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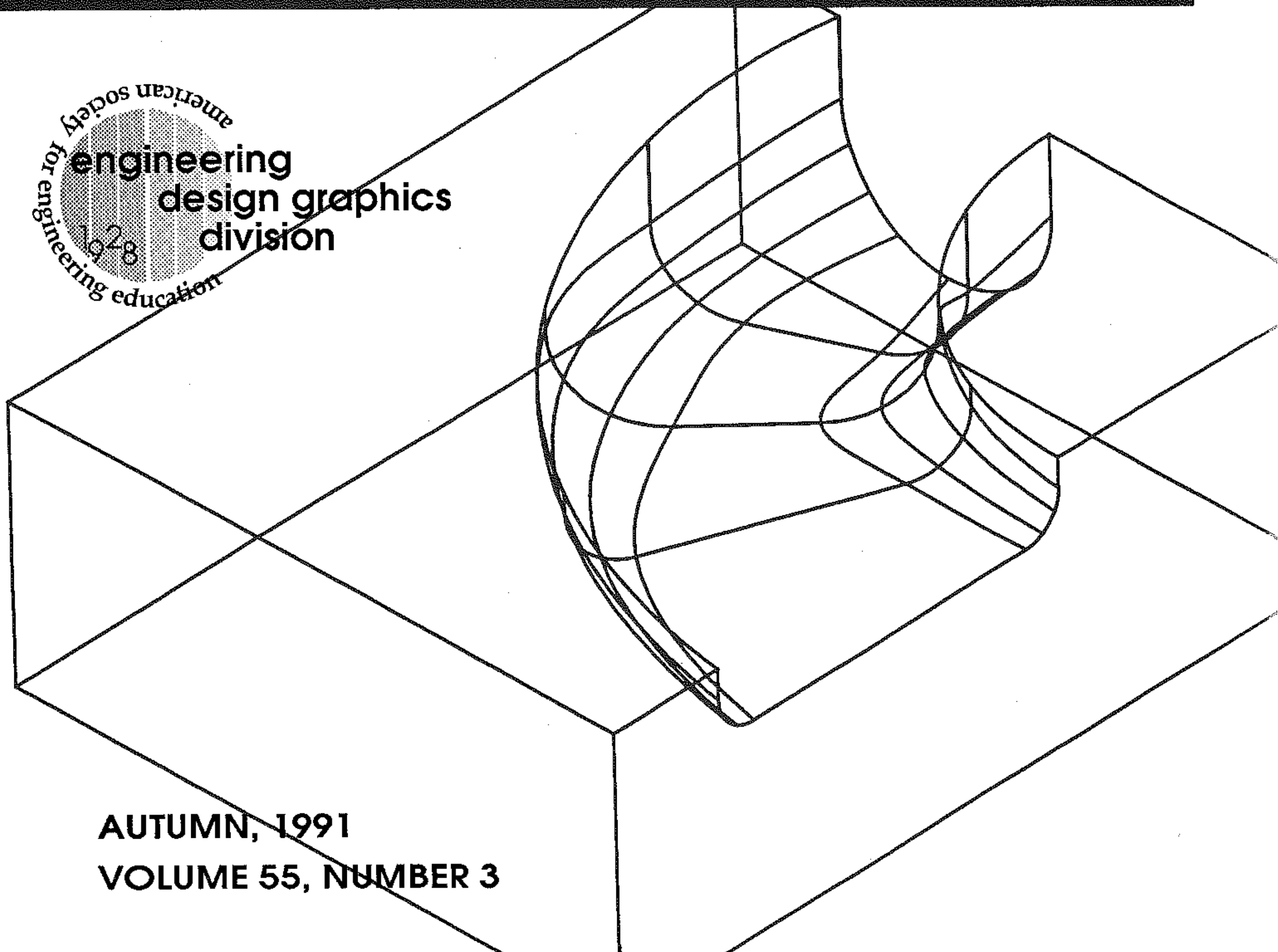

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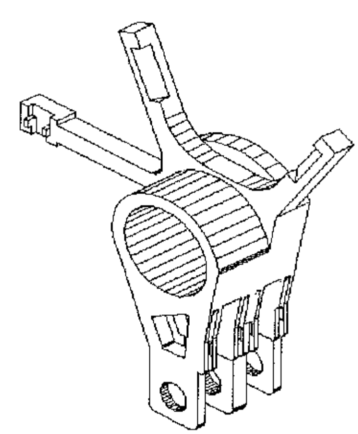

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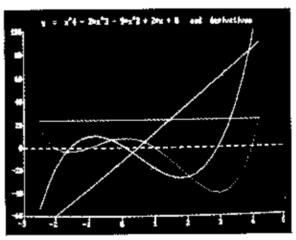

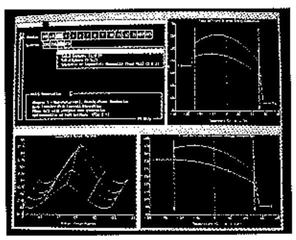

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The *Engineering Design Graphics Journal* is the official publication of the Engineering Design Graphics Division of ASEE. The scope of the Journal is devoted to the advancement of engineering design graphics, computer graphics, and subjects related 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 Editor . .

As the new editor of the *Engineering Design Graphics Journal*, I would like to preface this publication with a hearty thanks to Barry Crittenden and Clyde Kearns who have sent me information, helpful hints, and graciously responded to my telephone calls. Like any new editor, I started out knowing very little about what it takes to produce a journal of this magnitude. As Barry can tell you, I now know that it takes time, perseverance, and numerous phone calls.

I have received plenty of good advice from many EDG members about the looks of the journal. People were highly complimentary of Barry's term as editor which leads me to believe that I have big shoes to fill. After compiling many of the suggestions, I realized that although I agreed with most, I couldn't possibly implement them all. Since I work on a college campus, I took the next logical step and went over to the engineering library to do a little research. I stopped at the door to look at the list of over 1500 current periodicals that were available in the Engineering and Technology fields. I knew then, that I would be able to find the definitive answer to what a 'professional' journal should look like.

To my dismay (and delight) I found *everything*. I had heard more than once that all 'professional journals' use a two-column format and have the table of contents (toc) on the outside cover. I had also heard that since our membership is aging, we must use large type size. Of course, I also heard that to attract younger members to our organization we should use a smaller type size.

Using a very unscientific approach, I selected 50 journals that looked similar to the *EDG Journal* in size and content and proceeded with my survey. Of the 50, 41% used a two-column format, 33% used a three-column format, 14% used a variety of column formats, and 12% used a single column format. You will find two-columns for the technical papers, and a variety for the EDG division news.

In response to the (toc) on the cover and type size, 41% had the table of contents on the front, 39% on the back, and 20% on the inside. You will find the technical papers listed on the back, and the entire table on contents on the inside. This way, if the cover is inadvertently torn off, the table of contents is still available. I found no journals using anything larger that 10 point type, and many used smaller. This journal is done mainly in 10 point type.

Some covers kept the same format throughout the year, many changed at least partially from one issue to the next. Some kept the same design but used a different color each issue. Some kept the same color but changed an illustration each time. My personal favorite cover color was the *Journal of Planning Literature* which used a different pastel each issue. The lavender one was especially nice.

The point I am trying to make here is that it is impossible to make everyone happy, but I have attempted to make educated choices about how the EDG Journal will look over the next three years.

Other things I learned from my trip to the periodicals include: (a) many international journals use sizes that are very different from those in the United States, (b) true professional, reviewed journals have no advertisements, and very few illustrations or photographs, (c) and that the journals with the most advertisements use the most color. I have learned a great deal in preparing this first issue and hope that you enjoy it.

Mary

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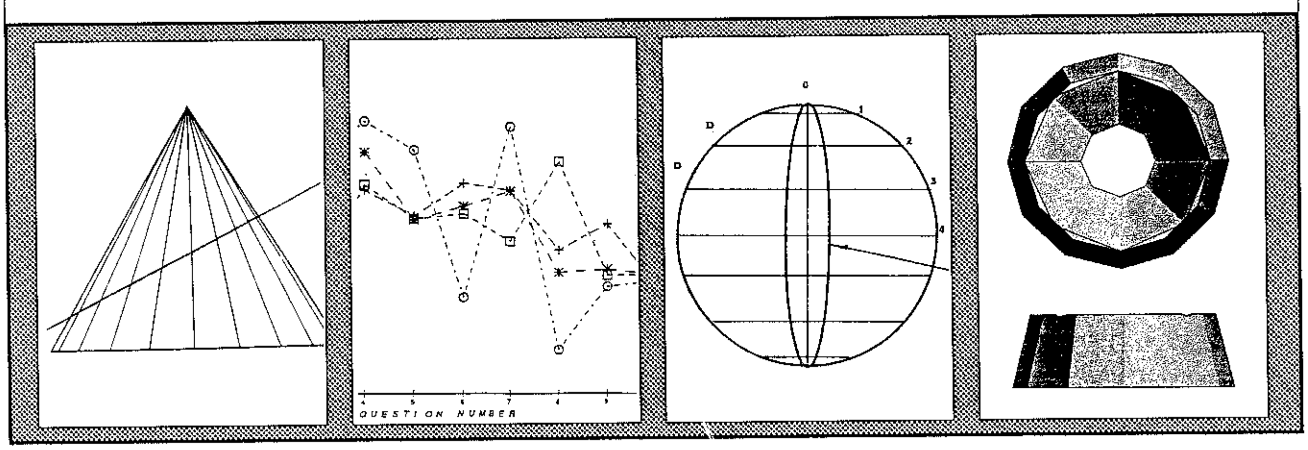

Spatial Visualization Research and Theories: Their Importance in the Development of an Engineering and Technical Design Graphics Curriculum Model

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Abstract

Recently, engineering and technical graphics educators within the profession have proposed various curriculum models that would bring about basic changes in the engineering design graphics discipline. These curriculum proposals are hopefully based on sound philosophical reasoning and would direct the profession in the future. The area of visualization is of central interest to both the National Science Foundation and the SIGGRAPH funded curriculum developments for engineering design graphics.

Traditionally, engineering design graphics has described visualization as the ability to read and develop orthographic drawings or to solve descriptive geometry problems. If a student were able to develop orthographic or descriptive geometry drawings then the student had visualization ability. The accuracy of traditional approaches of visualization in engineering graphics has recently been challenged by many educators in the profession. If engineering graphics educators are convinced that the traditional approaches of visualization are incorrect then they should undertake research in the area of visualization. But what the profession must realize is that there is a vast area of visualization theories and research in many other disciplines. The visualization theories postulated and research conducted in cognitive psychology, art education, math education, science education, and in many other disciplines could be very beneficial to the engineering graphics profession.

What is visualization? What is perception? Is there a difference between visualization, spatial visualization, and perception? What are the major and minor spatial factors that impact visualization? What are different sources of variance that impact the performance of individuals on visualization tasks or hinder individuals from developing the ability to visualize? Currently, answers to these questions may exist in research studies that have been conducted in various disciplines outside of engineering graphics.

With the knowledge of previous research conducted by other disciplines, the engineering design graphics profession can conduct research in visualization which is theoretically based upon research findings. Results of extensive research in visualization by the engineering design graphics profession will provide the knowledge and methods necessary to improve students' ability to visualize in three dimensions.

Introduction

Recently, with the influx of new, more powerful, and economical computer-aided software and hardware technology, the traditional engineering design graphics curriculum has been challenged. Funded curriculum efforts, such as the National Science Foundation Curriculum Development Program for Engineering Design Graphics by Barr and Juricic and the SIGGRAPH Curriculum Model for Engineering Graphics by Bertoline, et al. have called for sweeping changes in the engineering and technical design graphics course of study. Of central importance to both of these curriculum efforts and to the profession as a whole is spatial visualization. Although spatial visualization has been a central part of the engineering graphics curriculum for years, it is just now receiving, and rightly so, more attention in journal articles and conference proceedings.

Wiley (1989) claims that many of the goals of visual disciplines, including engineering and technical graphics, are weak and do not produce meaningful amounts of effective research. Wiley advocates the development of visual perception as the major focus of the curriculum of engineering and technical graphics. With this thought in mind, if engineering graphics educators expect the engineering and technical design graphics curriculum to become accepted as a recognized discipline by other established disciplines, we must center our curriculum efforts in the area of spatial visualization. Although other areas of the engineering and technical design graphics curriculum such as freehand sketching skills, the use of graphics tools, geometric constructions and concepts, etc. are very important for the development of highly-qualified professional engineers and technicians, these areas may be of special interest to our field only, and may not be recognized or accepted by many other disciplines as being representative of a discipline. However, the area of spatial visualization and the development of spatial abilities have been shown repeatedly to be a vital component of success in a wide range of engineering, technical, mathematical, and scientific professions.

"...meaningful amounts of effective research have not been developed, investigated, or published by our profession."

The engineering and technical design graphics profession is in a unique position to become a leader in spatial research and thus become accepted as a discipline equal to psychology, chemistry, and the various specializations within engineering because we are the experts in visual communication and the development of spatial visualization abilities. Although we have been experts in spatial visualization for years, meaningful amounts of effective research have not been developed, investigated, or published by our profession. Now, however, the increased interest in visual research in many disciplines coupled with the recent advancements in computer technology have provided us the opportunity to conduct more research in the area of spatial visualization and become the leaders in this area. But which other disciplines have conducted research in spatial visualization? What results have they found? What have they concluded from these results? What do they recommend for further study? Without knowledge of the prior research, theories, and other related information on spatial visualization, engineering graphics educators would essentially be "reinventing the wheel" with further research in this area. We must investigate all prior research that has been conducted in spatial visualization as well as study areas closely related to it. The intent of this paper is to give a limited overview of prior research that has been conducted in spatial visualization and closely-related topics. This overview, while by no means comprehensive, gives an introduction to the theories, terms, concepts, and prior research conducted in visualization.

Where did spatial research begin?

Research in spatial visualization has been conducted by many different disciplines. Psychology, art education, mathematics, science, and engineering and technical graphics have all conducted research into this topic to various degrees. The majority of prior research conducted in spatial visualization has been by psychologists investigating spatial testing. Eliot and Smith (1983) have identified three major phases in the development of spatial testing, which has in turn led to various theories and research investigations in spatial visualization.

The first phase (1901-1938) was an effort by psychologists to establish and identify the presence of a spatial factor. Historically, because of Greek influences, intelligence was erroneously viewed solely as the ability to perform verbal tasks. Visual tasks were not considered to be a measure of intelligence. Evidence of this bias could be found in such tests as the Binet-Simon Scales of Intelligence and tests used by the United States Army to test military personnel. The intent of the United States Army test was to measure a person's verbal and nonverbal abilities. The test was broken down into two sections: the Alpha test which measured verbal ability, and the Beta test which measured a variety of performance tasks. The Beta test was significant in that it was the first non-verbal test battery that was administered to a very large sample of subjects. If a person scored well on the Alpha test he was considered to be educated or verbally literate, while if a person scored well on the Beta test he was considered to be uneducated or verbally illiterate. Thus the Alpha and similar tests were a biased means of measuring intelligence based on verbal abilities. But many psychologists did not agree with the theory that intelligence was limited to the verbal realm and research studies and testing conducted by El Koussy (1935), Kelly (1928), and Thurstone (1938), among others, established the identification of the spatial factor as a very important aspect of human intelligence (Eliot and Smith, 1983).

The second phase (1938-1961) of research in spatial testing and intelligence noted by Eliot and Smith (1983) tried to identify different spatial factors and how they varied from each other. During this stage, large-scale research studies were conducted on spatial testing and spatial intelligence and, as a result, a large number of paper-and-pencil spatial tests were developed. Several terms, such as spatial relations, visualization, spatial orientation, and imagery, were advocated by several researchers, and these terms could be grouped into two major categories: (1) The ability to recognize spatial configurations; and (2) The ability to mentally manipulate spatial configurations (Eliot and Smith, 1983). Although there was not agreement among researchers on exactly how many spatial factors existed or what they should be labeled, research showed that at least two spatial factors did exist and that paper-and-pencil spatial tests could be used to measure a person's spatial ability.

The third historical stage (1961-1982) of research and testing of spatial factors and spatial intelligence identified by Eliot and Smith (1983) centered on studies determining the interrelation of spatial abilities with other abilities and the discovery of various sources of variance in testing of spatial abilities. Studies were conducted to determine if spatial abilities were related to a person's sex, age, environmental upbringing, and hereditary influences. The studies conducted during this stage showed that the various areas of variance did indeed affect a person's spatial ability.

