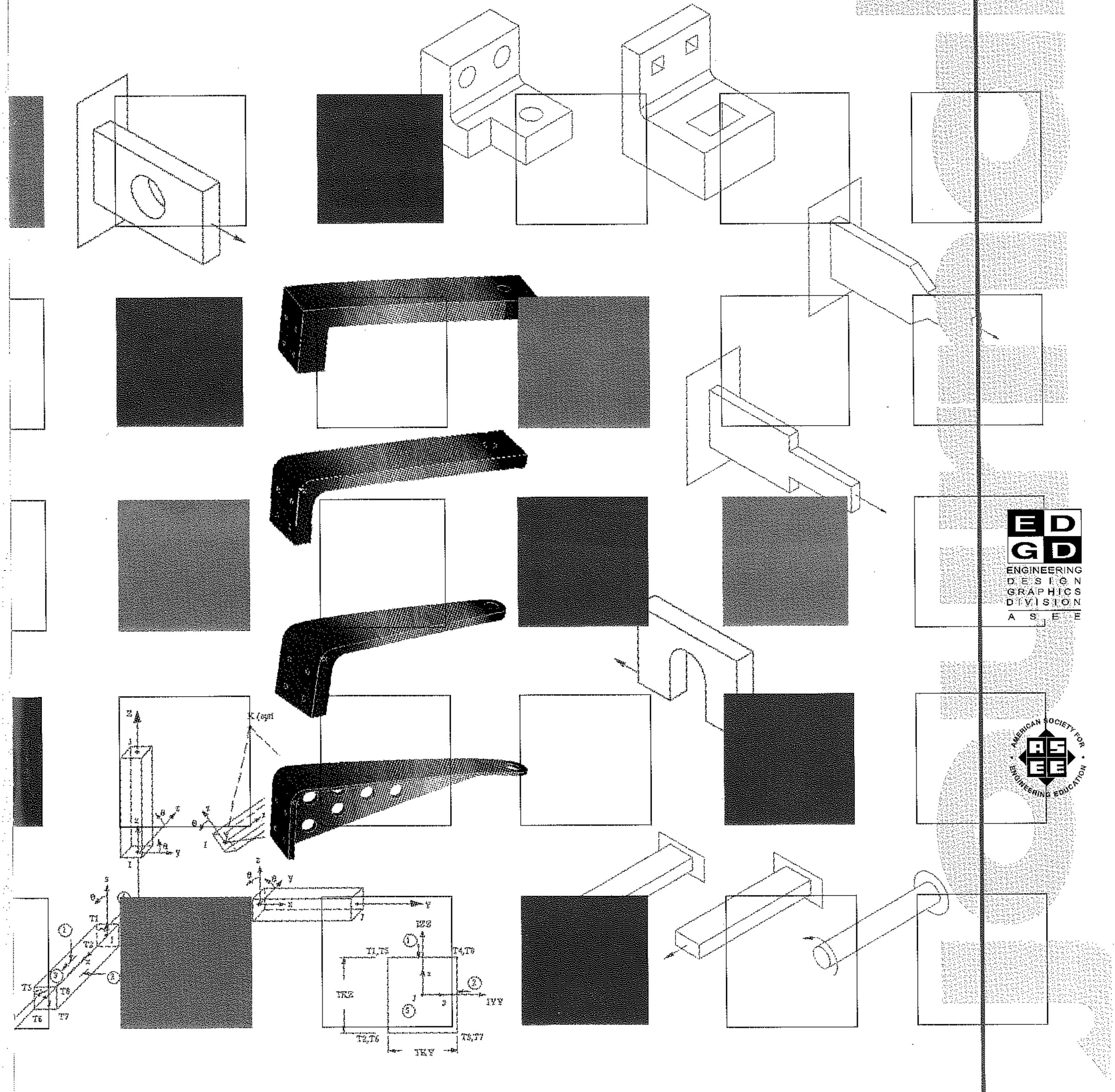
SPRING 2002

volume 66 number 2

THE ENGINEERING DESIGN GRAPHICS Journal



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THE ENGINEERING DESIGN GRAPHICS

Journal

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

Cover graphics from pages 27-38 of the Balamuralikrishna and Mirman paper.

