database); and
(7) Reduced inventory (record-keeping of parts needed is easier)

CAD/CAM, visual simulation, and the other design communication techniques allow engineers to develop new products or improve existing products in less time than ever before and without using traditional paper drawings. The reduced design-cycle time facilitates the evaluation of more design alternatives and, ultimately, assists in obtaining better products.

Conclusion

The guiding principles introduced in this paper are based on past and present theory and practice of engineering design graphics. They were provided as a synopsis, and should serve to foster a dialogue between educators and practitioners. The author seeks the collaboration of his colleagues in "discovering" other universal principles, as well as the discussion and improvement of the principles stated here.

Design and communication are processes that can be considered a combination of three interrelated and overlapping phases: ideation, simulation, and implementation. Ideation involves the conceptualization of a design. The ideation phase includes market research, problem definition, generation of preliminary ideas, and the preliminary decision. Simulation involves the maturation of a design. The simulation phase includes geometric modeling, spatial geometry analysis, engineering analysis, and sometimes animation. Implementation involves the manufacturing or the construction of the product from a mature design. The implementation phase includes prototyping and testing, generating a report, creating design documentation, carrying out production, and marketing the product.

Six important design and communication principles that the beginning designer must keep in mind are the: (I.) Concurrent, (II.) FDR, (III.) Early-Decision, (IV.) Independence, (V) Implementation, and (VI) Design Management Principles.

Three other principles are linked with visual thinking, namely the: (VII.) Communication, (VIII.) Visualization, and (IX.) Effectiveness Principles. Visual-thinking cognitive processes are considered essential to design communication and, is individualized instruction. Dees (1991) conducted a study in a college remedial mathematics course to determine the effectiveness of cooperative learning on problem-solving skills. Students in the treatment group were required to work together during their laboratory sessions on algebra problems and geometry proofs. She determined that students who worked cooperatively performed significantly better on problem-solving activities than students who worked individually. Lambiotte, Dansereau, Rocklin, Fletcher, Hythecker, Larson, and O'Donnell (1987) also found that students working in groups performed significantly better than students who studied individually. In their study, students studied text passages in dyads or individually. Results indicated that students who studied the reading cooperatively recalled significantly more accurate information than those who studied individually.

". . .cooperative learning, like other methods of instruction, is not appropriate for all classroom situations."

In a study conducted by Klein, Erchul, and Pridemore (1994) however, cooperative learning was not as successful. In this particular study, undergraduate education students viewed an instructional television program on objectives-based assessment, completed some workbook activities, and then took a posttest on the material. Students who worked individually on the workbook activities performed better on the posttest than students who worked cooperatively. In our society, most people consider viewing television programs as an individual experience with very little interaction taking place with others. The Klein et al. (1994) study has implications for activities that are either traditionally thought of as individual activities or ones that have been designed for individualized instruction. Cooperative learning should not be used in situations where individualized instruction has been shown to be more appropriate.

In addition to carefully recognizing when cooperative learning is appropriate, it is also important to recognize the appropriate frequency of implementation. Hagen and Moffatt (1992) directed a study investigating students' satisfaction with cooperative learning and the extent to which cooperative learning is integrated into a course. They found that students in a course developed based on cooperative learning principles were more likely to be satisfied with cooperative learning than students enrolled in a course in which cooperative learning was limited to only one three hour session. Students who participated in cooperative learning throughout the course reported that they received more individual attention, and that the group work allowed them a chance to apply what they had learned. Although implementing group activities on a daily basis may not be ideal, using it for only one class session may not produce the expected learning outcomes.

A second conclusion drawn from research is that effective cooperative learning requires teaching students how to interact within a group environment. Dees (1991) indicated that simply encouraging students to work together during the semester is not enough to ensure that group interaction will take place. Many students do not feel comfortable working with others because cooperative learning is new to them. They have not acquired the communication skills necessary to interact in a group environment. Some type of teacher intervention is required where students can practice interacting with one another in a constructive manner.