What are the various spatial theories?

Liben (1981) notes that before one can begin to understand, theorize, and conduct spatial research, one must first have a definition of space. Space can be identified as being either absolute or relative. Absolute space is a framework that exists independently of anything within it. Conversely, relative space is a set of relationships among objects and is changed by altering the position of the objects or the point of an observer within it. She also notes that space is typically defined by the Euclidian three-dimensional model. Liben contends that the study of space should be approached from the standpoint that it is relative and is three-dimensional in nature. This position is usually maintained by the engineering and technical graphics discipline and will be used throughout this paper.

"Liben contends that the study of space should be approached from the standpoint that it is relative and is three-dimensional in nature."

Liben (1981) notes that there are three radically different epistemological positions regarding the biological developmental theories of space. The first is the empiricists' position in which psychological space is derived directly from experiences with physical space. Sharply contrasting this view is the nativists' position in which psychological space is determined by inheritance. The third is the constructivists' position in which psychological space is developed in an individual by a combination of inheritance and environmental factors.

Although researchers disagree on the epistemological positions regarding biological developmental theories of space, most of this conflicting research has been conducted solely in spatial cognition. This research has been conducted by developmental psychologists who define spatial cognition as:

> inner space or spatial cognition, the spatial features, properties, categories

and relations in terms of which we perceive, store and remember objects, persons, events, and on the basis of which we construct explicit, lexical, geometric, cartographic, and artistic representations (Olson & Bialystok, 1983, p. 2).

and

... the knowledge and internal or cognitive representation of the structure, entities, and relations of space; in other words, the internalized reflection and reconstruction of space in thought (Hart & Moore, 1973, p. 248).

It is now appropriate to differentiate between several terms that are sometimes associated with or used in place of spatial cognition. Hart and Moore (1973) contend that an important distinction should be made between spatial cognition and spatial perception. They maintain that spatial cognition involves all aspects of knowing including: perception, thinking, imagining, reasoning, judging, and remembering. They consider spatial perception as both a function and subsystem of spatial cognition with spatial perception and spatial cognition being distinct but interchanging processes (p. 249).

"Spatial cognition, then, is the underlying mental process that allows an individual to develop spatial abilities."

Theories of Jean Piaget (1970) consider knowledge of the world to be divided into two aspects: the figurative and the operative. Figurative knowledge is related to the perception or imagery of the configurations of the world in successive or momentary states through immediate direct contact. Operative knowledge is the inner intervention of successive or momentary states of figurative knowledge that transforms this knowledge into recognizable patterns and schemes. Spatial cognition in this theory is based on the operative mode while spatial perception is one of many aspects of figurative knowledge.

Other researchers, such as Rudolph Arnheim, do not agree with theories separating spatial cognition and spatial perception with spatial cognition as the overall controlling process. Arnheim (1986) makes a direct connection between spatial perception and spatial cognition:

> Perceiving and thinking require each other. They complement each other's functions. The task of perception is supposed to be limited to collecting the raw materials for cognition. Once the material has been gathered, thinking enters the scene, at a supposedly higher cognitive level, and does the processing. Perception would be useless without thinking; thinking without perception would have nothing to think about.

Olson and Bialystok (1983), and Hart and Moore (1973) contend that a distinction between spatial cognition and spatial abilities must be made. They theorize that spatial cognition is a set of mental representations and procedures that allows an individual to demonstrate a certain spatial ability or a range of spatial abilities. Defining and measuring specific spatial abilities is adequate as long as the use of these definitions and measurements is concerned solely with the problems of individual differences and learning styles or for the prediction of performance differences between individuals, but these different spatial abilities cannot by themselves define or represent spatial cognition. Spatial cognition, they contend, is the set of mental representations and operations that underlie and allow spatial ability.

Spatial cognition, then, is the underlying mental process that allows an individual to develop spatial abilities. Thus, if an individual has a highly-developed set of mental representations and operations or spatial cognition, various spatial ability measurements might predict that individual may perform better on spatial tasks than an individual who does not have as highly developed spatial cognition. But what are some of the accepted spatial factors that will allow researchers to measure spatial abilities and thus predict an individual's performance on various spatial tasks?

Spatial abilities

Lohman and Kyllonen (1983) have identified three major spatial factors that are usually tested to determine an individual's spatial abilities:

1. spatial relations - ... are tests that are parallel forms of one another, and the

factor emerges only if these or highly similar tests are included in the battery. Although mental rotations is the common element, the factor probably does not represent the speed of mental rotation; rather it represents the ability to solve such problems quickly by whatever means;

2. spatial orientation - ... the ability to imagine how a stimulus array will appear from another perspective. In the true spatial orientation test, the subjects must imagine that they are reorientated in space, and then make some judgment about the situation; and,

3. visualization - The tests load on this factor (visualization), in addition to their spatial-figural content, share two important features: they are all administered under relative unspeeded conditions, and most are much more complex than corresponding tests that load on the more peripheral factors (p. 111).

Eliot and Smith (1983) note that different researchers have described many different spatial factors. Kelly, in 1928, described two spatial factors: (1) Sensing and retention of visual forms; and (2) Manipulation of spatial relations. Anderson, et al., in 1954, also identified two spatial factors that were very close to Kelly's earlier descriptions: (1) Spatial relations, which was described as the ability to determine the relationships between different spatially-arranged stimuli and responses, and the comprehension of the arrangement of elements within a visual stimulus pattern; and (2) Visualization, which was described as the ability to imagine the rotation of depicted objects, the folding and unfolding of flat patterns, and the relative changes of positions of objects in space. French, in 1951, supported the existence of three spatial factors: (1) The spatial factor as the ability to perceive spatial patterns accurately and to compare them to each other; (2) Orientation as the ability to remain unconfused by the varying orientation in which a spatial pattern may be represented; and (3) Visualization as the ability to comprehend imaginary movement in three-dimensional space or to manipulate objects in imagination (pp. 3-4).

McGee (1979) identified two distinct spatial abilities: spatial visualization and spatial orientation. He defines spatial visualization as:

> [T]he ability to mentally manipulate, rotate, twist, or invert pictorially presented visual stimuli. The underlying ability seems to involve a process of recognition, retention, and recall of a configuration in which there is movement among the internal parts of the configuration, or of an object manipulated in three-dimensional space, of the folding or unfolding of flat patterns.... (pp. 3-4)

and spatial orientation as:

> [T]he comprehension of the arrangement of elements within a visual stimulus pattern, the aptitude for remaining unconfused by the changing orientations in which a configuration may be presented, and the ability to determine spatial relations in which the body orientation of the observer is an essential part of the problem (p. 4).

Although there seem to be variations among what researchers believe to be basic spatial abilities, they do agree that there are various spatial factors that can measure specific spatial cognitive abilities. But how do cognitive spatial abilities develop in human beings? What are some of the theories on cognitive spatial development?

Developmental theories of spatial cognition

The study of spatial cognition would not be complete without reviewing the theories and research related to this area. Spatial development is vital in the process of cognitive development in human beings from infancy to death. Most researchers agree that the concept of cognitive development is not limited to a relation of age ranges, but is controlled by the theory of natural development. Thus cognitive abilities may vary among individuals of the same age because these individuals may be at a different natural age of spatial cognitive development.

Hart and Moore (1973) note that Ernest Cassier was one of the first theorists to use developmental theories in the area of spatial cognition. Cassier divided spatial experience into three types: (1) Organic or active space, which is used by the lowest order of animals; (2) Perceptual space, which is used by higher-order animals; and (3) Symbolic or abstract space, which human beings alone possess.

Hart and Moore (1973) also note that the first comprehensive developmental theory of space to be theorized from empirical findings was the organismic-developmental theory of Werner. Werner theorized that there are three levels of spatial development: sensorimotor, perceptual, and contemplative, which progress from concrete acquaintance with the world to abstract knowledge of the world.

Probably the most extensive and influential theories on the development of spatial cognition are that of Jean Piaget and his associates. Piaget and Inhelder (1967) identified four major levels in the development of spatial cognition: sensorimotor space, preoperational space, concrete operational space, and formal operational space. They also identified three major types of spatial relations: topological, projective, and euclidian, as well as three systems of reference: egocentric, fixed, and coordinated.

The sensorimotor space (birth to about age 2) is the first stage of spatial development. The child operates from a purely egocentric perceptual view of the world. Perception of the world is that of topological properties and knowledge gained through perceptual sensations (Piaget and Inhelder, 1967).

Intuitive or preoperational space (ages 2 to 7) is the second stage of spatial development. The child's frame of reference continues to be egocentric in nature and learning is haptic (by touch) and continues to be limited to topological shape, size, and proximity features of objects (Piaget and Inhelder, 1967).

Concrete operational space (ages 7 to 12) is the third stage of spatial development. During this stage, children begin to develop concrete operations and can develop concrete spatial thoughts that are independent from images, but that still require the presence of actual or represented objects. By this stage the child loses his or her egocentric frame of reference and is able to view objects from various viewpoints other than his or her own and perceive projective spatial relationships (Piaget and Inhelder, 1967).

Formal operational space (ages 13 through adulthood) is the final stage of spatial development. Abstract mathematical concepts, such as euclidian geometry, can be acquired and the individual can make use of infinite spatial possibilities (Piaget and Inhelder, 1967).

Although some theorists do not accept the notion that children's spatial cognitive development occurs in stages, most research in cognitive psychology supports the developmental theories of spatial cognition. Other theorists contend that there are other factors that influence the spatial cognitive development of individuals. Factors such as the characteristics of the individual, physical environment, and history will be discussed in the next section.

Sources of variance in spatial cognition

Liben (1981) contends that there are differences between persons in individual characteristics (e.g., cognitive level), cultural heritage (e.g., societal practices that affect males' versus females' freedom to explore the environment), and in physical space (e.g., the urbanization of rural environments) (p. 17).

Liben (1981) further advocates that qualities of spatial behavior can be grouped into three major categories: physical, cognitive, and socioemotional. The age factor is the most influential one in the physical category. As individuals mature, their locomotion changes from dependency on other human beings to crawling, then to walking, then to bicycling, then to driving a car. Depending upon the environmental exposure throughout the various spatial developmental stages, an individual may be exposed to various environments or environmental experiences that either advance or hinder his or her spatial cognitive development and abilities (pp. 17-19).

A second physical factor that can influence spatial cognition is whether an individual has physical or sensory handicaps. Handicaps such as cerebral palsy, orthopedic handicaps that restrict environmental mobility, blindness, or deafness may affect how the environment is spatially represented and therefore cause these individuals to develop an abnormal spatial cognition.

The cognitive characteristics that Liben (1981) speaks of are closely related to the concepts of spatial cognitive development advocated by Piaget, and she agrees that the cognitive spatial characteristics develop in individuals in various natural stages.

Finally, Liben (1981) claims that socioemotional factors play a vital role in the development of spatial cognition. Thus every different individual will possess various spatial abilities because of the interaction of social, environmental, and emotional experiences.

McGee (1979) claims that there is empirical evidence for sex differences in spatial cognition. He cites three different illustrative spatial tests: Thurston's Primary Mental Abilities Space Test, the Differential Attitude Space Relations Test, and the Mental Rotations Test. In the Mental Rotations Test, males scored higher in space factors despite a higher IQ for females. The Mental Rotations Test has shown internal consistency and test-retest reliability showing that sex differences have favored males over females in the entire age ranges of the general population. McGee (1979) also notes: (1) a consistent sex difference that favors males in each of the twenty items on the test; and (2) a strong positive correlation between rank-order item difficulties for the males and females. He further notes that these results would seem to rule out any explanation of the observed sex differences that relies solely on the motivational differences between the sexes (pp. 20-303).

McGee (1979) also notes that research has shown that spatial abilities could be influenced by heredity and hormonal influences within the individual. Spatial abilities are as inherited or are more inherited than verbal abilities. This evidence is based on research indicating that the presence of an X-linked recessive gene could have effects on spatial abilities. Because a majority of inherited traits occur in greater frequency within males than females, this could be a plausible explanation for sex differences in spatial cognition (pp. 203-205). McGee (1979) also suggests that hormonal levels may influence spatial abilities, although there is not sound evidence of what the relationship of these effects may be and this area of research remains an open question (p. 218).

McGee (1979) further notes that there is an abundance of psychological literature that theorizes a difference between male and female cognitive functioning in the two separate hemispheres of the brain. Males are stronger in spatial tasks that utilize the right hemisphere while females show advantages in tasks that involve verbal abilities and utilize the left hemisphere of the brain. Although this evidence is inconclusive it suggests that spatial and verbal sex-related differences may be related to basic sex differences in the makeup and function of the brain.

"... individuals with verbal learning strategies may have extreme difficulties with spatial problems."

Clinical study results have tended to show that among right-handed adults, nonverbal and spatial information processing is completed by the right cerebral hemisphere, while verbal processing is completed by the left. This theory contends that males have greater hemispheric specialization than females and this specialization is usually associated with the right cerebral hemisphere. Females are less hemispherically specialized in respect to both spatial and verbal functions (McGlone, 1980). Although conclusive evidence in this area has not been established, a majority of experts conducting brain research generally agree with this theory and many scientists believe that there are actual perceptual ability differences between the different halves of the brain.

Research by Bryden (1966) has identified three possible reasons for differences of cognitive abilities related to patterns of brain function:

> 1. There may be a fundamental biological neurologic difference in cerebral organization between males and females, so that cognitive information processing is more likely to be bilaterally represented in females than males.
> 2. The observed differences may arise from the test procedures; that is, females may use different strategies to perform the behavioral tests that are used to measure hemispheric spatialization.
> 3. It is possible that whatever sex related differences are observed result from the interaction of strategy effects with cerebral organization (p. 215).

Background experiences or socioemotional factors as described by Liben (1981) could also have an effect on spatial visualization. If an individual, because of background experiences, has been exposed to or has developed spatial learning strategies, this person might then have more dominant brain development in the right hemisphere. By the same token, just the opposite could have occurred because of different experiences, making the person possess more verbal learning strategies. Because spatial visualization is such an important aspect of learning in many different areas, individuals with verbal learning strategies may have extreme difficulties with spatial problems. Bertoline (1988) suggests that human beings are not born with spatial visualization abilities and that these abilities are a cognitive function that is developed through ordered life experiences. The development of spatial visualization abilities occurs at various stages in life and exposure to different learning environments may cause some children to develop greater spatial visualization abilities later than others.

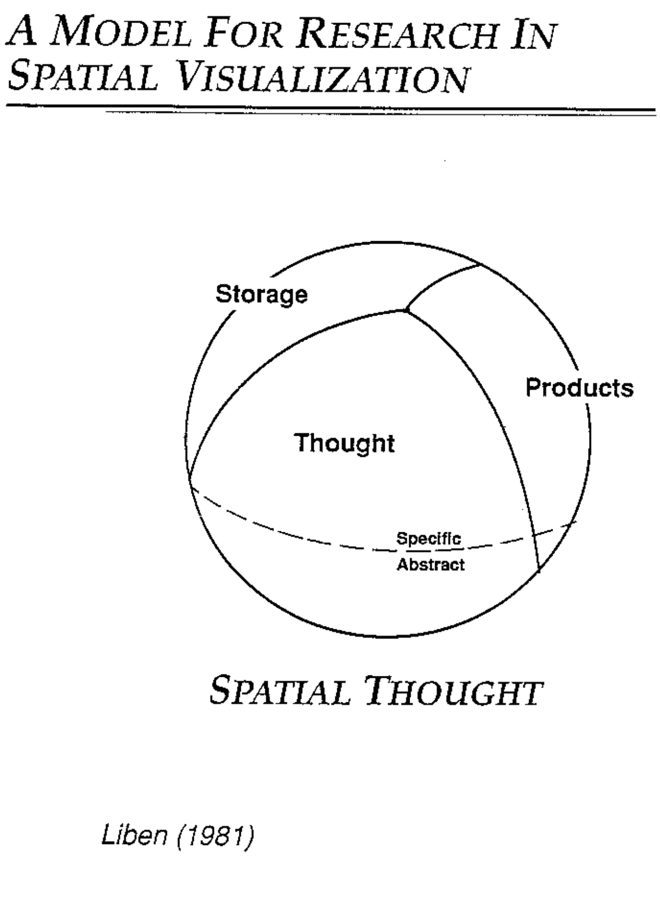

Figure 1. Liben's model of the type and contents of spatial representation (1981, p. 11).