ISSN 0046 - 2012

[From the Editor]

Dear Members:

As hard as it seems this is the end of my second year as editor of the *Journal.* I would like to thank and commend Mike Stewart for his service as Chair of the Division. His efforts allowed the division to continue to function in a professional manner. In this same tone I want to welcome Sheryl Sorby as the incoming Chair of the Division.

Congratulations are in order for Jon Duff of Arizona State University-East who won the 2002 editor's award for the most outstanding paper published in Volume 65 of the *Engineering Design Graphics Journal.* The following individuals should also be congratulated for election as officers of the Engineering Design Graphics Division: Judy Birchman who was elected as Vice Chair, Alice Scales as Director of Zones, and Ted Branoff as Director of Professional and Technical Committees. I would like to thank Judy Birchman who has severed as the Technical Editor for the first two years of my term as the Editor of the *Journal.* Because Judy has been elected to serve the Division as Vice Chair for the next year Mary Sadowski has graciously volunteered to serve as Technical Editor for me in place of Judy for my last year as Editor.

Last of all, Clyde Kearns is continuing to send the membership directory by email. Members need to update their information with ASEE to ensure that the correct information is publicized in the electronic membership directory. Please notify Clyde Kearns at kearns.1@osu.edu if you have not received the membership directory by email.

I hope that all of you have a safe and relaxing summer and I look forward to seeing you at the MidYear in Indianapolis, Indiana.

Susan G. Miller

Susan G. Miller

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[Message from the Chair]

Mike Stewart
Georgia Institute of Technology

The spring term has closed fast as I write my final message to you the members of the Division as Chair. It is hard to believe that a year can go by so fast. All of you members can attest to this fact I am sure. As a group we are always gearing up for a new term, or a new project, and always revising and honing our skills as educators. Re-visiting the semester or quarter just completed and identifying and assessing how that course went. It is so easy to get ourselves boxed in and covered over in our "own" little world and our set of things we are doing.

> **This Division is fortunate to have a very dedicated membership with not only the current officers, but the conference program chairs, past chairs and past officers all continuing to provide the leadership that this Engineering Design Graphics Divisions needs to stay abreast of today's issues and provide the forum for all to communicate and learn from one another. It has been my pleasure serving as your Chairman this year. Thank you.**

As engineering graphic professionals however, we know that we need to reach beyond our own campus and see what others are doing in our field of study and look at what we might want to add to our curriculums. That is why we have two conferences each year that we can attend. That is why we have Proceedings available from these two conferences. That is why we publish this Journal three times a year.

Change is an on-going process in our profession. More often than not, it is a result of technological advancements in software and or hardware, but quite often it is the result of new pedagogical advances resulting in new information, or delivery methods. Our Division provides many methods for you to hear the "newest" and network with other professionals, authors, publishers, and software and hardware vendors.

At our Mid-Year Conference held in Berkeley, California in January, we were provided with two jam packed days of technical sessions as well as vendor displays and demonstrations. Those who attended went home with many new and very novel ideas that were presented by many new members of our Division. It was great seeing so many new members attend this conference.

From June 16-19, 2002, we met as a Division in Montreal, Canada at the Annual ASEE Conference and had the opportunity to rub elbows with our fellow EDGD members, and hear their new ideas. We also had the opportunity to hear from many other engineering educators who spoke on curriculum issues that directly affect us and the topics we are teaching in our courses.

I believe we need to listen very carefully to these people, not only in what they say, but what they don't say and especially what they perceive about us as engineering education professionals in our area of expertise.