Several studies have been conducted at Texas Christian University that investigated the effects of assigned roles on students in cooperative groups. Spurlin, Dansereau, Larson, and Brooks (1984) directed a study in which students from general psychology classes were placed in dyads to study scientific passages. One student was given the role of recaller, and the other student acted as the listener. After both students read a 500-word passage, the recaller orally summarized the material. The listener was instructed to correct errors in the summarization. In this study, recallers significantly outperformed listeners on recalling the main ideas of a passage. Spurlin et al. (1984) concluded that recallers performed better because they were required to make their own memory links during the summarization activity, while listeners were merely exposed to these generations. Lambiotte, Dansereau, O'Donnell, Young, Skaggs, and Hall (1988) discovered similar results using cooperative dyads with undergraduate psychology students. Cooperative scripts were used in which one student related all that he or she could remember about a particular passage while the other student asked questions to get as much information as possible from the other student. Across all groups in the study, students remembered significantly more about the passages they had "taught" or "summarized" than the material they had "learned" or "listened to." Even though the Lambiotte et al. (1988) study revealed that groups in which students alternated roles did not perform as well as the recaller in groups where students had fixed roles, students that alternated roles still outperformed listeners in groups where the roles were fixed. These studies have implications for designing cooperative activities that require every student within a group to take the role of "teacher" or "recaller" at some point during a lesson.

Finally, the characteristics of students influence the effectiveness of cooperative learning strategies. A student's verbal ability level, achievement level, and need for affiliation can influence the effectiveness of cooperative learning. Studies conducted by Rewey, Dansereau, Dees, Skaggs, and Pitre (1992) and Wiegmann, Dansereau, and Patterson (1992) revealed performance differences for high and low verbal ability students in cooperative learning environments. In both studies the DELTA was used to determine the verbal ability of the students. The DELTA has moderately high correlations with the verbal portion of the Scholastic Aptitude Test. In the Rewey study, students enrolled in general psychology classes read passages and then used either k-maps (two-dimensional presentation of information where words are contained in nodes and connected by nameable links), text-based materials, or no supplements to summarize and study the material. As one might expect, low verbal ability students in the cooperative learning condition performed significantly better when using the k-map to summarize the readings than when a text supplement was used. In the Wiegmann et al. (1992) study, the relationship between students' verbal abilities and the memorial benefits of the role of either a teacher or learner during group interaction was investigated. As with the other studies mentioned that were conducted at Texas Christian University (Lambiotte et al., 1987, Lambiotte et al., 1988, Rewey et al., 1992, and Spurlin et al., 1984), psychology students read text passages and then studied the material in dyads or individually. Students working cooperatively assumed either the role of the teacher or the learner. High verbal ability students in the learner role benefited more than high verbal ability students in the teacher role, whereas low verbal ability students in the teacher role performed better than low verbal ability students in the learner role. High verbal ability students in the teacher role may have been burdened when asked remedial questions by low verbal students in the learner role. Low verbal ability students benefited from the teacher role since it required them to summarize and paraphrase the information, thereby creating mental links.

"Cooperative learning should not be used in situations where individualized instruction has been shown to be more appropriate."

Another student characteristic that influences cooperative learning is achievement. Peterson (1993) studied the effects of motivational variables in cooperative learning examining the relationships between high and low achieving students. Elementary education students were put into high and low achievement groups based on midterm exam scores. After working cooperatively for six class periods creating an elementary level classroom test, each student completed an attribution questionnaire that contained eight attributions commonly made by college students for performance on group tasks. This study revealed some interesting data concerning students' perceptions in group environments. High-achieving students rated their partners lower than low-achieving students, high-achieving students felt less pride in the outcome than did low-achieving students, and high-achieving students were less likely to expect future success with the same partner than were low-achieving students.

A student's need for affiliation also influences group activities. Klein and Pridemore (1992) conducted a study examining the effect of cooperative learning and the need for affiliation on performance, time on task, and satisfaction. Undergraduate education majors were required to work individually or in dyads while watching an instructional television program and completing workbook exercises. After the treatment activities, students completed an affiliation scale, a satisfaction questionnaire, and a content specific posttest. Students with a high need for affiliation who worked individually performed significantly lower on the posttest than any of the other groups. Students with a low need for affiliation who worked alone outperformed students with a high need for affiliation on the posttest measure.

"...the characteristics of students influence the effectiveness of cooperative learning strategies."

Participants

During the summer and fall semesters at North Carolina State University, cooperative learning exercises were introduced to three sections of GC200 (Applied Computer Aided Drawing). A total of 78 students from technology education and mechanical, aerospace, industrial, civil, and electrical engineering participated in the group activities.