A model for research in spatial visualization

But what plan should the engineering and technical design graphics profession use to conduct research in spatial visualization? Liben (1981) uses a model (see Figure 1) to describe three different types of spatial relations. This model could be used as a basis for spatial visualization research in engineering and technical graphics.

Liben (1981) describes the model in more detail:

> First, a sphere is used to accentuate the notion of rotation. Any particular researcher might study the sphere from a different angle. Thus, one investigator might be primarily concerned with spatial thought about abstract spatial concepts, whereas a second investigator might be concerned primarily with spatial storage of information about a specific space (environment). Second, the types and contents are given equal sections to avoid any suggestion that one type or content of spatial representation is more important or more legitimate than another. Third, the representation is unrestrictive with respect to pathways. For example, to go from spatial storage to spatial products would be possible to go directly, or to pass through (be mediated by) spatial thought. Fourth, the intersections of latitudinal and longitudinal divisions are meant to suggest that each type of representation can be crossed with each content. Finally, boundaries should be thought of as permeable. (p. 11).

Liben (1981) describes the contents of her model further. She refers to spatial products as external products that represent space in some way. This term is meant to encompass any kind of external representation, regardless of medium. It includes, for example, sketch maps, miniature models, and verbal descriptions (p. 11).

Liben (1981) further describes spatial thought as thinking that concerns or makes use of space in some way. Spatial thought is knowledge that individuals have access to, can reflect upon, or can manipulate, as in spatial problem solving or spatial imagery. Examples of spatial thought include remembering the shape of one's living room and the arrangement of the furniture contained within it, or mentally manipulating an image of a motor part to determine where it will fit in the motor. Thus she contends that many of the standardized spatial abilities measures tap spatial thought (p. 12).

Lastly, Liben (1981) describes spatial storage as any information about space contained "in the head." This information may be stored as truth propositions, pure relations, stimulus-response bonds, or any other format, isolated or integrated, but the individual is not aware of this information. Once the individual reflects upon the stored spatial representations, it becomes spatial thought (p. 13).

Such research provides support for the notion that the engineering and technical design graphics profession could focus spatial visualization research in spatial products. Our spatial products could include the identification and development of spatial factors through the use of sketching, three-dimensional solid modeling or other CADD applications, or a combination of these.

Research could be conducted in the area of spatial thought specific to engineering and technical design graphics. If we can develop effective curricula that allow individuals to develop and expand their spatial thought, students within and outside our discipline would benefit.

Research could also be conducted in the area of spatial storage. If we can improve individuals' spatial storage, they will be able to apply this stored spatial information in future problem-solving situations. Again, this would be of specific benefit not only to engineering and technology students, but would help students in all disciplines.

Finally, as Liben emphasizes, no one particular area is more important than any other in spatial research. A research emphasis could be on any one of these areas or a combination of them. All spatial visualization research is important to engineering and technical design graphics as well as other disciplines, but before the results can be recognized a sound research base must be established.

Conclusion

What can the engineering graphics educators gain from a review of spatial research? In many ways our discipline is at the first stage of development in research concerning spatial visualization. Although we have known for years that spatial abilities are among the most important abilities an engineer or technician can possess, we have not yet convinced ourselves or colleagues outside our discipline of this fact. We can use prior research findings in spatial visualization to assert that engineering and technical graphics are central to the development of successful engineers and technicians. Thus, we must use prior spatial research findings as a basis for developing spatial research studies that lend support to the theory that the engineering and technical design graphics curriculum is important in the development of spatial abilities for engineers, technicians, and other individuals who use these abilities in their occupations.

> "... various curriculum activities could be developed that would allow individuals with spatial abilities deficiencies to develop their spatial skills."

Our profession should develop and validate evaluation instruments that test spatial abilities and determine the unique individual variables for training successful engineers and technicians and other individuals who need to possess spatial abilities. With the great influx of economical and powerful solid modeling software and hardware and our graphic expertise, we could develop, statistically evaluate, and implement interactive spatial abilities tests that could determine an individual's spatial abilities level. If these tests are developed in a professional manner using the latest state of the art equipment and are statistically evaluated to determine their validity and reliability, they could become a standard for spatial testing in many disciplines. From the results of spatial testing, various curriculum activities could be developed that would allow individuals with spatial abilities deficiencies to develop their spatial skills. This curriculum would become the basis for a revised engineering and technical graphics curriculum and would use any tool that allows for the development of spatial abilities whether involving computer-generated interactive solid modeling, hand-held models, sketching techniques, or a combination of the above. It would be necessary to develop this curriculum from a sound research base in spatial visualization.

Our discipline is in a new unique position that could allow us to become a leading force in the development of spatial testing and innovative curriculum development that could be used by many disciplines. This opportunity will not last forever, so we must take the initiative and center our present and future research in the area of spatial visualization. If meaningful research is conducted in spatial testing and spatial visualization-centered curricula are developed and implemented, our field could become a distinguished leader in the identification and development of spatial visualization abilities.

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Interactive Computer Graphics Software For Teaching CADD

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Abstract

This paper presents the methodology and approaches that are employed to develop interactive computer graphics for teaching CADKEY in a freshman Computer-Aided-Design-Drafting (CADD) course. The software was written in the CADKEY Advanced Design Language (CADL). The software consists of CADL subroutines (i.e., CADL files) and macros to provide the student with descriptions, examples, and exercises for several key functions of CADKEY.

The software is interactive, self-explanatory, and menu driven in nature. No additional system configurations are needed. Students communicate with the software by responding to the prompts and taking properly instructed actions. Many unique features were built into the software so that the training process will appear interesting and challenging to the student. The experience received from using this software and the availability of the software are provided in the paper.

Introduction

The interactive computer graphics technology is one of key elements in the development of modern Computer-Aided-Design-Drafting (CADD) software packages. Through an user interface device such as a mouse or a light pen, a CADD software can respond to a user's request to draw a line, a circle, an arc or any three-dimensional objects on the screen. These CADD software provide significant advantages in visualization, accuracy, and efficiency in comparing with the traditional manual drafting.

This interactive computer graphics technology also lends itself to be a powerful tool in teaching a student how to use CADD. This paper demonstrates a unique application of the interactive computer graphics on the development of an interactive software that is designed to teach CADKEY - the CADD software used in this campus. Through interactive communications between the student and the interactive software, the students are able to learn, to visualize, and to practice key functions of CADKEY.

An interactive software, called "CANCAD (You CAN do CAD.)," was developed by the authors and students to assist the student in becoming familiar with several basic CADKEY techniques. With the assistance of CANCAD, the student would have a good understanding of these techniques and could apply them to their CADD projects.

The responses from the students about this software were overwhelming. The software was also used in the CADD workshops for the engineers from the Ford Motor Company. It received very positive feedback, especially from the older engineers. Students were able to learn the CADKEY at their own pace and to enjoy the learning.

The design structure and operations of the CANCAD are presented in the paper. The methods and innovative approaches that are used in the developing process are also discussed in detail. We hope that this paper will stimulate the interest in using the interactive computer graphics for instructional software development and more interactive software similar to CANCAD could be developed in the near future to enhance the teaching and training of CADD.

CADKEY advanced design language (CADL) and macros

CADKEY has a primitive design language called "CADKEY Advanced Design Language (CADL)." CADL is a programming language which operates within the data structure of the CADKEY program (CADKEY). The language is very flexible. One can develop programs to show new menus on the screen, draw pictures, check the location of an entity, identify the selected entity, locate the cursor positions on the screen, and read in the user's responses. CADL provides the capability to simulate the functions of CADKEY and trace the menu selections from the user's responses.

Macros can be established in CADKEY to register a series of commands or menu selections. They can be assigned to a key stroke and to a file, i.e., TXT files. These macro files can be loaded into CADKEY and can be executed whenever they are needed. Since the macros can include any functions of CADKEY, they can be used to manage CADL files and geometric object files, i.e., part files.

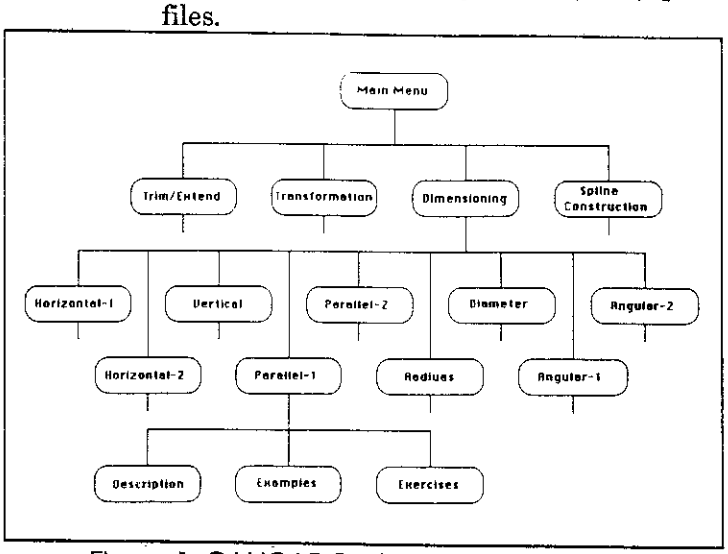

Figure 1. CANCAD Basic Design Structure

The most significant advantages of using CADL are: (1) this language provides a very simple mechanism to allow a programmer to interact with the user from the screen; and (2) it allows the programmer accesses to the data structure of the CADKEY.

Design Structure of the "CANCAD"

Figure 1 shows the basic design structure of the CANCAD. It is a tree structure starting from the main menu to the subjects covered in the software. The subjects included in CANCAD are Trim/Extend, Transformation, Dimensioning, Spline Construction, and Descriptive Geometry. More subjects are in the process to be added to the software. Each subject includes several submenus that are related to the functions of a subject. Each sub-menu includes three items: descriptions, examples, and exercises. The descriptions provide the definition of a specific CADKEY function or the sequential menu selections to give the student step-by-step instructions. The examples illustrate how CADKEY functions can be applied to CADD problems. The exercises challenge the student to complete a CADD problem using the function that he or she just learned. Although the proper sequence is to read the description, view the example, and try the exercise, the student can select the description, example, and exercises for a given subject in a random order. The discussion of description, example, and exercises is presented below.

Figure 2 presents the menu selection of the dimensioning subject, abbreviations used in CADKEY are also adopted in the CANCAD such as "DIMENSN" instead of "DIMENSIONING." Eight menu items are listed on the left-hand side menu area under the letter "CADL," which indicates that the system is in the CADL environment instead of the regular CADKEY environment. Items 1 to 5 are the descriptions of six different dimensioning functions (item 4 includes both radial and diametral functions), item 6 is the example menu, item 7 is the exercise menu, and item 8 is the exit menu which brings the software back to the main menu of CANCAD. Figures 3, 4, and 5 present the description of an angular dimensioning, nine dimensioning examples, and nine dimensioning exercises.

As one of the angular exercises, e.g, exercise 8, is selected, an exercise problem is shown on the screen as in Figure 6. It may be noticed that the "CADL" letters are no longer shown on the top of the menu, i.e., the software has exited from the CANCAD and back to CADKEY. The regular CADKEY main menu is shown and the student can try the exercise problem as he or she is working on a regular CAD project. Under the bottom of the exercise problem, an instruction says: "Press Alt_7 to continue when done"; this instructs the student how to return to CANCAD when he or she finishes the exercise.

The "Alt_7" is a macro which executes a series of commands that brings the system back from CADKEY to CANCAD. Other macros are also used in the software; for example "Alt_4" is to return to the main menu from anywhere in CANCAD, and "Alt_0" is to quit from CANCAD. "Alt_1" is to execute the CANCAD from the CADKEY environment. Therefore, the student can access to CANCAD from CADKEY at any time by simply pressing "Alt_1" in CADKEY and return to CADKEY by pressing "Alt_0" anywhere in CANCAD.

In the macro "Alt_1," commands are included to generate a dummy part file to save whatever already exists on the screen. In contrast, macro "Alt_0" has commands to retrieve the dummy part file back to the screen. Therefore, the student's current CADD project will not be damaged during his going back and forth between CADKEY and CANCAD.

In order to smooth the operation and provide the security to the software, the software does not allow students to work on an example or a description picture. They can only work on the exercise problem to try their skills. Furthermore, students cannot save their work in the CANCAD environment or overwrite the exercises in the CADKEY environment, so the original examples and exercises will not be replaced by mistakes.

Interactive User Interface

One of the unique features of this software is its interactive user interface. The software communicates with the student during the entire process through the prompts and the instructions printed on the screen. The student has to read, evaluate, and act on these instructions throughout the

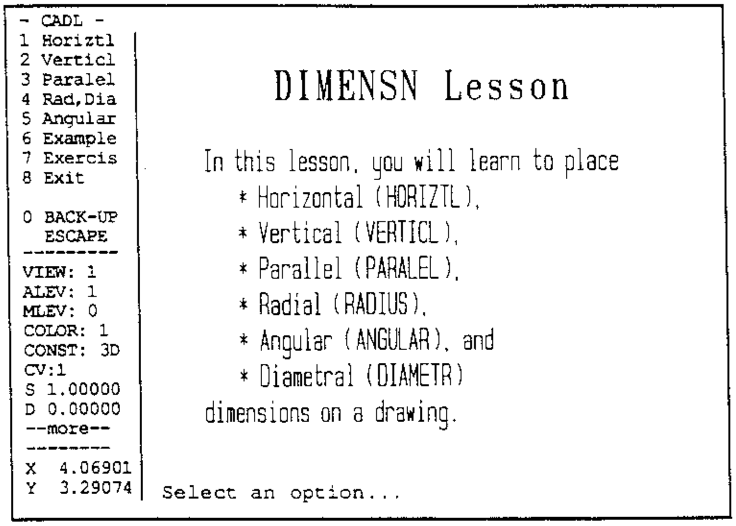

Figure 2. Dimensioning Lesson of CANCAD

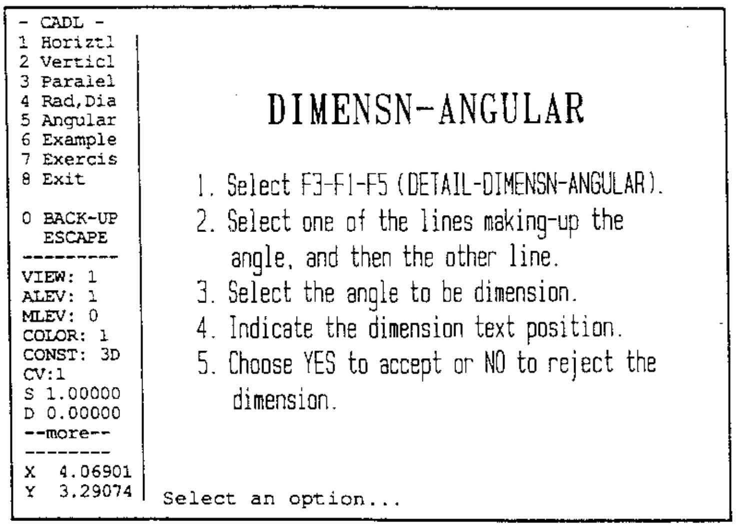

Figure 3. Angular Dimensioning Description

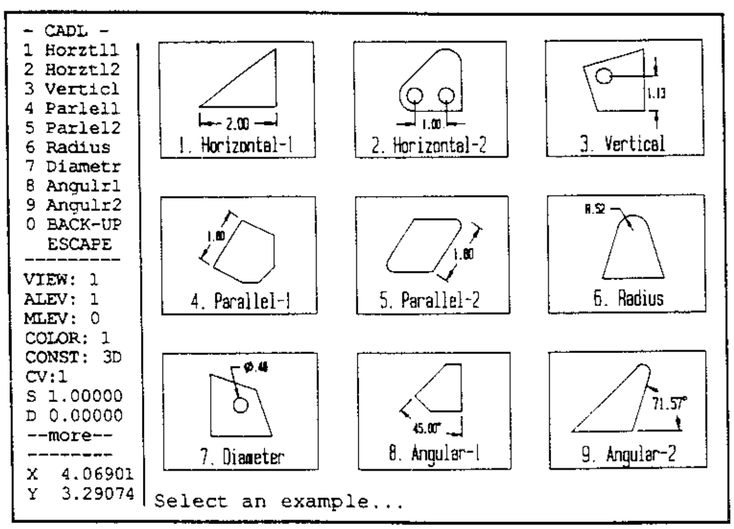

Figure 4. Nine Dimensioning Examples

students' finger tips. They can review the description or the example of a CADKEY function and try the exercise again.