I encourage each one of you to make your colleagues in other engineering or technical areas aware of what you are doing in your courses and how you are educating the students that you share with them. Let them know what knowledge and skills your students are gaining from your courses and what they can expect of those students based upon your courses. We do not "toot" our own horn enough. You will be surprised if you enlighten others about the exciting things you are doing in your courses. Try it!!

Change is an on-going process in our profession. More often than not, it is a result of technological advancements in software and or hardware, but quite often it is the result of new pedagogical advances resulting in new information, or delivery methods.

In closing, I would be remiss if I did not thank the officers of this Division for their work this past year. This Division is fortunate to have a very dedicated membership with not only the current officers, but the conference program chairs, past chairs and past officers all continuing to provide the leadership that this Engineering Design Graphics Divisions needs to stay abreast of today's issues and provide the forum for all to communicate and learn from one another. It has been my pleasure serving as your Chairman this year. Thank you.

Sincerely,

Mike Stewart
EDGD Chair

announcement

Schroff Graduate Student Participation Grant

Dear EDGD Members:

The Schroff Graduate Student Participation Grant is being offered again this year. This grant provides a maximum of $500 each for graduate students to attend the EDGD Midyear Meeting at Indiana University-Purdue University Indianapolis in Indianapolis, Indiana from November 3-6, 2002.

The Schroff Graduate Student Participation Grant is intended as a developmental program to encourage potential graphics instructors to participate in the activities of the Engineering Design Graphics Division (EDGD) of ASEE. It is also anticipated that the grant recipients will make the EDGD one of their professional affiliations and activities on an ongoing basis throughout their professional career.

The grant is provided by Schroff Development Corporation and must be used to pay for travel, accommodations, and/or conference registration. The grant is open to all graduate students in graphics-related programs (for example, Engineering Graphics, Technical Graphics, and Computer Graphics). Application forms and guidelines for the grant are available on the EDGD Web site at http://www.east.asu.edu/edgj/edgd/awards/awards.html.

The schedule for the application and selection process is:

October 15:	Deadline for applications submitted to the Selection Committee
October 30:	Selection Committee notifies potential grant recipients
November 15:	Deadline for notice of commitment of recipients submitted to Selection Committee
November 20:	Grant checks sent to recipients

Details about the Schroff Graduate Student Participation Grant are available on the EDGD Web site at http://www.east.asu.edu/edgj/edgd/awards/awards.html.

Sheryl Sorby
Vice Chair, EDGD

The Development of a Computerized Version of Vandenburg's Mental Rotation Test and the Effect of Visuo-spatial Working Memory Loading

Shawn Strong
Southwest Missouri State University

Roger Smith
Iowa State University

Abstract

Many tests have been developed for the express function of measuring spatial abilities. Most of these test are paper and pencil in nature, which severely limits the ease of evaluation and interaction that is possible. The development of computerized tests will allow for more meaningful and widespread testing of the various spatial factors. This paper reports the development of one such test modeled after Vandenberg's Mental Rotation test. First, the differences between traditional paper and pencil and computerized versions of the same test are examined. Second, an interactive test designed to measure a working memory factor is compared to the computerized version of Vandenburg's test.

Introduction

Spatial abilities measurement has been studied in virtually all age groups and facets of society. Spatial abilities research has resulted in many paper and pencil tools for the measurement of various spatial factors. Several hundred tests have been developed for the express function of measuring spatial abilities, many of which prove to be valid measurements. Even though many tests claim to measure an individual's spatial ability, Branoff (1998) in his research has shown that often these tests do not measure the same factors. Of the tests that have been developed, many have been withdrawn, lost, or have been declared restricted. Regardless of what aspect of spatial ability these tests have been purported to measure, virtually all of them have been paper and pencil in nature (Eliot & Smith, 1983). As occurs with many tests, the measurement and evaluation of spatial ability remains a lengthy process.

Paper and pencil tests are limited due to a lack of possible interaction with the test takers. Kline (1986) discusses how several spatially related tests such as rotated shape identification and imbedded figures in a dot matrix could be positively effected by the interaction that is possible with the computer. Interactive tests allow test takers to manipulate the figures used and may prove to be more accurate and efficient measures of student spatial visualization ability.