Procedures

At the beginning of the semester, students were assigned to groups of three or four individuals. They were informed that cooperative learning methods would be used throughout the semester to help them review and master material presented in the course. Three types of cooperative strategies were used during the course of the semester.

The first cooperative learning method was used to review the topics of multiview sketching, isometric sketching, and dimensioning. Although these topics were covered in an introductory course, most students had not reviewed the material for one or two years. For multiview drawings, each group was given four isometric pictorials and asked to sketch the top, front, and right side views. Each student was to sketch two of the objects for the next class meeting and to be prepared to check the work of other group members. For example, one student in the group sketched objects 1 and 2, the next student sketched objects 2 and 3, etc. Students then had to check the work of at least two other group members against their own sketches. Following two rounds of this activity, students individually completed a 10 minute test. This format was continued for pictorials and dimensioning.

The Jigsaw method of cooperative learning was used to study material on threads and fasteners. All students were assigned to read the entire threads and fasteners chapter before coming to class. The instructor lectured on the material in the chapter before assigning each student in the original groups to be an expert on a particular portion of the reading. Four expert sheets were given to each group covering standard cap screws, machine screws, set screws, and keys. Each group member was responsible for a particular expert sheet. Four expert groups were then formed with one person from each of the original groups. Students were given approximately 30 minutes to answer the questions on the expert sheets. During the following class period, students met with their original groups to teach each other the material gathered in the expert groups. One week later, students were given a thirty item multiple-choice test on threads and fasteners that included looking up information on standard tables. After completing the test, students completed an evaluation form for the first two cooperative learning strategies.

The four quizzes that were given on multiviews, pictorials, dimensioning, and threads and fasteners counted for 10% of the final course grade. In addition to receiving an individual grade for the quizzes, groups that performed the best for a particular quiz were recognized in class. Group grading was based upon improvement scores for the quizzes. Students who received a perfect score or scored at least 10 points higher than their base score (average of the raw quiz scores) received 30 improvement points. Quiz scores that were 0-9 points higher than the base score earned 20 improvement points, scores from 1-9 points lower than the base score earned 10 improvement points, and scores 10 or more points lower than the base score did not earn any improvement points. Improvement points for each person in the group were combined to determine a group improvement score. This scoring method provided an opportunity for every group to be recognized during the semester.

During the last portion of the course, students were assigned to dyads or triads to complete the final project. Students were given a design that consisted of 6 to 14 parts and were assigned to complete the detail drawings for non-standard parts and the assembly drawing. Groups had to come up with a plan for completing the working drawings, design title blocks that included a logo for their group, and decide upon a logical drawing or part numbering scheme. At the end of the semester, each student evaluated the project activity.

Summary of Evaluations

Overall, students responded positively to the cooperative learning activities. Most students felt that the exercises gave them a chance to catch mistakes that they had overlooked, and the group setting also gave them an opportunity to work with others in a productive, non-threatening environment. The most frequently occurring negative comments were that sketches with consistent mistakes were not caught, absences hurt the group's success, and more time was needed for the Jigsaw method. Two students felt that the cooperative learning strategies were a waste of time. Both commented that they could have learned the material more thoroughly and in less time if they would have studied alone.

The instructor also made several observations during the cooperative learning exercises. As was stated by the students, if a group member was absent when a quiz was given, the group's chance of success was greatly reduced. Secondly, some students did not have their sketches completed and ready to be checked by the other members of the group at the beginning of class. Even though the individual sketches were not graded, the instructor did collect them and give feedback. Finally, some groups did not take the checking activities seriously enough. The instructor had to constantly encourage some groups to do a better job when looking over sketches since many mistakes were overlooked. This may have resulted from the group's lack of experience in engineering drawing.

> "...instructors can expect a wide range of student satisfaction levels when introducing cooperative learning strategies into a course."