Although it was difficult to assess the difference in the student's performance before and after the use of CANCAD, the authors and lab assistants could sense the difference by the nature of the questions that students brought to us. Before the software was used, many questions were related to the CADKEY software instead of how to approach to the CADD project. After CANCAD had been integrated into the course, the questions related to CADKEY software were significantly reduced and instead more designing questions were being asked by the students. It appears that they spent a large amount of time understanding the CADKEY in the past, but they can now concentrate more on the design project.

Conclusions and recommendations

An interactive instructional software, CANCAD has been developed and implemented in a freshman engineering design graphics course. The software has demonstrated that it can assist and motivate the students during the learning process of a CADD tool, i.e. CADKEY. The author's experience of using CANCAD has shown that an instructional software, to be successful, should include the following features:

1. It covers the key functions of the CADD.
2. It is intuitive.
3. It is interactive, self-explanatory, and menu driven.
4. It is interfaced with the CADD and has direct accessibility between the software and the CADD.
5. It is interesting and challenging.

CANCAD has revealed a new teaching concept that is very important to our today's engineering education. A challenging and interesting software can be very effective in teaching CADD. This type of software can certainly be used in any organization, including industrial and commercial institutions. Almost all CADD packages have their own programming language such as AUTOCAD, a software similar to CANCAD, can be developed by using the same approaches presented in this paper. This type of software would be very useful in all training centers for educators as well as CADD developers.

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The authors would like to give our sincere appreciation to those who had participated in the project, especially, Mr. James Dagg, Mr. Jim O'Haggan, and Mr. John Laidlaw for their excellent work in developing the first generation of this software. Although the current version's structure is very different from the previous one, a lot of their work has been kept in CANCAD. In addition, Mr. Chris Pfreiffer contributed substantially in the recent revisions and code modifications. Their enthusiasm is the key factor to the success of this software.

This software has received an Enhancement Educational Award at the University of Michigan-Dearborn.

Availability of this software

The authors will be more than happy to share this instructional software with any institutions that will consider using it in their training CADKEY courses. Please write the authors at the above addresses or simply contact Dr. Cherng at (313) 593-5047.

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Profile and Practices of Contributors to the Engineering Design Graphics Journal [1]

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Abstract

This study describes and evaluates selected bibliometric patterns associated with feature articles published in the Engineering Design Graphics Journal (EDGJ) from 1970 to 1989. Data from each issue of the journal were collected and compiled, forming a database composed of year of publication, volume and issue numbers, author names, author affiliations, and the presence or absence of reference citations.

The data were then analyzed and a profile of the contributors was developed in terms of author productivity and author affiliation. The data were also analyzed and a profile was developed of selected authoring practices associated with the preparation of feature articles published in the EDGJ. This analysis included an examination of the extent of collaborative efforts and whether or not references were cited.

Demographic data are reported and include the number of feature articles published in the journal from 1970 through 1989, the number of individuals involved in the preparation of those feature articles, the number of different organizations with whom the authors were affiliated, and the number and proportion of feature articles in which references were cited.

With respect to the author profile, the data tend to suggest that certain individuals have an affinity for publishing in the journal. The data also suggest that individuals affiliated with selected organizations make frequent use of the EDGJ as a means of disseminating research findings.

With respect to practices associated with the preparation of feature articles, the data tend to suggest that, more and more, there is a general inclination on the part of researchers toward collaborative efforts and that selected individuals are more involved in collaborative efforts than others. The data also suggest that with increasing frequency, authors of feature articles are citing works associated with their research and works used in the preparation of their articles.

Introduction [1]

The *Engineering Design Graphics Journal* (*EDGJ*) is the official publication of the Engineering Design Graphics Division of the American Society for Engineering Education. It is also the principle medium of formal communication in English for engineering design graphics professionals.

While the *EDGJ* continues to play an eminent role in communicating ideas among engineering design graphics professionals, no formal analysis of the *EDGJ* has ever been conducted.

Purpose

The purpose of this study was to shed some light on (a) the process of written communications and (b) the nature and course of engineering design graphics as it is reflected in feature articles published in the *EDGJ* from 1970 to 1989. Specifically the research sought to answer the following questions:

1. With which organizations have researchers in engineering design graphics been affiliated?

Table 2

Authors Who Have Had Three or More Articles Published in the *EDGJ*

Author	Affiliation	n
M. H. Land	Miami (Ohio) & Appalachian State	11
F. A. Mosillo	Illinois at Chicago Circle	9
R. P. Kelso	Louisiana State & Louisiana Tech	8
A. Rotenberg	Melbourne, Australia & Princeton	8
R. E. Barr	Texas at Austin	7
G. Voland	Northeastern	7
D. W. Brisson	Rhode Island School of Design	5
J. Arwas	Israel Institute of Technology	4
Y. Arwas	Israel Institute of Technology	4
J. M. Duff	Ohio State & Purdue	4
R. J. Foster	Pennsylvania State	4
L. D. Goss	Indiana State & Southern Indiana	4
E. Holland	Federal City College	4
C. M. Hulley	Cincinnati	4
W. J. Kolomyjic	Ohio State	4
R. Lehnert	none	4
E. V. Mochel	Virginia	4
R. W. Paffenbarger	Ohio State	4
W. A. Ross	North Carolina State	4
L. Bonfiglioli	Israel Institute of Technology	3
J. Charit	Israel Institute of Technology	3
Y. Charit	Israel Inst. of Technology & Witwatersrand, Johannesburg	3
J. T. Coppinger	Texas A & M	3
P. S. DeJong	Iowa State	3
W. G. Devens	VPI & SU	3
J. W. Duane	Ohio State	3
J. S. Duggal	Texas A & M	3
C. E. Hall	Louisiana State	3
R. D. Jenison	Iowa State	3
J. K. Jenson	Marquette	3
N. M. Karayanakis	Austin Peay State & North Florida	3
M. M. Khonsari	Ohio State & Pittsburgh	3
H. Niayesh	Arya-Mehr University of Technology, Iran	3
D. L. Ryan	Clemson	3
S. M. Slaby	Princeton	3
M. B. Waldron	Ohio State	3
I. Wladaver	New York	3
	Total	**157**

Question 1: With which organizations have researchers in engineering design graphics been affiliated?

Table 1 features a summary of organizations cited three or more times in article by-lines.[2] Specifically, the table lists those organizations with which authors or first authors (in cases of collaborative efforts) were affiliated when their articles were published.

While the list features 28% (n=39) of the population, the total number of feature articles associated with these organizations represents 69% (n=277) of all the feature articles published in the *EDGJ*.

The organizations with which 10 or more feature articles were associated were responsible for 29% of the feature articles published. That is, individuals affiliated with 5% (n=7) of the 141 organizations were responsible for over a quarter (n=118) of the feature articles published in the *EDGJ* during this time frame. It should be pointed out that these data, however, do not take into consideration the size of the organization, budget, etc. that may play a role in an organization's ability to support research.

Question 2: Who has been conducting research in engineering design graphics?

Of the 307 contributors of feature articles to the *EDGJ*, 241 served as the first author according to the by-lines of each article. Sixty-eight served as the second author, and 18 as the third or subsequent author. Fifteen of the 68 second authors also appeared as first author contributors, and five of the 18 third or subsequent authors appeared as either first or second authors.

Table 2 features contributors who were listed in three or more by-lines as the first author, and in many instances the only author. While these 37 individuals make up 15% of all first authors, they contributed, as the first author, to 39% (n=157) of all the feature articles published in the *EDGJ*. The individuals with seven or more first author by-lines made up 3% (n=6) of the population of first authors. Yet they were instrumental in the publication of over 12% (n=50) of the feature articles appearing the *EDGJ*.

Table 3 features contributors who were listed in two or more by-lines as the second or subsequent author. In addition to their contributions as co-authors, all have first author by-lines to their credit.

Question 3: To what extent have collaborative efforts contributed to the discipline's research production?

Table 4 depicts the frequency with which collaborative efforts have resulted in contributions to the *EDGJ*. The data tend to suggest that collaborative efforts are occurring with increasing frequency. The data also suggest that the most dramatic increase took place between the periods 1982 through 1985 and 1986 through 1989 when the proportion of articles authored by two or more individuals more than doubled.

Question 4: To what extent do researchers make use of other sources of information when conducting research and preparing papers?

The purpose of citations, whether it be in the form of reference lists or footnotes, is to identify sources used in the research and preparation of a paper. That is, citations document the statements made about the literature.

Table 5 depicts the frequency with which authors of feature articles published in the *EDGJ* made reference to other sources while conducting their research and in the preparation of their papers. While all papers may not require a literature review, the data suggest that more and more, *EDGJ* contributors are citing the sources that serve as the basis for their research efforts.

Summary and conclusions

The purpose of this study was to shed some light on (a) the process of written communications and (b) the nature and course of engineering design graphics as it is reflected in feature articles published in the *EDGJ* from 1970 to 1989. The findings from this limited bibliometric analysis suggest that:

1. Almost half (44%) of the authors of feature articles published in the *EDGJ* made reference to other sources of information during conduct of their research and in the preparation of their papers. The data also suggest that the proportion of authors making reference to other sources has increased considerably since the early eighties.

Table 3

Individuals Cited as the Second or Subsequent Author in Two or More Articles Published by the *EDGJ*

Author	Affiliation	n
D. Juricic	Texas at Austin	3
S. M. Slaby	Princeton	3
J. T. Demel	Texas A & M	2
J. W. Duane	Ohio State	2
R. D. Jenison	Iowa State	2
R. P. Kelso	Louisiana State & Louisiana Tech	2
M. M. Khonsari	Ohio State & Pittsburgh	2
B. L. Kreimer	Northeastern	2
F. O. Leidel	Wisconsin-Madison	2
F. F. Marvin	VPI & SU	2

Table 4

Authorship Collaboration of Articles in *EDGJ*

Vol.(years)	Authorship n			Proportion	
	Single	Joint	Total	Single	Joint
34-37 (1970-73)	67	6	73	92	8
38-41 (1974-77)	70	6	76	92	8
42-45 (1978-81)	89	17	106	84	16
46-49 (1982-85)	65	16	81	80	20
50-53 (1986-89)	38	28	66	58	42
Total	**329**	**73**	**402**	**82**	**18**

Table 5

Citation Frequency in *EDGJ Articles*

Vol.(years)	Number of Articles			Proportion of Articles	
	with citations	without citations	Total	with citations	without citations
34-37 (1970-73)	26	47	73	34	66
38-41 (1974-77)	24	52	76	31	69
42-45 (1978-81)	39	67	106	37	63
46-49 (1982-85)	39	42	81	48	52
50-53 (1986-89)	47	19	66	71	29
Total	**175**	**227**	**402**	**44**	**56**

cations. Much of the fundamental mathematics of geometric analysis remains the same, however, the complexity of geometric entities and solution methodologies which are now commmonly used in engineering practice has increased due to the computational power available.

Following Tyler's curriculum development model as suggested by Bertoline and Pleck (1990), the need for an advanced course in engineering design graphics (EDG) can be evaluated. Pleck, et al, (1990) predict that design in the 1990's will be based on an integrated 3D geometric database for optimum design and productivity. Indeed, this is already true for many companies which have implemented state-of-the-art CAD systems and practice such concepts as concurrent engineering. They also note that visualization is an important factor in the effective use of 3D design tools. Barr and Juricic (1990) present a model for a modern EDG curriculum dedicated to the "knowledge and application of methodology and procedures needed for the development and conveying of design ideas." The geometric data base is a central element between the design development and documentation, analysis and manufacturing phases. Similarly, Bertoline and Pleck (1990) identify the applications of the subject matter in their curriculum development model to include ideation, clarification and documentation. Thus, both curriculum development studies have identified an understanding of the geometric data base as a fundamental component in EDG courses, with similar applications in the engineering design process.

"... visualization is an important factor in the effective use of 3D design tools."

These studies are focused on the EDG curriculum at the freshman level. Due to the availability of powerful computational resources, more complex geometric data bases can be used. Thus, the theories and techniques of 3D geometric design and computation need to be studied in more depth than can be accomplished at the freshman level. Industry needs knowledgeable engineers capable of fully utilizing the powers of sophisticated solid modeling systems for mechanical design. Zeid (1991) has pointed out that a balance must be struck between teaching theory and practical applications in CAD/CAM. Thus, a graduate level course is designed to combine the principles of analytical geometry, computational methods, and engineering design with an emphasis on computer-aided geometric modeling and design applications in mechanical engineering. The generation of high-quality graphics using state-of-the-art hardware and software will aid the student in visualization of design of complex geometric entities.

Course objective

The objectives of the course are to familiarize the students with complex geometric modeling and analytical techniques used in modern computer-aided design and graphics systems. Upon completion of the course, students should have an understanding of and ability to manipulate complex geometric entities for design and analytical purposes. They should understand computational aspects of computer-aided geometric design systems and be able to develop and convey design concepts using these systems. Students are introduced to computational methods, data structures and topics in computer graphics which have applications in computer-aided design and engineering. This course is not intended to teach students how to use a CAD system, but rather to emphasize the fundamentals of mathematics and the theories which are used in CAD systems. Practical exercises are used to illustrate these concepts and the effects of geometric modeling in engineering analysis. Students are expected to have some experience with a CAD system, computer programming, linear algebra and calculus commensurate with graduate level engineering status.

Course outline

The course meets for two 1-1/2 hour lectures per week over a fourteen week semester. Figure 1 shows the course outline. The text by Mortenson (1985) is used.

Week 1

A general course overview is presented, along with a survey to assess the background and interests of the students. Special topics and design applications presented at the end of the course may be tailored to meet the needs of the students if the class size is small and students have common interests. The students are introduced to fundamental concepts in geometric modeling and computer graphics. Topics covered include a review of explicit, implicit and parametric equations, coordinate systems, vector and matrix operations, homogeneous coordinates and transformations.

Weeks 2-4

The mathematical development of parametric curves such as Hermite, Bezier, spline and B-spline curves is discussed. Methods for manipulation and modification of curves such as reparametrization, insertion of control points or knots, and subdivision are covered. Relational properties such as shortest distances and intersections are applied to design problems.

Weeks 5-7

The concepts of parametric geometric entities are extended to surfaces and solids. Analytical surfaces are also discussed.

Week 8

Concepts in solid modeling include Constructive Solid Geometry (CSG), Boundary Representation (BRep) and swept solids, octree representations, topology and Boolean operations.

Weeks 9-10

Data structures used in various CAD systems are discussed. Standards for data transfer in CAD and computer graphics such as IGES, DXF, GKS and PHIGS are compared. Topics in rendering and visualization of geometric models are presented. These may include ray tracing, shading algorithms, clipping, and silhouettes. A simple data structure for planar faceted polyhedral surfaced models is used to demonstrate hidden line and surface removal algorithms.

Weeks 11-14

Characteristics of the geometric entities (curves, surfaces and solid models) previously covered in the course are evaluated with respect to applications in design and analysis of mechanical systems. Topics may be selected according to interests of the students and instructor, and may include determination of mass properties, automatic mesh generation, parametric design and feature-based models, kinematic analysis and synthesis, numerical control and toolpath generation, image processing, alternative representations of geometric models, robot vision and robot motion, animation, tolerancing, assembly and interferences, and graphics design programming. Students will present results of a literature review project as described here.