Literature Review

Tests that quickly, accurately, and reliably measure spatial abilities would assist in widespread testing of spatial abilities. Widespread testing may be an initial step in the development of a graphic curriculum that will achieve greater levels of success for students. Establishing and reporting students' spatial abilities followed by instructional material designed to eliminate weaknesses would then be possible (Miller & Bertoline, 1991). The widespread testing of spatial abilities will require an accessible, reliable, and valid adaptive test for spatial abilities. This test should be web based for easy access, distributed freely among educational institutions, and allow for ready measurement of a student's true spatial ability level. Prior to this occurrence, an effective method(s) for the measurement of spatial abilities must be identified.

Computerized testing may change the way we evaluate spatial-visual reasoning and memory (Hunt & Pellegrino, 1985). Kail (1997) found that performance on spatial memory span tasks were largely predicated on imagery skill. It is apparent that a memory component is a critical part of spatial visualization. The integration of this memory component may result in a better measure of spatial visualization.

Spatial visualization abilities and working memory are often linked using the terms "visuo-spatial scratch pad" or "visuo-spatial working memory" (Logie, 1995). Visuo-spatial working memory is believed to be the component of the mind responsible for temporary storage of visual and/or spatial material. Logie assumes visuo-spatial working memory to be responsible for generating and maintaining visuo-spatial information, including mental imagery (Shah & Miyake, 1996). It is suggested that a visuo-spatial working memory may have a significant affect on spatial visualization abilities. Within tests of spatial visualization used in engineering graphics, there is no mention of a visuo-spatial working memory component.

While there are many tests of spatial visualization, they all should "reflect the processes of apprehending, encoding, and mentally manipulating spatial forms" (Carroll, 1993, p.309). Two tests of spatial visualization have been identified in engineering graphics and are utilized in the paper and pencil form. These are the Purdue Spatial Visualization Test (PSVT) (Figure 1) and the Mental Rotation Test (MRT) (Figure 2). Both appear frequently in the Engineering Design Graphics Journal for the assessment of spatial skills (Deno, 1995, Devon et al., 1994, Sexton, 1992).

Both of these tests may in fact measure a visuo-spatial working memory component, as several of the definitions for spatial visualization imply, although this component is not mentioned or emphasized. The research reported in this article will ascertain whether computer versions of Vandenberg's Mental

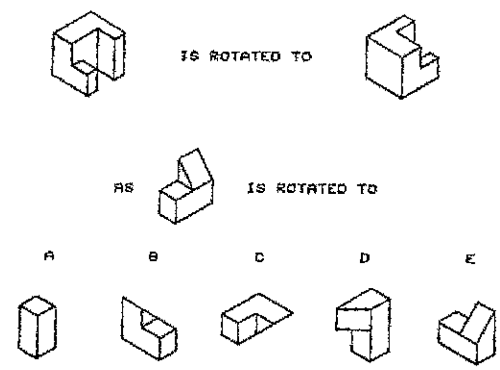

Figure 1 *Example of The Purdue Spatial Visualization Test (PSVT) (Guay, 1977)*

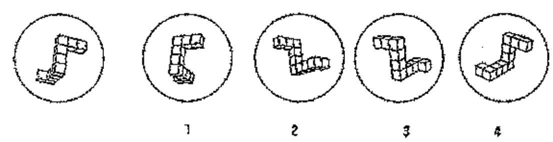

Figure 2 *Example of Vandenburg's Test of Three-dimensional Spatial Visualization 1971) (Eliot and Smith, 1983)*

Rotation Test are statistically equivalent to a paper and pencil version of the test, as well as to ascertain if a test designed to capitalize on working memory will prove to be an effective measure of spatial visualization.