Conclusions and Discussion

Based on the previous studies, the student comments, and the instructors observations, enough evidence exists to warrant further research involving cooperative learning in engineering graphics courses. These exercises allow students the opportunity to engage in active learning, creating important connections with previous knowledge and developing stronger communication skills with others. When preparing cooperative learning activities, instructors should only implement cooperative activities in appropriate environments, students must be informed about their role within the group and how to interact with others, and student characteristics can influence the effectiveness of the learning. As the Klein and Pridemore (1992) and Peterson (1993) studies reported, instructors can expect a wide range of student satisfaction levels when introducing cooperative learning strategies into a course. Educators who understand that all students do not respond to cooperative learning strategies the same way will be able to recognize potential problems and prepare meaningful instruction for the entire class.

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The 50th Mid-Year Conference

Engineering Design Graphics Division
Iowa State University, Ames, IA
November 5 – 7, 1996

The program for the 1995/1996 Mid-Year Conference is being developed. This is the 50th annual conference and therefore is a milestone meeting, so make your plans early to attend.

ENGINEERING DESIGN GRAPHICS DIVISION
ASEE

Conference Theme:

THE FUTURE ISN'T WHAT IT USED TO BE

Possible Topics:

I. **YESTERDAY:** *How Did We Get To Where We Are?*
- ✔ What has happened to the topics that were important?
- ✔ What topics should we still be teaching?
- ✔ Why is there a split between computer and traditional graphics?
- ✔ Has visualization been enhanced by computers?
- ✔ Any special topics related to the 50th anniversary meeting

II. **TODAY:** *Current Topics*
- ✔ The role of visualization and analysis to teaching graphics
- ✔ What is the state of the art in teaching?
- ✔ The role of design and synthesis in teaching graphics
- ✔ Can traditional and computer graphics be integrated?
- ✔ What determines effective teaching software?
- ✔ Effective teaching aids
- ✔ Role of standards in a rapidly changing environment

III. **TOMORROW:** *The Future of Engineering Design Graphics*
- ✔ Instructional initiatives
- ✔ New/Breaking technologies
- ✔ Recommendations for development

General Chair: Rolland D. Jenison
Program Chair: EFMD/400 Marston Hall
Iowa State University
Ames, IA 50011-2150
FAX: (515) 294-4007James C. Shahan

Chair's Message III

William A. Ross

Engineering Design Graphics Talks,
Engineering Graphics Walks!

Anonymous

First, a correction for an oversight in the previous Chair's Message. The correct dates for the 50th EDGD Mid-Year Conference in Ames, Iowa is Nov. 5-7, 1995; not Nov. 15-17 as previously stated. My apologies! It will be here even sooner than I thought.

Is design a truly important part of our divisional name? When our division added the word design to its name, I am persuaded that it could not have chosen a better term to describe its mission and future. In my final message to you, I would like to take a moment of your time to address this point.

What's design got to do with it? Few would argue that one of the ultimate goals of engineering design graphics instruction is to enable students to seamlessly integrate graphic tools with problem solving and design issues. Historically, due in part to the nature of the tools involved, the knowledge base of most engineering graphics courses has been focused heavily on visualization, geometry, sketching, engineering drawing methods, and standard practices. Consequently, in the precious available time we have for instruction, insufficient attention has been paid to integrating graphic tools with problem solving and design.

Over the past 15 years, rapid changes and developments in applied computer graphics tools have enabled us, in some cases kicking and screaming, to migrate several levels up the evolutionary path created by technology. In the early 80's our first major tool shift, thanks largely to microcomputers, was to 2D CAD. From the mid 80's through the early 90's we began to migrate to 3D CAD and more recently to 3D solid modeling. Now, in the early to mid 90's, we are beginning to experiment with and incorporate parametric tools which use integrated 2D and 3D CAD as a graphic base for design. Developmental efforts, such as those occurring currently at Northern Arizona University, Michigan Technological University, and the University of Texas, are noble examples of continuing efforts to incorporate new technological tools.

One of the most exciting prospects of graphics based on parametric design is its potential to link real world constraints, and more importantly students, with equation solving software, spreadsheets, and other system based tools which are all part of the 'global' information system of corporate America. Out in the 'real world', many corporations envision a global solution to corporate problem solving with the same platform, same operating system, and everyone sharing data across the organization; with graphics at the core! Preparing students to integrate graphics with the constraints of actual design problems is tailor made for this current corporate paradigm. But what about the future?

What are some of the future technological horizons in computer graphics? To name but a few: Virtual reality, Visual simulation, Rapid prototyping, and Global 3D model data bases. From an engineering perspective, these advances in computer graphics, plus many others, will eventually be integrally linked to the design process. Where do we go from here? I'm not sure but it should be an exciting trip.