ME593S

Computer Aided Design and Graphics Course Outline

Weeks	Topics
1	Fundamentals of Geometric Modeling and Computer Graphics
2 to 4	Parametric Curves (Hermite, Bezier) Composite Curves, Splines, B-Splines Relational Properties of Curves Design Applications
5 to 7	Analytical and Parametric Surfaces Surface Modification Relational Properties Design Applications Parametric Solids Mid-term Exam
8	Solid Modeling
9	Data Structures for CAD Data Transfer, Standards
10	Rendering and Visualization
11 to 13	Design and Analysis Applications Mass Properties, Automatic Mesh Generation, Parametric Design, Numerical Control, Kinematic Synthesis
14	Final Exam, Student Project Presentations

Figure 1. Outline of Topics for a Graduate Course in Computer-Aided Geometric Design

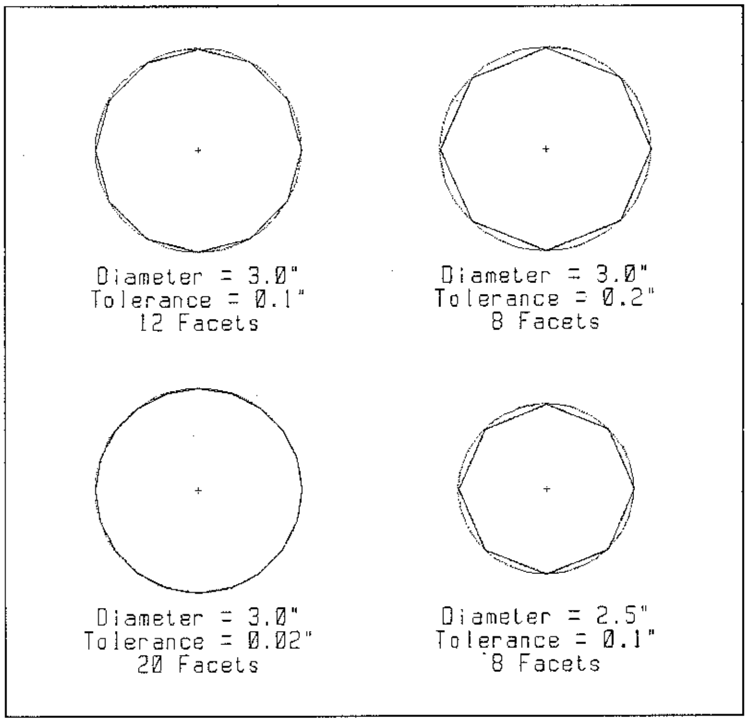

Figure 2. Polygonal approximation of circles with various diameters and tolerances.

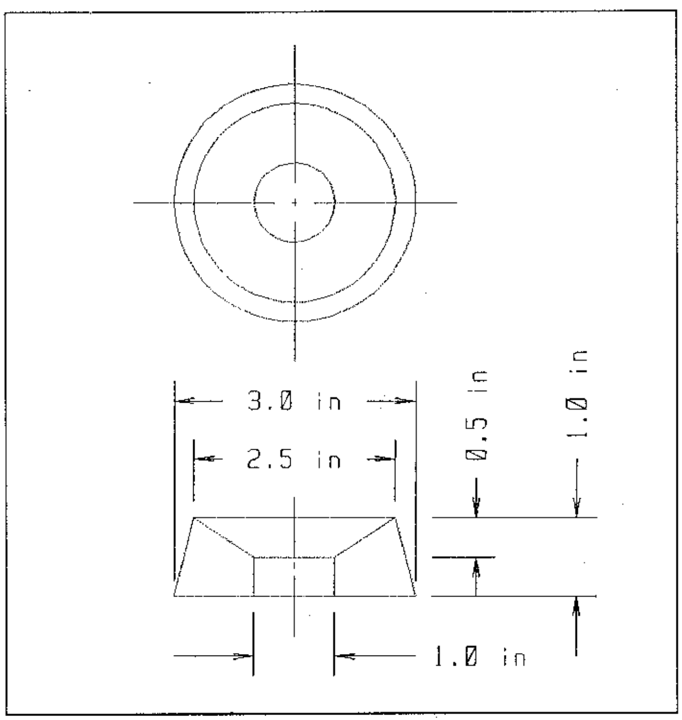

Figure 3. Hub

Facilities

ARIES Technologies' MCAE software is installed on Sun Microsystems SPARCStation1 and DECStation 3100 hardware. This state-of-the-art workstation-based solid modeling software has interfaces to finite element (Swanson Analysis Inc. ANSYS) and mechanisms (Mechanical Dynamics Inc. ADAMS) analysis software packages. Each workstation is connected through a campus-wide ethernet system to the Encore Multimax 250 mainframe which acts as a file server for the system. All computations are performed locally at the workstations.

Sample exercise

Practical exercises using the CAD system are used to illustrate the interaction between analytical geometry and computational methods in modeling applications. The following example illustrates the effects of modeling methodologies in solid modeling systems as affected by construction strategies, data storage and engineering applications in the CAD system.

Many CAD systems use hybrid Constructive Solid Geometry (CSG)/Boundary Representation (BRep) models for construction and storage and/or rendering of geometric models. Curved entities are approximated by polygons or polyhedra. A tolerance level selected by the designer determines the resolution and number of facets generated. Figure 2 shows the effects of tolerance levels on the polygonalization of circles of various diameters.

The methods used to construct and store the geometric model may have a dramatic impact on results and use of the model. A simple hub is shown in Figure 3. Using a relatively large tolerance of 0.1", the hub is modeled using both CSG and BRep methods. The resultant models are shown in Figures 4 and 5, respectively.

Using CSG methods, the hub is generated by subtracting a small frustum from a larger frustum with the same nominal diameter on their top faces. A cylinder is then subtracted for the hole. Note the "sliver" faces on the top edge where a mismatch occurs between the number of facets on the inner and outer frusta. Students are asked to calculate the size of the sliver faces. One possible remedy to this problem may be to decrease the tolerance level until the sliver faces disappear. This approach will substantially increase the size of the data base for the hub. Also, although obscured by the resolution of the graphics output device, the sliver faces still exist in the database and may lead to computational difficulties in subsequent phases of modeling or analysis. For example, automatic meshing routines for finite element analysis will fail when applied to the CSG model. The sliver faces do not occur when the hub is modeled by generating a surface of revolution from its cross-sectional curve (BRep method). All curved edges are polygonalized with the same number of edges. The result is shown in Figure 5. As a laboratory exercise, students are asked to generate a solid model of the object shown in Figure 6 with a relatively large tolerance for facet generation. The model must not contain sliver faces. The students are asked to submit a diagram of their model construction methodology and computer output listing all of the face entities in the model to verify that there are no mismatched edges.

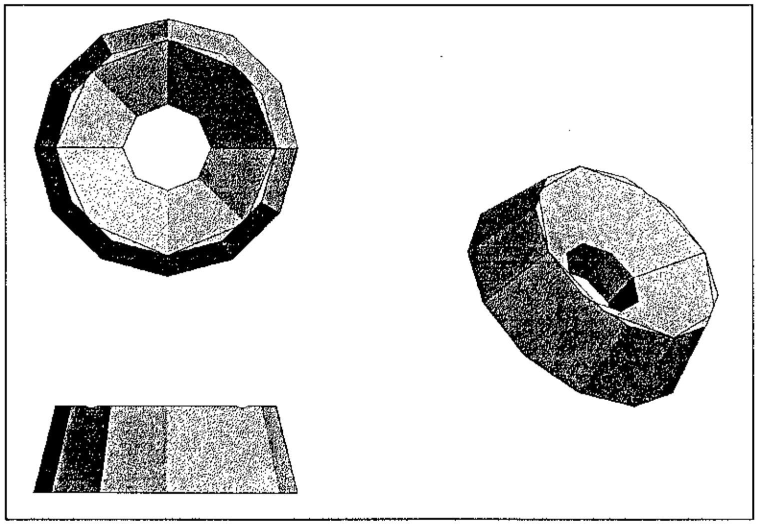

Figure 4. CGS model of hub

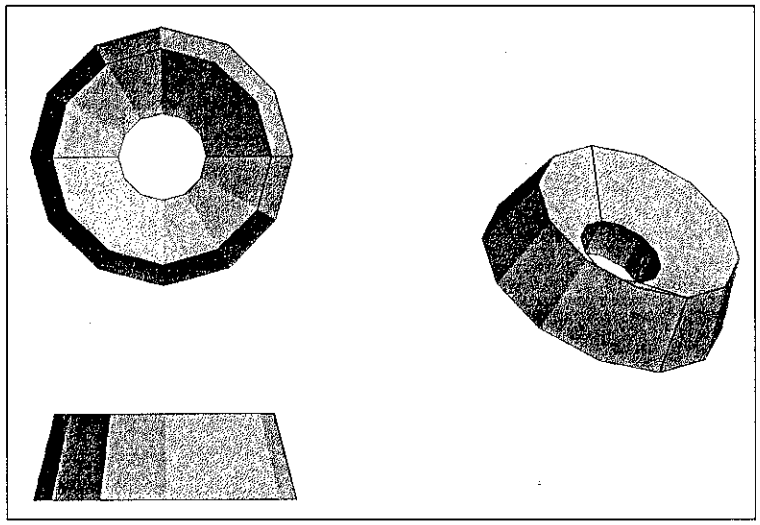

Figure 5. B-Rep. model of hub (solid of revolution)

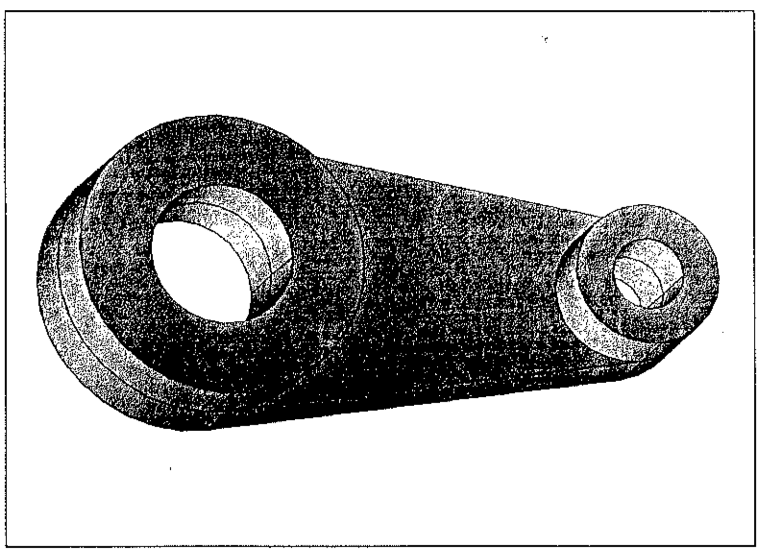

Figure 6. Part used for Sample Exercise

Final project

As a final project in the course, students are required to select and review a technical paper from a selected list of journals. The paper may contain an application of geometric modeling concepts as the solution to an engineering design problem, or may discuss a novel approach to geometric modeling which may be used in engineering or scientific applications. The objective of the project is to highlight current trends in geometric modeling and to allow the students to independently evaluate new concepts in geometric engineering analysis which may be of interest or of use in their research. The students are required to submit a written review of the journal paper and to present a 15 minute oral summary of the paper to the class.

Conclusion

A course in computer-aided geometric modeling and design has been developed. The course is intended to meet the needs of upper level undergraduate and graduate students in mechanical engineering and manufacturing with interests in design, manufacturing and computational mechanics. Theory and techniques required for the generation and manipulation of complex geometric entities utilized by contemporary CAD systems are presented. A state-of-the-art solid modeling system is used to generate models for design analysis and visualization, and to give students practical experience in CAD. The final portion of the course is devoted to an independent review of current literature in engineering design with geometric and graphical applications.

Acknowledgments

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Balancing Research And Professional Development With Engineering Graphics Instruction

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Abstract

As many educational institutions across the country increase pressure on faculty to conduct funded research, many engineers turned educator, find themselves expected to devote less time to a larger group of students and more time to conducting research. It is important to develop ways to assure survival of the faculty member's well-being, the students' education, and the institution's reputation. To that end, the authors have been conducting a series of experiments to investigate alternative methods of managing lower division graphics courses. In this experiment, daily work was never collected and graded, but simply accounted for by evaluating project completion and "reasonable effort." All class periods were devoted exclusively to student assistance, exercise accounting being done while proctoring exams. Non-exam grading time was reduced to nearly zero, creating time for professional growth, proposal development, and meaningful research. Results of the experiment are described and recommendations made based on tabulated and graphed student grade profiles, attitudes, and comparisons with control groups also taught by the authors.

Introduction

First there was time ...

It should come as news to no one that there seems to be a national trend to make engineering college faculties more productive not only in terms of student credit hours per full-time faculty member but also "measurable" research accomplishments; this is taken to imply, if not mean, new knowledge and associated papers. Some see this as a means of putting hard science and engineering faculty members into the yoke to obtain dollars from sources like NSF and use the overhead to support other faculties who have less opportunity to obtain outside funds. On the positive side, most of us would agree that, in general, faculty members at any major university should be on the cutting edge of knowledge in their fields of expertise, and it logically follows that some form of research and dissemination of knowledge must arise out of that condition. In the final analysis, one's position on the issue is of little consequence; the swing of the pendulum is irresistible, and for the foreseeable future, faculty productivity will be subject to study and criticism in several ways (NSPE 1990a). The concept of Academic Leisure in engineering education is only a pleasant memory, if it ever really existed.

1. The absence of daily grades caused no problem for me.
2. I was able to get all of the exercises done when expected.
3. I didn't postpone work until the last minute.
4. My work was as good as if it had been done for grading.
5. There was enough feedback about the quality of my work.
6. My friends in other sections were better off with grading.
7. This system eliminated pressure and promoted growth more.
8. I had trouble keeping up in the absence of "due dates."
9. I didn't get enough help during the laboratory portion.
10. I made use of my instructor's office hours for help.

    Estimated number of visits ________

TABLE 3

CONCLUSIONS

Educators should and generally do place a high value on the teaching function. However, assuming that one's classes, grading, preparation, myriad committee tasks, counseling and assisting students, etc., tend to fill the day, then there are only two major sources of time with which to expand one's creative productivity. Those are: class contact time and evaluation (grading) time. These experiments have confirmed the importance of contact time and verified that the "skills" element of basic engineering graphics courses has changed enough in recent years that demanding standards and careful grading are neither necessary, appropriate, or even reasonable. If productive time is to be found, it is better to obtain it by eliminating grading time than by reducing student contact time.

An important point must be made here regarding retention, particularly as it applies to nontraditional students. While there will always be a "fringe" of marginal students, and we primarily provide educational opportunities, we should also work to expand the "circle of successful students." Past efforts at improving engineering retention have been marginally successful at best, largely, it is becoming realized, because the character of engineering education has been based for decades on what might be called "survival of the fittest." If we truly wish to retain more entering students to graduation, education must change from a "survival" to what has been called a "nurturing" mode (Norman). It