The Study

The target population of this study was general university students enrolled during the spring semester 1999 in engineering graphics courses in the disciplines of industrial technology and engineering fields in selected universities. The sample size of this study consisted of 107 students. The subjects were solicited from freshman through senior levels of engineering graphics courses at the following post-secondary institutions: University of Missouri ñ Rolla, Missouri, Purdue University ñ West Lafayette, Indiana, Penn State ñ Erie, Pennsylvania, Greenfield Community College ñ Greenfield, Massachusetts, Wayne State College ñ Wayne, Nebraska, and Iowa State University ñ Ames, Iowa. Male participants outnumbered female participants in this study. Of the 77 participants in Phase 2, 64 were male while 13 were female. The majority of participants fell into the 19-24 age bracket (Figure 3).

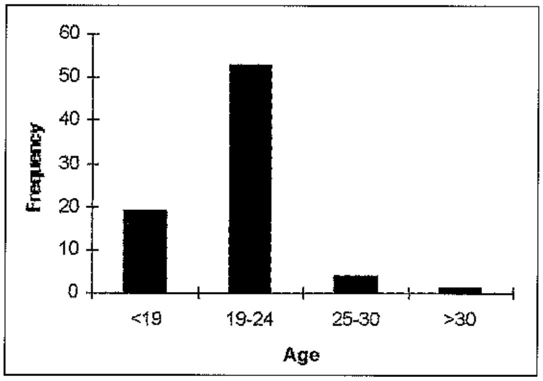

Figure 3 *Distribution of subjects by age*

Thirty subjects were solicited from Iowa State University; fifteen for Phase 1A and fifteen for Phase 1B. These subjects completed all three versions of the MRT. The remaining seventy-seven subjects were solicited from the post-secondary institutions other than Iowa State University for Phase 2 and completed the MRT Memory and MRT Computer only.

Instrumentation

Three versions of the Mental Rotation Test (MRT) were used for this study. The first was the paper and pencil version originally developed by Vandenberg. All of the questions were taken from Vandenberg's MRT (1978) acquired from Behavioral Measurement Database Services, Pittsburgh, Pennsylvania. The 20-question (40 point) Vandenberg MRT was developed by Vandenberg and Kuse (1978), following the work of Shepard and Metzler (1971). Shepard and Metzler developed the stimulus objects consisting of ten connected blocks in a study dealing with rotation and time required for recognition. The researcher for this study developed the second test, the MRT Computer, and the third test, the MRT Memory. The paper and pencil MRT, the MRT Computer, and the MRT Memory versions of the tests all used the same twenty questions. Each question consisted of a criterion object and four alternatives.

Vandenberg's paper and pencil MRT is frequently mentioned as a test for spatial visualization in engineering graphics related research studies. The reliability of Vandenberg's paper and pencil MRT is .88 using the Kuder Richardson 20 formula based on an N=3268 adults and adolescents. Reported Pearson correlations of .31-.68 with other tests of spatial ability were used to establish validity. Vandenberg's paper and pencil MRT compares well with other tests of spatial ability and especially well with tests of spatial visualization (Vandenberg & Kuse, 1978).

The scoring, number of questions, and stimulus objects from the 1978 version of Vandenberg's MRT were not altered for any of the three tests; only the interface and the directions needed to accommodate the interface were changed. The MRT Computer was created using the twenty digitized images, placing them with corresponding alternative check boxes (Figure 3). Questions were placed in the same order as the original paper and pencil Vandenberg's MRT. Test questions were identical to that of the paper and pencil MRT with the exception of the computer interface.