The theme for the upcoming 50th Annual Midyear Conference of the Engineering Design Graphics Division is "The future isn't what it used to be." Looking optimistically ahead, our future will quite probably be much more than it used to be; presumably with a maturing emphasis on design. What's design got to do with it? Come to the Conference in Ames this Fall and join us as we continue to seek answers to this timeless question.

Calendar

1995-1996 EDGD 50th Annual
Mid-Year Conference
Iowa State University,
Ames, Iowa
November 5-7, 1995
General Chair: Roland D. Jenison
Program Chair: James Shahan
Division of Engineering Fundamentals,
Iowa State University,
206 Marston Hall,
Ames, Iowa 50011-4007
(515) 294-1614
FAX: (515) 294-4007
EMAI: estaben@iastate.edu

Graphic Communications Teacher Conference
October 7-9, 1995
McCormick Place, Chicago, IL.
Who should attend: Full-time graphic communications educators form high schools, colleges, and universities.
Contact: Jack Simich, Education & Training ,
Graphic Arts Technical Foundation
4615 Forbes Ave.
Pittsburgh, PA 15213
FAXL 412-621-3049

SECTAM XVIII
Southeastern Conference on Theoretical & Applied Mechanics
April 14-16, 1996
Bryant Conference Center & Hotel
Tuscaloosa, AL
Contact: J. L. Hill
Department of Engineering Science and Mechanics
University of Alabama
Box 870287
Tuscaloosa, AL 35487-0278
Email: jhill@ualvm.us.edu

1996 Annual ASEE Conference
June 23-26, 1996
Washington, D.C.
Program Chair: Moustafa R. Moustafa,
Engineering Technology,
Old Dominion University
11-KDH
Norfolk, Virginia 23529-0244
(804) 683-3767
FAX: (814) 863-5655

International Conference on Engineering Computer Graphics and Descriptive Geometry
July 18-22, 1996
Cracow, Poland
Cracow University of Technology (CUT)
ICECGDG Organizing Office
Cracow University of Technology, A-9
Warszawska St. 24
31-155 Cracow, Poland
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Fax: +48 12 233212
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1996-97 EDGD 51st Annual Mid-Year Conference
Location: North Carolina State University
General Chair: Eric N. Wiebe
Program Chair: Bob Chin
Graphic Communications Program
Department of Occupational Education
College of Education and Psychology
North Carolina State University
Box 7801, Raleigh, NC 27695-7801
(919) 515-2234
FAX: (919) 515-7634
EMAIL: eric_wiebe@ncsu.edu

1997 Annual ASEE Conference
Milwaukee, WI, June 15-18, 1997
Frank Croft, Program Chair

ICED '95 Praha
International Conference on Engineering Design
Aug. 22-24, 1995
Czech Technical University (CVUT), Prague, Czech Republic
Theme: Design Science for and in Design Practice
Contact: Czech Technical University (CVUT)
Faculty of Mechanical Engineering,
Techniciká4, CZ-166 07 Praha 6, Czech Republic
Tel: +42-2-311-1273
Fax: +45-2-311-1273

EDUGRAPHICS '95
Second International Conference on Graphics Education
COMPUGRAPHICS '95
Fourth International Conference on Computational Graphics and Visualization Techniques
Alvor Algarve , Portugal
December 11-15, 1995

In Cooperation with the "International Society for Geometry and Graphics," these conferences will be held concurrently.
Contact: Harold P. Santo
Department of Civil Engineering - IST
Technical University of Lisbon
Av. Rovisco Pais, 1
1096 Lisboa Codex Portugal
Tel. + Fax : +351-1-848-2425
E-mail: chpsanto@beta.ist.utl.pt
Submission deadline: May 31,1995

CADEX '95
International Conference and Exhibition on Computer Aided Design
Seville, Spain
December 4-8,1995
Contact: Harold P. Santo (See above)
Submission deadline: May 31,1995