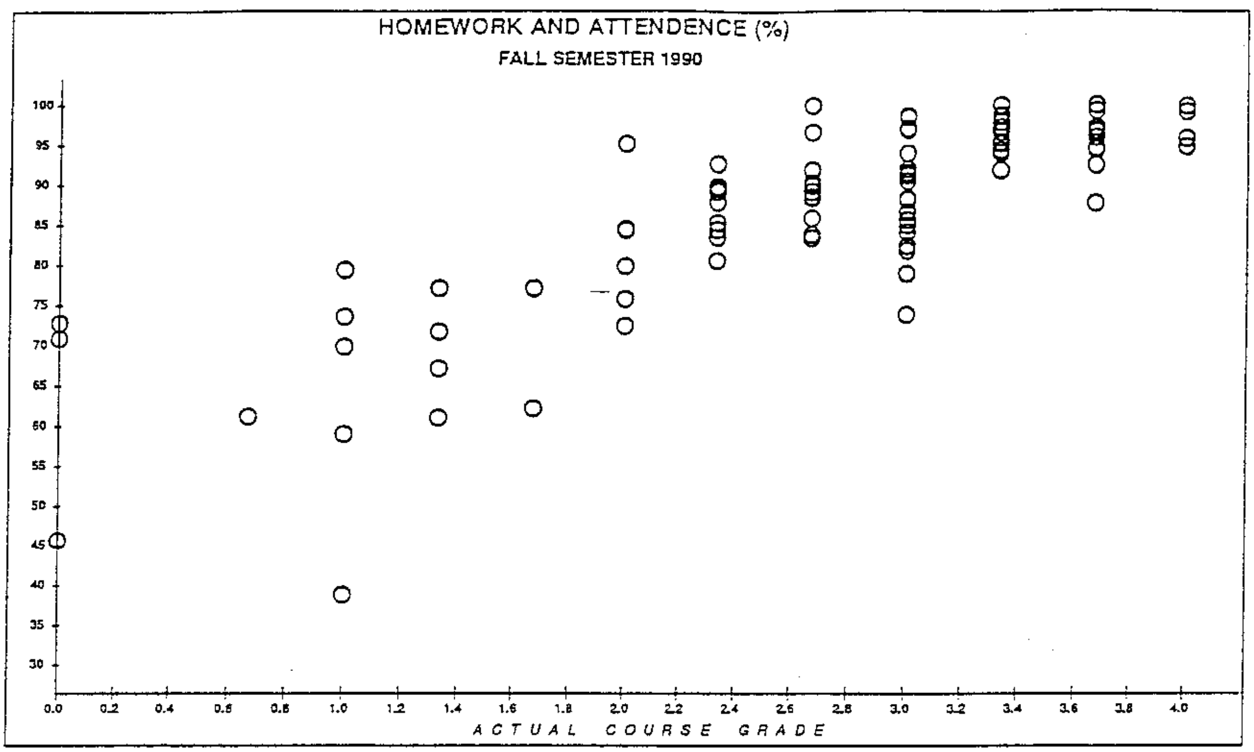

Figure 3

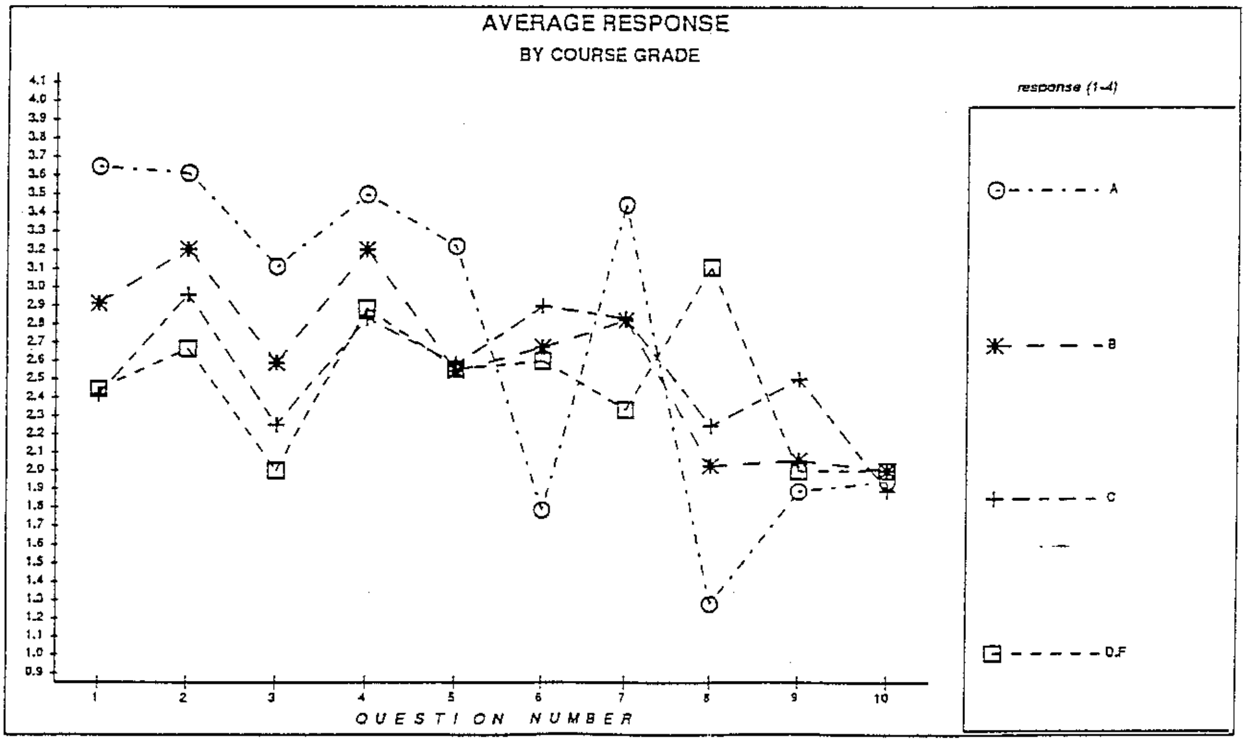

Figure 4

might even be argued that those most able to "survive" are those whose upbringing has been most "nurturing." Traditional "grading" of nontraditional students simply results in early destruction of their hopes for accomplishment, and we simply must change from responding with a judgmental "Work Complete, Quality Poor" to a supportive "Good start - here's how to improve" which can only be done well in conversation. For many complex reasons, more intelligent and promising students are reaching the point of entry with less-solid self images, fewer mechanical experiences, and less analytical experience than a decade ago. Although those conditions should not exist, they are a fact of life, and we are left to deal with them with high expectations, clear explanations, and perhaps, the patience of Job. It has fallen to us to help show these people how to succeed and realize their full potential. While that may not have been one of our original career goals, it is a high and humanitarian calling, worthy of our effort.

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COMPUTER-AIDED DEVELOPMENT OF SPHERICAL SURFACES BY THE GORE METHOD

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Abstract

The difficulty in graphically representing nondevelopable surfaces led to approximate representations. One method used for spherical surfaces is called the Gore Method. This paper describes the computer generated development of a sphere using the Gore Method and presents an approach to fabricating a sphere with minimum material waste.

Introduction

Little CAD/CAM attention is given to the automation of sheet metal fabrication. Only a handful of software packages address the development of the special class of surfaces called nondevelopable surfaces. Sheet metal products often require developable and nondevelopable surfaces. Development is the process of unwrapping a surface into a plane while preserving the surface's original metrical properties. This process requires a geometric description of the surface which is not well suited for automation processes.

The method of describing a surface depends on whether it is ruled, double-curved, or sculptured (free-form). Ruled surfaces such as polyhedrons, cones, and cylinders are generated by a moving straight line. Warped surfaces, such as those found in transition pieces connecting rectangular ducts and circular ducts are also classified as ruled surfaces. They are generated by moving straight lines in such a manner that any two consecutive positions of the generating line do not lie in the same plane. Ruled surfaces are developable because they can roll onto a plane. One exception to this rule is the warped surface.

Warped and some double curved surfaces are approximately developed with sufficient accuracy for many engineering applications. A sculptured surface because of its complex forms, similar to those modeled by scupltors, is another application of an approximately generated surface. These surfaces have been extensively researched by Richards and Onwubolu (1986), Ferguson, and Coons (1964). An algorithm is needed to develop double-curved surfaces. Although double curved surfaces are non-developable, some, like the sphere, are developed by approximation.

Approximate Devolopment of a Sphere

Two methods of approximate development of a sphere include: dividing the surface into either conical or cylindrical segments. Vertical planes (meridian planes) divide the sphere into sections called gores; hence, the Gore Method. This method is also called the polycylindric method because each cut-out spherical section is substituted with a cylindrical section. Horizontal cutting planes divide the sphere into sections called zones. Each zone is taken as frustum of a right-circular cone. This method is known as the Zone Method or Polyconic Method.

The Gore Method subdivides the sphere into "m" equal gores with meridian planes. A Gore is subdivided into "n" equal zones by horizontal planes (Figure 1). Each gore extends half around the sphere and therefore, is developable as a cylinder. It must be noted that this development is approximate since in reality a gore cannot form a cylinder without stretching. A gore is developed by determining elliptical contours to represent the great circle arc of the gore. The elliptical arcs are determined by projecting a top view showing points (points 1, 2, etc.) of intersection between horizontal cutting planes and the surface of the sphere. The boundaries of the gore are developed by mapping the points 1, 2, etc., from a rectified line with a length equal to one-half the circumference of the sphere (Wellman, Earle). Dhande and Ramulu (1984), discuss a first attempt in computer-aided surface development.

This process requires great care in drafting. Length D must be accurately measured to insure the developed ellipse is the same length as the great-circle arcs of the gore. This procedure is time-consuming, error prone and unsuitable for computer application. A procedure better suited for computer application is presented here.

Development of an Algorithm

Consider a gore in the top view (Figure 2). The length of each horizontal arc between two meridian planes is approximated by its chord. The chord length of each arc is determined from the radius L of each horizontal circle (Figure 2). The length L is computed

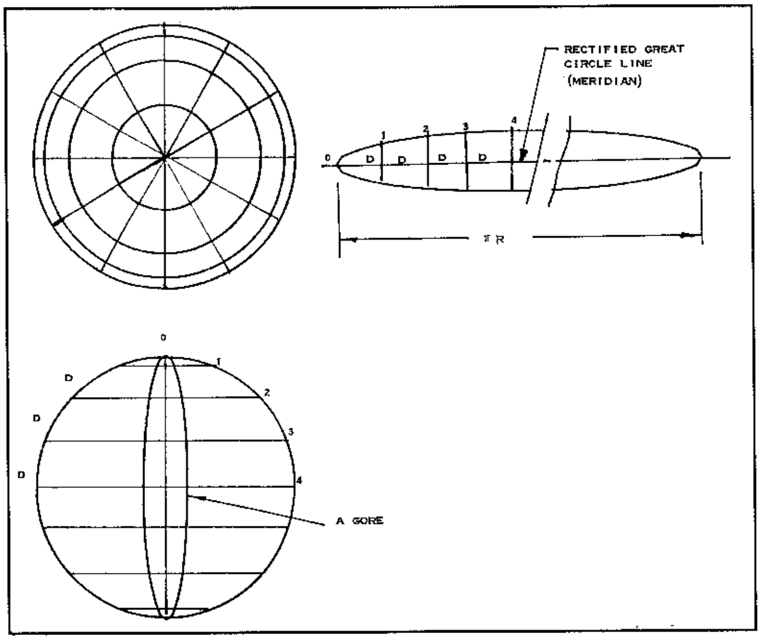

Figure 1. Graphical Development of A Sphere by the Case Method

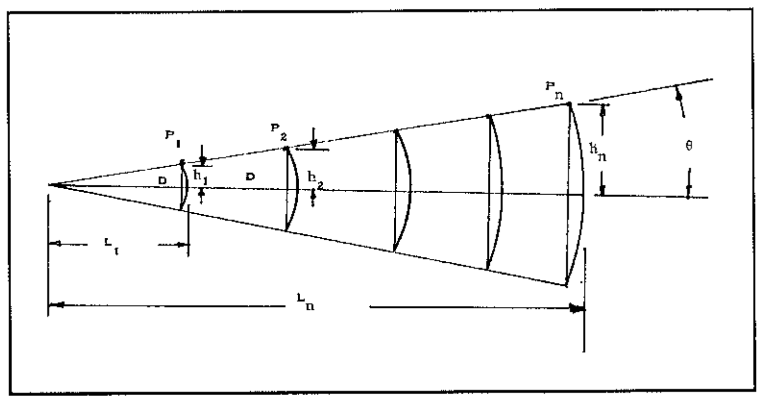

Figure 2. A Gore: A Top View

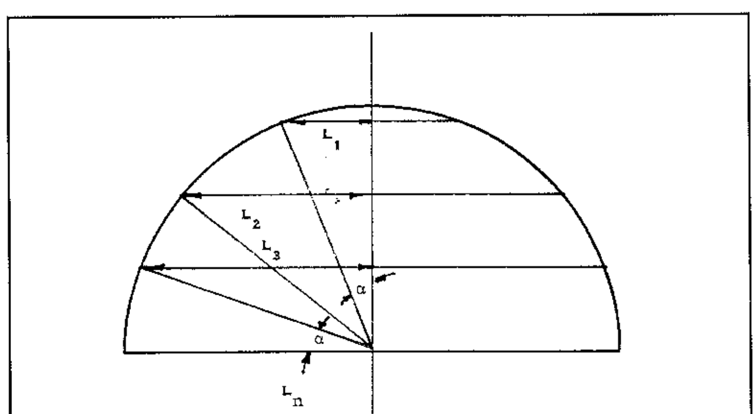

Figure 3. Geometry for the Determination of the Radius of Each Horizontal Circular Plane

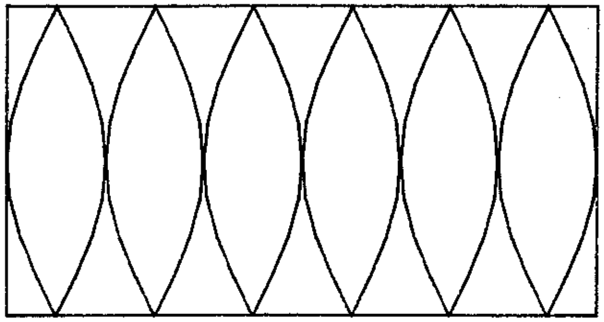

Figure 4. A Typical Pattern Layout of One Half of the Surface Area of a Sphere

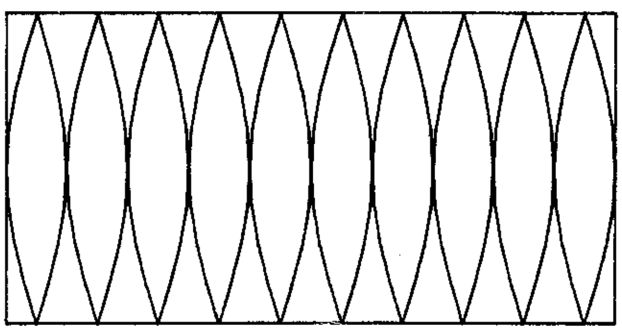

Figure 5. A Typical Pattern Layout of one Half of the Surface Area of Sphere

from the geometry in Figure 3. Each radius is given by:

$$L_{i+1} = R\cos(i\alpha), \quad i = 0, 1, \ldots, n \tag{1}$$

where

$\alpha = 90/n$

R = radius of sphere to be developed

n = the number of zones

From Figure 2, one half of the length of each arc, h_i is given as:

$$h_i = L_i \sin\theta, \quad i = 1, 2, \ldots, n \tag{2}$$

where

$\theta = 180/m$

m = number of equal gores

Using equation (2), a point on the ellipse P_i, (Figure 2) is computed using:

$$P_i = [\, iD \;\; h_i \,] \tag{3}$$

$i = 0, 1, \ldots, n$

where

$D = \pi R/2n$

The application of equation (3) results in a mapping of the upper left half of the profile of the ellipse which approximates the gore. Using symmetry, map the other half of the upper boundary of the gore. The lower contour of the ellipse is mapped by the points:

$$P_i = [\, iD \;\; h_i \,]\,[B] \tag{4}$$

where

$$[B] = \begin{pmatrix} 1 & 0 \\ 2 & -1 \end{pmatrix}$$

By applying equations (1) through (4) an algorithm to generate a single developed gore is developed below:

Step 1: Input m, n, and R

Step 2: For i = 0 to n, compute L_i and h_i using equation **(1)** and **(2)**. Set s = 0

Step 3: For i = 0 to 2n, calculate P_i using equation **(3)**.
Set $x_i = iD$.

If $i * D \leq \pi R/2$ go to **Step 4** else

Set cc = 1
s = s + 1

Step 4: If cc = 0 set $y_i = h_i$
else $y_i = h_{n-s}$

Step 5: Output x_i , y_i

Step 6: For j = 0 to 2n set $y_j = -y_j$

Step 7: Output x_j, y_j

Step 8: Stop

Note, steps 6 and 7 plot the mirror image of the half gore generated in steps 2 through 5. To develop one half of the sphere repeat steps 2 through 7 m times. The algorithm was coded in BASIC. An HP pen plotter 7475A was used to plot the half sphere seen in Figures 4 and 5.

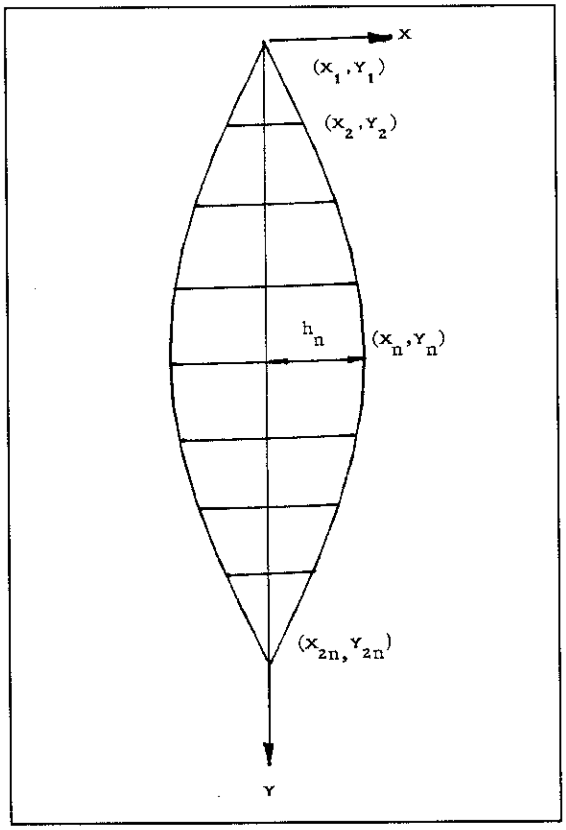

Figure 6. Determination of the Area of a Single Gore

Table 1

Developed Area of a Sphere for Different m and n. Radius - 2 Units.

	m/n	3	4	5	10	% error
	3	26.61	28.98	30.12	31.67	5.90
		65.34	71.14	73.92	77.73	
A	4	32.67	35.57	36.96	38.86	29.94
		65.34	71.14	73.92	77.73	
	5	28.75	31.30	32.52	34.07	14.35
		65.34	71.14	73.92	77.73	
	10	32.67	35.57	36.96	38.86	29.94
		65.34	71.14	73.92	77.73	

Table 2

Developed Area of a Sphere for Different m and n. Radius - 3 Units.

	m/n	3	4	5	10	% error
	3	59.89	65.21	67.76	71.25	5.90
		147.01	160.06	166.32	174.88	
A	4	73.51	80.03	84.88	87.44	29.94
m, n		147.01	160.06	166.32	174.88	
	5	64.69	70.43	73.18	76.95	14.35
		147.01	160.06	166.32	174.88	
	10	73.51	80.03	84.88	87.44	29.94
		147.01	160.06	166.32	174.88	

Table 3

Developed Area of a Sphere for Different m and n. Radius - 10 Units.

	m/n	3	4	5	10	% error
	3	665.50	724.55	752.88	791.65	5.90
		1633.47	1778.43	1847.97	1948.74	
A	4	816.73	889.22	923.98	971.57	29.94
m, n		1633.47	1778.43	1847.97	1948.74	
	5	718.73	782.51	813.11	854.99	14.35
		1633.47	1778.43	1847.97	1948.74	
	10	816.73	889.22	923.98	971.57	29.94

Minimum Encasing Rectangular Area

Applying the algorithm results in a fabrication of an approximate sphere. To reduce material waste, determine a rectangular sheet of minimum area for laying out the gores' development. See layout of the gores' development in Figure 5. Obtain the area of each gore using Figure 6.

$$A_g = 4 \int_0^{hn} g(X_i)\, dx \qquad (5)$$

where,

A_g = the area of each gore

$x_i = i\pi R/2n$

$i = 0, 1, \ldots, n$

Compute the values of h_n and $g(x_i)$ from equation (2). Equation (5) is numerically integrated to obtain the area of a single gore.

The total surface area of the m gores which approximates half the surface area of the sphere, Ad, is:

$$A_d = mA_g \qquad (6)$$

The area of the encasing rectangle is:

$$A_r = 2\pi R m h_n \qquad (7)$$

Obtain the optimum area of the rectangle by selecting the appropriate values of m and n such that A_d is equal to or greater than the surface area of one half of the sphere. Execute to find the best values of m and n through trial runs for spheres of different radii. Results are presented in Table 1, 2, and 3. The entry $A_{m,n}$ is the area associated with a given set of m and n. The area of the resulting rectangle is shown on the second row for each run.

By comparing the various values, it is apparent that the minimum area of the rectangle is that for which m = n - 3. The optimum layout is obtained by using six meridian planes and six horizontal planes. The maximum approximation error for one half of the developed sphere for optimum combinations of m and n is 6%. This error is computed as the difference between the true area of one half of the sphere and the developed area divided by the area of one half of a sphere. The justification for using an upper limit of ten for both m and n is that, in practice, the number of gores rarely exceeds twenty (ten for one half of the sphere) in approximate development of the sphere. Besides, more gores means an increasing cost for seaming the gores together.

Conclusion

In Tables 1, 2, and 3, we see that the accuracy of the development depends on the number of gores and the number of horizontal cutting planes. Therefore, the greater the number of gores the more accurate the approximation. This is because the arc of each gore is approximated by its chord: the developed gore is a smaller area than the true surface. But, if the gore surface is circumscribed about the sphere, the developed gore is larger than the true surface. This is why the error in a developed sphere increases to 30% as the number of gores increases. This work provides the algorithm for the automation of the metal fabrication of a sphere.

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Richards, T. H. and Onwubolu, G. C. (1986). Automatic interpretation of engineering drawings for 3D surface representation in CAD. *Computer-Aided Design.* Vol. 18, No. 3, 156-160.

Wellman, B. L. (1957). *Technical Descriptive Geometry.* New York: McGraw-Hill.

Earle, J. (1973). *Engineering Design Graphics.* Massachusetts: Addison-Wesley.

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Division News and Notes

Chairman's Message
by John T. Demel

During the next four years the engineering curricula are going to be examined again and again. Each time this is done educators will try to make the process more efficient and effective. This is as it should be but many of the engineering educators that are unwilling to accept incorrect analytical results, and incorrect English in reports are willing to accept incorrect drawings and graphs that portray information incorrectly.

It is in this process of communication done incorrectly that United States industry loses money and market share. We, the members of the EDGD, have to be creatively involved in this curricula revision process so that correct engineering communication (read this - 'Graphics') is considered to be part of the engineering core. For example, our contribution may be in team-taught courses rather than individual courses.

There are two initiatives for massive reform that have been funded by the National Science Foundation under the Engineering Education Coalition program. These two coalitia have 15 colleges but only two, Iowa State and Penn State, that are heavily involved with the EDGD. This Division needs to be represented in the ongoing planning process for curricular change and Professors Jenison and Foster can carry the Division's message.

We have had two studies that have been externally funded (NSF and ACM-SIGGRAPH.) I say 'we' because the principal investigators (Professors Barr, Juricic, McGrath, Pleck, Bertoline, and Bowers) are active members of our Division. Their voices need to be heard in the coming years as decisions are being made.

Please take time to read the articles that they have written. I would suggest that you also should read a letter written by Steve Slaby to Ed Ernst at the NSF that discussed and disagreed with the findings of Barr and Juricic. Reflect on what they have to say and let us begin active dialog about what works and doesn't work. This Journal and our two yearly meetings are the forum for exchange.

1893 ASEE 1993

SHAPING OUR WORLD – CENTURY II

Calendar of Events

Prepared by William A. Ross
Program Chair

1991-92 EDGD Mid-Year Conference

November 3-5, 1991
Norfolk, Virginia
Host: Old Dominion University
General Chair: Mustafa R. Mustafa
Old Dominion University
(804) 683-3767
Program Chair: Barry Crittenden
Virginia Polytechnic Institute and State University
(703) 231-6555

1992 Annual ASEE Conference

June 21-25, 1992
Toledo, Ohio
Program Chair: Doug Frampton
The University of Akron
(216) 627-7065
Theme: Creativity..Educating World-Class Engineers

1992 5th International Conference on Engineering/ Computer Graphics and Descriptive Geometry

August 17-21, 1992
Melbourne, Australia
Host: Royal Melbourne Institute of Technology
Melbourne, Australia
Contact: Larry Goss
University of Southern Indiana
(812) 464-1892
Fax No. (812) 464-1960

1992-93 EDGD Mid-Year Conference

Date: To be announced
Host: San Francisco State (tentative)
San Francisco, California
Program Chair: Ron Pare'
(713) 749-4652

1993 Annual ASEE Conference

June 1993
Champaign, Illinois
Host: University of Illinois
Program Chair: To be announced
Theme: ASEE 100th Anniversary

International Computer Graphics Calendar

Prepared by Vera B. Anand
International Relations Committee

6th International Forum on CAD

September 11-13, 1991
Hilton Hotel
East Midlands Airport, United Kingdom.
Contact: Carolyn Hall, Euroteam
University of Leicester, LE1 7rh, U. K.
Phone: (44) 533-522408.

Compugraphics 91

1st International Conference on Computational Graphics and Visualization Techniques
September 16-20, 1991
Villas de Sesimbra, Sesimbra, Portugal.
Contact: Harold P. Santo
Department of Civil Engineering
Institute of Engineering
Technical University of Lisbon, Av. Rovisco Pais
1096 Lisboa codez, Portugal.
Phone: (351) 1-801579/8020 x1638.

Eurographics Workshop on Computer Graphics and Mathematics

October 28-31, 1991
Genoa, Italy.
Contact: B. Falcidieno
instituto per la Matematica Applicata
Via LB Alberti 4, 16132, Genova, Italy

Visualization 91

October 22-25, 1991
San Diego, California
Contact: Arie Kaufman
Department of Computer Science
SUNY at Stony Brook
Long Island, New York 11794-4400
Phone: (516) 632-8441, or 8470

1992 Symposium on Interactive 3D Graphics

March 29-April 1, 1992
Cambridge, MA.
Contact: Ed Catmull
PIXAR
1001 West Cutting
Richmond, California 94804
Phone: (415) 215-3533

Eurographics 92

September 7-11, 1992
Cambridge, England
Contact: Jane Thorp
EG 92 Conference Secretariat
The Registry, University of East Anglia
Norwich NR4 7TJ
Phone: (44) 603-592802

Rogers, Bob LaRue, and Clarence Hall.

Many of these good people guided our Division from one with a drawing emphasis to one with design and computer emphases. But more than anything else I realize that these elders took a particular pride in our profession, and also gave meaning to the words courtesy, humility, and honor. They indeed passed a valuable torch to us to carry forward.

We deal, however, in the present, and I have learned a third point: to value my contemporaries. We share many things and develop lasting friendships. We here this evening represent a core of contemporaries. We do share much: our successes and joys and hopes, and, yes, perhaps even our shortcomings. In many ways we are like an extended family which gathers for a reunion one or twice a year. We share a bond which has been a characteristic of our Division for many years.

The cement that holds our bond together is our common profession of education. A fourth point I've learned is to value education. Education takes its blows these days: tight budgets, increased demands on faculty, and occasional scandals. Still, education remains a noble profession. What other profession has the high calling of working with young minds to provide knowledge and ideals? Yes, it is a challenge to be an idealist within education. The flip side of the idealist, however, is the cynic. If and when we become cynics, it is time to move on.

We can express our commitment to education in three principal ways, I've learned as a fifth point. These three ways are the well known avenues of teaching, research, and service. Most of us here probably identify most closely with teaching. Engineering graphics is a very teaching-oriented discipline. We spend the great majority of our time working with students. Many or our present papers at these conferences deal with how to make our teaching more effective, often using the computer as a tool.

You have shown me also the value of research in our field. Our research may deal more often with curricula and educational methods than with equations and abstracts, but it is sound research. We are rightly proud of our research. Research keeps us humble as we grapple with unexpected outcomes and implication for our teaching, and humility is a good trait in a teacher!

Let us not forget service as part of the trilogy of commitment: teaching, research, and service. Service is going that extra mile beyond our classroom and lab. It can be that long committee meeting, that panel we serve on, or spreading the word at a career night. Service is often the thankless part of our work, but it makes us more rounded, better balanced professionals.

So I feel privileged to have learned by being with our Division over the years. I thank you for teaching me the value of elders, the value of contemporaries, and the value of our profession of education. There is one more important sixth point I have learned which has a special focus tonight. I've had the pleasure of attending a number of Annual Banquets. Each one has presented an honored recipient with the Distinguished Service Award.

I've noted that each recipient extends the long and honored line that began in 1950 with Frederic Higbee. No, I wasn't at that banquet! My first was in 1969 when Edward Griswold received the award. What I have learned especially is that each person has received this fine award with such grace. We can think back across a few years and we find men and women who accepted the mantle of this award with dignity and grace. Stepping back a few years, one at a time, we have Clyde Kearns, Frank Oppenheimer, Paul DeJong, Clarence Hall, Claude Westfall, Klaus Kroner, and wonderful Amogene DeVaney. These are our colleagues who perhaps felt surprised and undeserving of the award, as I do now. I do want to say, though, that I accept this award as one of the grand parade of educators who have been marching along since 1950. It is a grand tradition and I'm proud to be part of it. Thank you very much, good friends.

SIX POINTS

- Watch where you sit
- Value your elders
- Value your contemporaries
- Value education
- Commitment to education
- Tradition of the recipients

AMENDMENT TO THE BYLAWS

In accordance with Article X, Amendments to Bylaws, Sections 1 through 3, the following amendment to the Division's Bylaws was proposed and recommended for the consideration of the Chair and members of the Executive Committee on June 17, 1991. The changes were accepted by the Executive Committee at their meeting in New Orleans.

EXISTING

Article V
CONFERENCES

Section 2. MID-YEAR CONFERENCE. There shall be a Mid-Year Conference to be held at an appropriate date annually between November 1 and January 31, and shall include a Division Mid-Year dinner meeting, one or more conferences, and a luncheon business meeting. The Executive Committee will be responsible for selecting sites for conferences.

2a. PROGRAM FOR MID-YEAR CONFERENCE. The program for the Mid-Year Conference shall be considered by the Executive Committee at the Annual Conference of the Division. The Chair shall present the Mid-Year Conference program to members of the Division at the annual luncheon business meeting. The program the Mid-Year Conference shall be published in the Fall issue of the Journal.

PROPOSED

Article V
CONFERENCES

Section 2. MID-YEAR CONFERENCE. There shall be a Mid-Year Conference to be held at an appropriate date annually between November 1 and January 31, and shall include a Division Mid-Year dinner meeting, one or more technical/professional sessions, and a luncheon business meeting.

2a. PROGRAM FOR MID-YEAR CONFERENCE. The program for the Mid-Year Conference shall be considered by the Executive Committee at the Annual Conference of the Division. The Chair shall present the Mid-Year Conference program to members of the Division at the annual luncheon business meeting. The program for the Mid-Year Conference shall be published in the Fall issue of the Journal.

2a(1). SITE SELECTION FOR MID-YEAR CONFERENCES. Individuals wishing to host a Mid-Year Conference shall submit a letter of proposal to the the Chair of the Division no later than one-year in advance of the Conference date. The Chair of the Division shall then include the proposal on the agenda for the next regularly scheduled Executive Committee meeting. A representative of each campus wishing to host a Mid-Year Conference must be present at the Executive Committee meeting to present a brief proposal to the Committee. The Executive Committee will then be responsible for selecting sites for conferences. Whenever possible, preference will be given to geographic distribution of conference sites.

engineering design graphics division mid-year meeting

November 2 - 6, 1991
Norfolk, Virginia

Co-Sponsored by:
College of Engineering and-Technology
Old Dominion University

Schedule of Events

General Chair
Moustafa R. Moustafa
Old Dominion University

Technical Program Chair
J. Barry Crittenden
VPI & SU

SATURDAY - November 2, 1991

Special Sessions: Workshops
Saturday, November 2, 1991
Sponsored by AutoCAD, CADKEY, SilverScreen, and MicroCADAM

SUNDAY - November 3, 1991

Special Sessions: EDGD Committee Meetings

Special Session: EDGD Executive Committee Meeting

Session 1: 8:00 p.m. to 10:00 p.m.

Moderator - Edward W. Knoblock, University of Wisconsin - Milwaukee (retired)

- *Developing a Comprehensive Taxonomy of Graphics Terms for Engineering and Technology*
  Gary R. Bertoline & Scott E. Wiley
  Purdue University
- *What Do We Mean When We Say 'Design'?*
  Edward W. Knoblock
  University of Wisconsin - Milwaukee (retired)

MONDAY - November 4, 1991

Session 2: Main Plenary - 9:00 a.m. to 10:15 a.m.

Moderator - Moustafa R. Moustafa
Old Dominion University

Welcome and Opening Remarks
Dr. Ernest J. Cross, Dean
College of Engineering and Technology
Old Dominion University

Keynote Speaker
Mr. Ed Campbell, President
Newport News Shipbuilding and Drydock Company

Morning Break
Session 3: 10:30 a.m. to 12 noon

Moderator - Michael D. Stewart
University of Arkansas - Little Rock

- *Investigation of the Application of Geometric Dimensioning and Tolerancing in a Group of Mid-western Manufacturers*
  Frederick D. Meyers, The Ohio State University
- *ANSI Geometric Dimensioning vs. ISO Geometric Dimensioning*
  Patrick J. McCuistion, Ohio University
- *The Relationship of Just In Time Manufacturing with CADD Design and Documentation*
  Jon M. Duff, Purdue University

Special Session: 1:00 p.m. to 5 p.m.
Tour of Newport News Shipbuilding and Drydock Company

EDGD Dinner at Captain George's - 6:15 p.m.

Guest Speaker - Dr. Joel Orr of LEAP

TUESDAY - November 5, 1991

Session 4: 8:30 p.m. to 10:30 p.m.