EUROGRAPHICS '95
Graphics•Multimedia•Virtual Realtity
Maastricht, The Netherlands
August 28 - September 1, 1995
Contact: Lidy Groot, Congress Events
P.O. Box 83005, 1080 AA Amsterdam,
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EMAIL: eg95@cwi.nl
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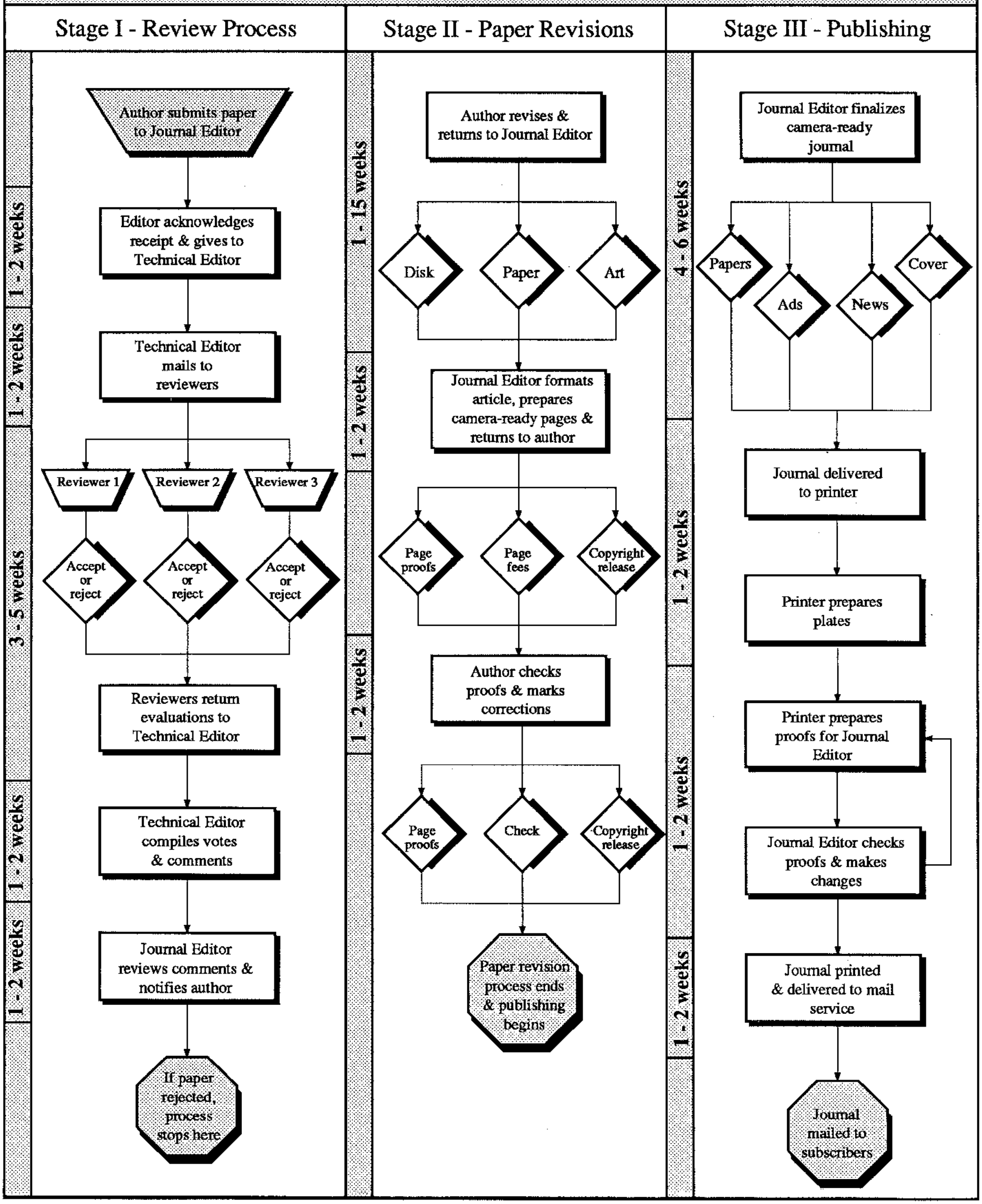
Engineering Design Graphics Journal Publication Process



Mary A. Sadowski, Editor

Judy A. Birchman, Technical Editor

Engineering Design Graphics Journal Review Process

Judy Birchman, Technical Editor
Mary A. Sadowski, Journal Editor
Department of Technical Graphics
Purdue University
West Lafayette, IN 47907-1419

Introduction

Because the *Engineering Design Graphics Journal* is a reviewed publication, there is a lengthy review process before a paper which has been submitted can (or will) be printed. As most of you know, the review process ensures that each paper that is accepted for print has been reviewed by a member of a qualified review panel. In our case, we have a panel of 20 reviewers who volunteer their time, energy, and expertise to review papers for both the *EDGD Journal* as well as the *ASEE Annual Conference Proceedings.* We use a blind review which means that the names of the authors have been removed before a copy of the paper is distributed to three different reviewers.