Moderator - Charles W. White, Purdue University

- *The Results of Integrating Real and Computer Generated models into a Traditional Sketching Based Engineering Graphics Course*
  Craig L. Miller, Purdue University
- *A Review of Dynamic and Static Visual Display Techniques*
  Eric N. Wiebe, North Carolina State University
- *Producing Animations Using CADKEY*
  Edward V. Mochel, University of Virginia
- *GUIs Performance in an Interactive Animation Display Environment*
  Shane McWhorter & Walter E. Rodriquez
  Georgia Institute of Technology

Morning Break

Session 5: 10:45 a.m. to 12:15 p.m.

Moderator - Edward D. Galbraith
California Polytechnic State University - Pomona (retired)

- *The Design of CAM Mechanism Using CAD*
  Dennis R. Short, Purdue University
- *True Perspective Projection*
  Robert P. Kelso, Louisiana Technical University
- *Graphical Math Is Alive and Well and Living Inside Your CAD System*
  Larry D. Goss & Matthew Goffinet
  University of Southern Indiana

Special Session: EDGD Business Luncheon

Moderator - John T. Demel, Division Chairman

(Poster) Session 6: 2:15 p.m. to 3:30 p.m.

- *Integrating Solid Modeling Projects into an Existing CAD Course*
  Holly K. Ault & Kenneth E. Scott
  Worcester Polytechnic Institute
- *Communication, Visualization and Technology*
  Terry L. Burton, Purdue University
- *A Computer Application Dilemma In Course Development*
  Terry L. Burton, Purdue University
- *An Assessment of Research Activities in Engineering Design Graphics*
  Robert A. Chin, East Carolina University
- *Economical Optimization of Engineering Classroom Facilities*
  Paul S. De Jong, Iowa State University
- *Introductory Engineering Graphics at the Post Secondary Level in North Carolina: Are We Meeting the Challenge of Advancing Technology?*
  Gayenell C. Gull, North Carolina State University
- *Upgrade/Replace Decisions of Microcomputer Based CAD Systems*
  Sunil Hazari, East Carolina University
- *Visualizing Parametric Surfaces with the Enhanced Reverse Ray Tracing Technique*
  Augusto Op den Bosch & Walter Rodriguez
  Georgia Institute of Technology
- *2+1+15 .. an Alternative to Declining Student Enrollment in, and Required Credit Hours for Engineering Graphics Courses*
  William J. Vander Wall
  North Carolina State University
- *Modernizing the Interior Design Curriculum*
  Billy H. Wood, The University of Texas at Austin

Afternoon Break

Session 7: 3:45 p.m. to 5:15 p.m.

Moderator - Linda J. Bode, University of Toledo

- *The Integration of Sketching into the Instruction of Computer Aided Design*
  Thomas J. Krueger
  Southwest Texas State University
- *On Including Design Into a Freshman Graphics Course*
  R. S. Engel, The Pennsylvania State University
  S. C. Kranc, University of South Florida
- *A New Look at the ENGINEERING DESIGN GRAPHICS PROCESS Based on Geometric Modeling*
  Ronald E. Barr & Davor Juricic
  The University of Texas at Austin

Special Session: EDGD Banquet and Awards
Evening dinner cruise aboard the NEW SPIRIT
Moderator - John T. Demel
The Ohio State University

Spouses' Sessions

Monday, November 4, 1991

- Norfolk Sightseeing
- Tour of Chrysler Museum and/or McArthur Memorial
- Tour of Newport News Shipbuilding and Drydock Company

Tuesday, November 5, 1991

- Williamsburg and Vicinity Sightseeing
- Tour of Colonial Williamsburg and Pottery Factory

5th International Conference on

ENGINEERING COMPUTER GRAPHICS AND DESCRIPTIVE GEOMETRY

August 17 - 21, 1992
Hilton International, Melbourne, Australia

CALL FOR PAPERS

Papers dealing with the following topics are solicited:

1. Theoretical Graphics
   Descriptive Geometry
   Kinematic Geometry and other applications of Geometry
2. Engineering Computer Graphics
   Computer Aided Design
   Computer Aided Geometric Design
   Computerised Descriptive Geometry
3. Graphics Oriented Expert Systems
   Scientific and Technical Visualisation
   Engineering Animation
   Image Processing and Remote Sensing
4. Graphics Teaching
   Graphics Exercises
   Computers in Engineering Graphics Education
5. Other Topics of Interest will be considered.

Deadlines and Requirements

- Papers will be reviewed for presentation at the conference and publication in the conference proceedings
- Authors are requested to submit manuscripts in camera-ready form prepared as per the conference publication format before March 2, 1992

Sponsored by: *Engineering Design Graphics Division American Society for Engineering Education (ASEE).*

Co-sponsored by: *Association for Computer Aided Design, Victoria (ACADS).*

Hosted by: *Royal Melbourne Institute of Technology, Melbourne Australia*

For Further Information contact:

In Australia:
Mr. Tom Thomas, Mechanical Engineering, Department of Manufacturing and Process Engineering, RMIT, GPO Box 2476V Melbourne, Vic. 3001 Australia. Ph. +613 660 2166, +613 660 2523, Fax No: +613 663 7873

In USA
Prof. Larry. D. Goss, University of Southern Indiana, 8600 University Boulevard, Evansville, Indiana 47712, USA PH. (812) 464 1892, Fax No: (812) 464 1960

EDG COMMITTEE CHAIR VACANCY

As Chair of the Technical and Professional Committee for the EDG Division, Gary Bertoline would like to announce that there is an opening for Chair of the Geometric Modeling Committee. If you are interested in serving as chair of this committee, please contact Gary.

Gary Bertoline
Technical Graphics / Knoy Hall
Purdue University
West Lafayette, IN 47907-1419

Ph. (317) 494-7507

POSITION ANNOUNCEMENT

TECHNICAL GRAPHICS. Purdue's Department of Technical Graphics invites application for tenure-track faculty position beginning August 24, 1992. A Master's degree in technology, engineering or closely related area is required; industrial experience suggested. Responsibilities will include undergraduate teaching, course development and scholarly activities. Rank and salary commensurate with qualifications. Position open until filled. Send resume and list of three references by January 1, 1992, to Professor Michael Gabel, Faculty Search Committee, Technical Graphics Department, 1419 Knoy Hall, Purdue University, West Lafayette, IN 47907-1419.

Purdue University is an Affirmative Action/Equal Opportunity employer.

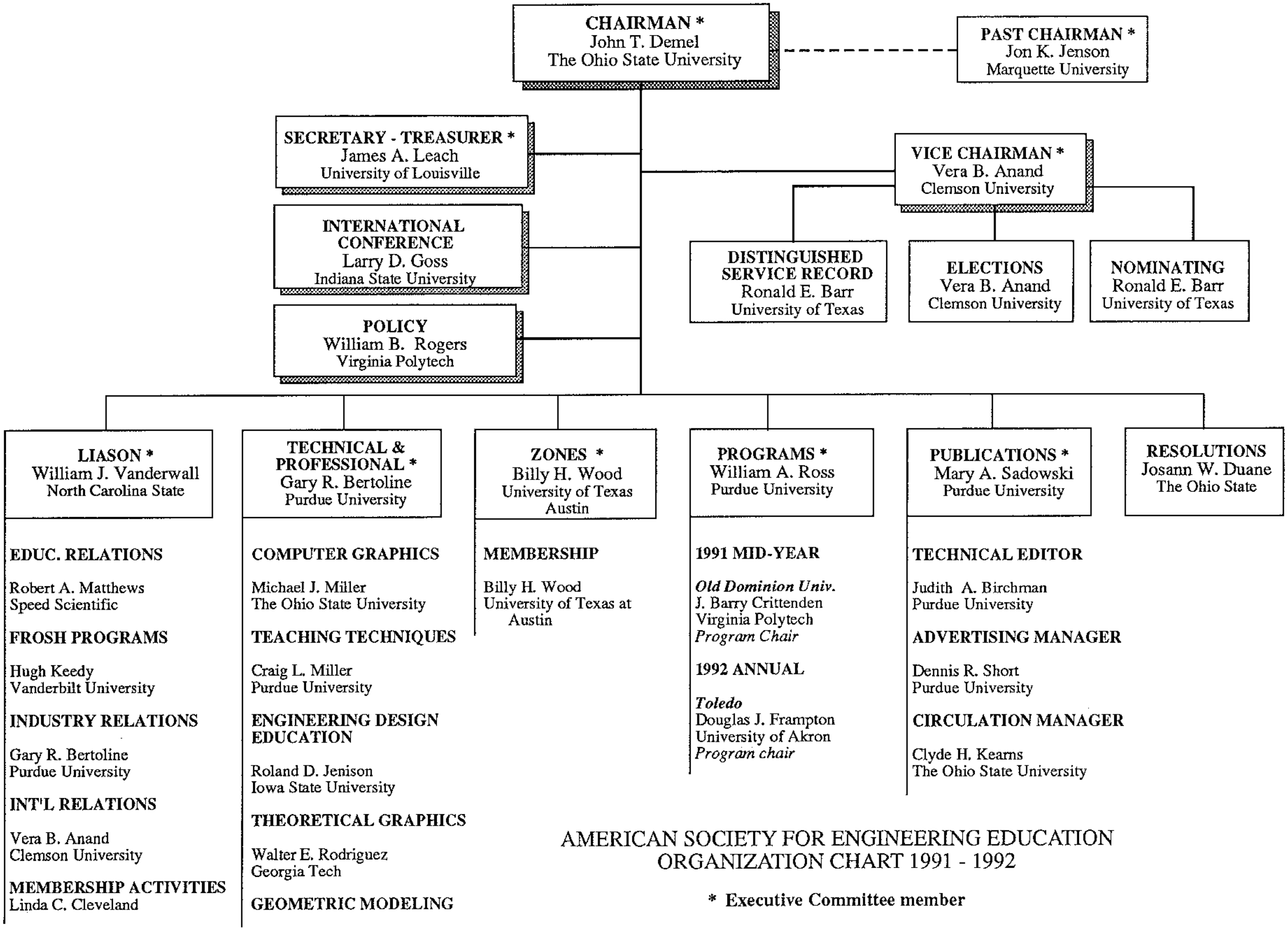
1992 ASEE Annual Conference
Toledo, Ohio
June 21 - 25, 1992

The Glass Capitol of the World and the home of the Mud Hens, Toledo, Ohio, is the site of the 1992 ASEE Annual Conference. Currently in the planning stages, the EDGD program will include five technical sessions, the annual business luncheon, and the annual awards banquet. Come, participate, and enjoy.

Program Chair:
Doug Frampton
Engineering & Science Tech. Div.
The University of Akron
120 Shrank Hall South
Akron, Ohio 44325-6104

Ph. (216) 972-5139
FAX (216) 972-5300

ENGINEERING DESIGN GRAPHICS DIVISION



AMERICAN SOCIETY FOR ENGINEERING EDUCATION
ORGANIZATION CHART 1991 - 1992

* Executive Committee member

Submission of Papers and Articles for the *Engineering Design Graphics Journal*

Submit papers, including an abstract of no more than 200 words, as well as figures, tables, etc. in quadruplicate (original plus three copies) with a cover letter to M. A. Sadowski, Editor, Engineering Design Graphics Journal, Technical Graphics/Knoy Hall, West Lafayette, IN 47907-1419. Use standard 8-1/2 x 11 inch paper only, with pages numbered consecutively. Clearly identify all figures, graphs, tables, etc. All figures, graphs, tables, etc. must be accompanied by a caption. Illustrations will not be redrawn. Therefore, ensure that all the line work is black and sharply drawn and that all text is large enough to be legible if reduced to single or double column size. High quality photocopies of sharply drawn illustrations are acceptable. The editorial staff may edit manuscripts for publication after return from the Board of Review. Galley proofs may not be returned for author approval. Authors are therefore encouraged to send editorial comments from their colleagues before submission of papers.

Page Charges

A page charge will apply for all papers printed tin the *EDG Journal* The rates are as follows:

$5 per page for EDGD members
$10 per page for ASEE members who are not members of EDGD
$25 per page for non-ASEE members

This charge is necessitated solely to help offset the increasing costs of publication. Page charges are due upon notification by the Editor and are payable to the Engineering Design Graphics Division at:

Mary. A. Sadowski
Editor, EDGD Journal
Technical Graphics/Knoy Hall
Purdue University
West Lafayette, IN 47907-1419

FAX: 317-494-0486

PH: 317-494-8206

The EDG Journal is entered into the ERIC (Educational Resources Information Center), Science, Mathematics, and Environmental Education/SE at:
The Ohio State University
1200 Chambers Road, 3rd Floor
Columbus, OH 43212.

Article copies and 16, 35, and 105 mm microfiche are available from:
University Microfilm, Inc.
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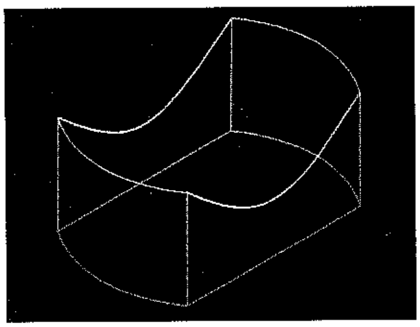
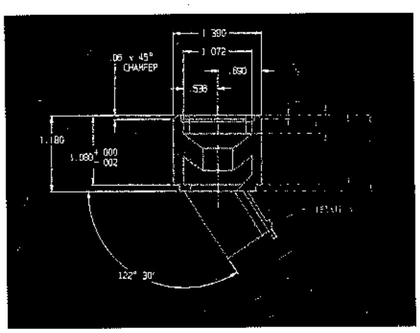
While our competition relies on its *name* to sell products, we rely on our products.

You might think that the 3-D CADD system with the biggest "name" in the business is also the best. But look closely at how well they handle *real* 3-D CADD problems. Then look at CADKEY.®



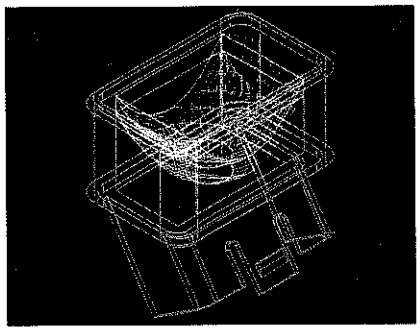
Problem #1

Problem #1: How do you translate your "bright idea" into a form others can understand? CADKEY gives you *all the tools you'll need —from wire-frame to CADKEY SOLIDS®*—to create complex designs quickly and easily. The parabolic curve pictured above may look simple, but it's a design our competition *can't* handle. Ask them.



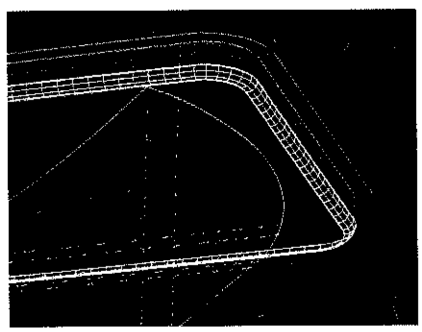
Problem #2

Problem #2: Need to convey your idea to engineers in Zurich and CNC machinists in Seoul . . . with accuracy in the *ten thousandths?* CADKEY'S ANSI, ISO, DIN and JIS compliance assures clarity and reliability *anywhere in the world.*



Problem #3

Problem #3: Want to make design changes? With CADKEY'S *transformation, editing, and detailing functions,* adjustments are no problem. Details and dimensions are *simultaneously and automatically updated.*

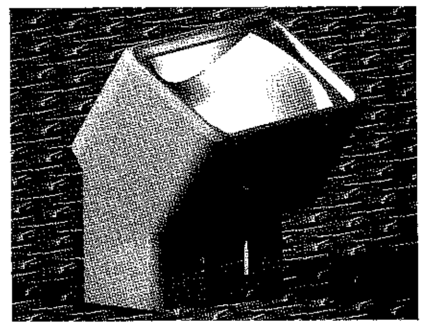


Problem #4

Problem #4: Will the design work? CADKEY goes way beyond simple polygon meshing to *true surface definition.* Ask our competition if they can handle variable radius fillet blends or surface intersections.

Need more illumination on the subject?
Send for your copy of the CADKEY 4 and AutoCAD® 11 technical comparison, and the name of the dealer nearest you. Write us or call CADKEY at 1-800-654-3413.

Problem #5: Do you see red when the sales manager asks for blue? With CADKEY RENDER® you can look at options and generate photorealistic soft prototypes *before* going into production. Change colors, even materials, without tooling a single machine!



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