What we are presenting here is an attempt to describe the process that every reviewed paper must go through before it can be printed. The process, which was instituted when Jon Duff was editor approximately nine years ago, is lengthy and time consuming. We feel, however, that it has helped the *EDGD Journal* become a quality publication.

On page 35 you will find a flowchart of the Engineering Design Graphics Journal Publication Process. On page 38 you will find reduced copies of the forms which accompany each paper when it is sent to the reviewers. We hope this short article can shed some light on the review process and help expain why it takes so long to actually get a paper in print. By the way, information that is printed in the New & Notes section of the *Journal* has not gone through the review process. In most cases selection for print in this section of the *Journal* is made by the *Journal* editor with input from the technical editor and other individuals including the Chair of the division.

Stage I- Review Process

The review process can be an emotional roller coaster for the best of us. As you can see from the flow chart, days stretch into weeks as your paper passes through the various stages of the review process. The process starts with a flurry of activity as you press yourself to finalize your paper and get it sent off for review.

When your paper is received by the editor, a folder is created with a checklist that keeps a time line of the review process. Upon receipt of the paper, the author is sent a letter of acknowledgement which also explains the page fees. At this point, the paper is handed over to the Technical Editor who is in charge of the review process.

Each paper is reviewed by three different members of the review board. When reviewers are selected for the board, they fill out a form which lists their areas of expertise. This form is used when selecting the appropriate reviewers for a given paper. The reviewer's are usually given three weeks to evaluate the paper. Reviewers have three options from which they can select.

These options are:

1. Acceptable with minor changes as noted.

2. Rejected for publication for reason(s) noted.

3. Topic not appropriate for publication in the *EDGD Journal.*

Engineering Design Graphics Journal Review Form

Paper Title: An Algorithm for Evaluating Team projects

Reviewer: ____________________

Date Mailed: ____________________

Return by: ____________________

Date Returned: ____________________

❑ Acceptable for publication with **minor** changes as noted

NOTE: ____________________

❑ Rejected for publication for reason(s) noted

NOTE: ____________________

❑ Topic not appropriate for publication in the **EDGD Journal**

NOTE: ____________________

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Evaluation

Criteria	Excellent	Good	Adequate	Weak	N/A
Significance of topic					
Comments:					
Quality of ideas					
Comments:					
Organization of text					
Comments:					
Clarity of expression					
Comments:					
Grammar & spelling					
Comments:					
References					
Comments:					
Quality of figures & charts					
Comments:					
Methodology & design					
Comments:					

The first option is selected for papers which are well written and appropriate for the *EDGD Journal*. The reviewerfs may note a few changes which the author might have to correct before final publication. The second option is for papers which are rejected. This may be for a variety of reasons. The paper may contain valid and interesting material but be so poorly written and organized that it needs a major reworking before publication. Another paper may be rejected because it is based on a poor methodology or has few references to support its arguments. Whatever the reason for rejection, many of these papers can be resubmitted for review once they are reworked. It is important to note that a resubmitted paper starts the review process anew rather than as a continuation of the first review.

The third option is for papers that fail to address the Engineering Design Graphics Division audience. Engineering and technical graphics is what we are concerned with and yet some authors fail to mention anything related to graphics in their papers.

Reviewers are asked to write comments directly on the paper and/or on the evaluation sheet.

ENGINEERING DESIGN GRAPHICS DIVISION ASEE

This is particularly valuable to an author whose paper has been rejected. It is important for authors to receive the feedback which will explain where their paper fell short so that they may be successful with future attempts. Following are the main categories for evaluation and some of the considerations:

Considerations for Reviewers

1. ***Significance of the topic.*** Does the paper discuss matters of concern to division members? Will it assist graphic educators in their work? Is the topic current?

2. ***Quality of ideas.*** Does it take a new approach to a problem? Does it share techniques that others can apply? Is it based on sound research? Is it innovative?

3. ***Organization of text.*** Is the material structured for readability? Are figures and tables used to help explain the text? Are heads, subheads and figure captions used to assist the reader?

4. ***Clarity of expression.*** Is the material explained well? Are jargon and abbreviations minimized? Is the writing level appropriate? Do explanations follow logically? Are terms and procedures fully explained?

5. ***Grammar & spelling.*** Has the paper been thoroughly proofed? Is the use of grammar correct? In addition to running a spellchecker on the computer, authors should have another person read their paper thoroughly. A reader who is not involved with the writing of a paper can often give suggestions about what is unclear. Remember, the purpose of the review process is to review; the reviewers are not editors!

6. ***References.*** Have you supported your paper with references? Are references in the correct format? Are there enough references?

7. ***Figures & charts.*** Have you used figures and charts to support and explain the text? Are the figures and charts of high quality (not too small, messy, inappropriate)? Are there clear references to the figures so that the reader understands the relationship between the text and the figures?

8. ***Methodology and design.*** Is the study well-designed? Is the data significant? Are procedures well-documented and explained? Are the practical applications and implications fully reported?

Once the reviewers return their evaluations, they are compiled for return to the author. The results and comments are passed on to the journal editor who notifies the author of the results. If the paper is accepted for publication, it proceeds to the next stage of revisions.

Stage II - Paper Revisions

Once your paper has been accepted for publication, it will be returned to you for revisions. At this point, you will examine the comments of the reviewers and make the necessary changes to correct the paper. Some comments are mere suggestions such as a word change whereas others might require reorganization of the text. Once you are satisfied with the changes, you will return a hard copy of your paper fresh artwork (if we don't already have it) as well as an electronic copy on a 3.5" disk to the editor. *Remember, it is the editor's job to format the text!*

Do not send formatted text; send only the raw, unformatted (ASCII text if fine) text on the disk. It is at this point that many authors drag their feet and delay the publication of their paper. An accepted paper cannot be printed until the revised, electronic version is received by the editor.

The editor now begins the process of formatting your paper to fit into the *Journal.* Once your paper has been formatted, the editor will mail you page proofs. At this stage you will see exactly what your paper will look like in the *Journal.* It is your responsibility to proof it and mark corrections before the final publication. It is at this point that corrections must be made. If you do not catch a mistake, your paper will be printed with the mistake. You will also receive a copyright release to sign and a bill for page fees. Once you return the proofs, copyright release and a check for the page fees, your paper will be ready to be published in the next edition of the *Journal* .

Stage III-Publishing

When everything has been returned, the editor combines all of the papers, ads, and Division News & Notes into camera-ready artwork. The artwork for the cover is also finished and made ready for publication.

Finally, the artwork is taken to the printers. The printer prepares a blueline proof for final approval. Once the blueline is approved, the *Journals* are printed and delivered to the mail service where they are labeled, bundled and delivered to the post office.

The publishing process can be very frustrating for those of us who are anxiously awaiting the arrival of the newest copy of the *Journal.* Anyone who has dealt with publications knows that you cannot rush a printer, and we all know that we cannot rush the U. S. Postal Service.

Conclusion

Our advice to present and future authors is to be patient. Publishing can be a lengthy process, especially when all the work except the printing and mailing is done by volunteers. Remember that your editor, technical editor, circulation editor, advertising manager, and reviewers all volunteer time to help produce a quality publication.

Artifacts needed

There will be an Artifacts Display at the Midyear Conference in November at Iowa State. If anyone in the division has items of historical significance relating to graphics practices or the profession, we'd like to consider them for display. We will provide security during the display and they can take whatever is on display with them when they leave. Items might include unusual instruments, graphical devices, rare books, maybe models, and we decided that unusual slide rules or other graphical calculating devices would qualify (not "typical" slide rules). Anyone who has a candidate item should contact me directly. I can be reached by regular old-fashioned mail or:

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Material submitted should not have been published elsewhere and not be under consideration by another publication. Submit papers, including an abstract as well as figures, tables, etc., in quadruplicate (original plus three copies) with a cover letter to

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