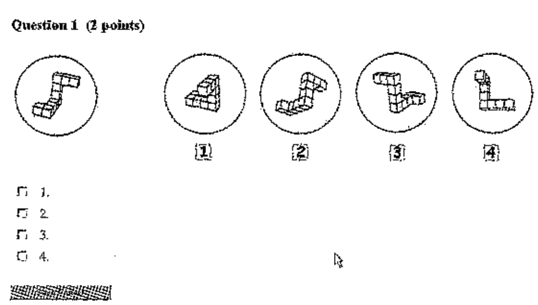

Figure 4 *Example of MRT Computer Question*

The MRT Memory version of the MRT was identical to the MRT Computer with the addition of a working memory factor. The number of questions, order, criterion and alternatives, and times were the same. The working memory factor made it possible for the test taker to see only the criteria figure or the alternatives, not both, at any given time. The working memory factor was incorporated using researcher designed JavaScript. As the mouse was moved over the criterion figure, the four alternatives appeared in place of the criterion figure. As the mouse was removed from the alternative figure area, the original criteria image reappeared. The use of this working memory factor required an additional reliance on visuo-spatial working memory for recognition of the correct alternatives from the distracters.

Research Questions

There were four research questions associated with this study:

Research Question 1

Does the type of test interface (paper and pencil MRT, MRT Computer, or MRT Memory) significantly impact the individual test scores, while testing spatial abilities?

Research Question 2

Does the type of test interface (paper and pencil MRT, or MRT computer) significantly impact the time required for completion of each test?

Research Question 3

Does visuo-spatial memory loading significantly effect the individual test scores between MRT computer and MRT memory test versions?

Research Question 4

Does the type of test (MRT computer, or MRT memory) significantly impact the time required for completion of each test?

Procedure

There were two phases to this study. Phase 1 determined any differences between paper and computer versions of the MRT (MRT and MRT Computer). Phase 2 was used to compare the computer version of the MRT with and without a working memory loading (MRT Computer and MRT Memory). A time limit of fifteen minutes was given for each of the three tests. Actual test times for each subject were recorded by the computer. Vandenberg recommended a time limit of 10 minutes for the paper and pencil MRT when given to high school students, and six minutes for college students. The time to complete the interactive version of the MRT was unknown, therefore subjects were directed to complete each of the tests as quickly as possible.

Phase 1

One objective of the study was to determine an efficient method for the measurement of spatial ability. Phase 1 consisted of having all subjects take the MRT and the MRT Computer tests. There were two parts to this phase, 1A and 1B. The subjects were divided into two groups and half (1A) took the MRT and then the MRT Computer and the other half (1B) took the tests in reverse order. Phase 1A and 1B were completed before Phase 2 was initiated. The purpose of Phase 1 was to ascertain the significant difference between the paper and pencil MRT and the MRT Computer, and to identify any potential problems with computer delivery of the tests. Additionally, Phase 1 determined if there was a significant time difference involved in taking the paper and pencil MRT or the MRT Computer. Upon completion of Phase 1, any significant difference between the time required to take the paper and pencil MRT, versus the MRT Computer tests, and the MRT Memory test could be determined.

Phase 2

Seventy-Seven subjects were included in Phase 2 of the study and completed the MRT Computer and MRT Memory. Each username and password included a randomly assigned letter, either A or B, which determined the subject's treatment group assignment. Subjects assigned to treatment Group A took the following instructions and test sequence:

1. MRT Computer Instructions
2. MRT Computer Spatial Visualization Test
3. MRT Memory Instructions
4. MRT Memory Spatial Visualization Test
5. Spatial Visualization Survey

Phase 1B, Paired difference test, Times								
	Mean	Std. Deviation n	Std. Error Mean	95% Confidence Interval		t	df	Sig. (2-tailed)
				Lower	Upper			
PAPER - COMPUTER	-1.74	3.07	.79	-3.44	-4.26E-02	-2.198	14	.045

Table 4

Phase 2, Paired difference test, Scores								
	Mean	Std. Deviation n	Std. Error Mean	95% Confidence Interval		t	df	Sig. (2-tailed)
				Lower	Upper			
PAPER - COMPUTER	1.60	6.60	.75	9.98E-02	3.09	2.124	76	.037

Table 5

observed between the subjects scores on the paper and pencil MRT and the MRT Computer occurred by chance alone. Null Hypotheses 1 was not rejected (fail to reject) at the .05 level. Therefore, there was no significant difference on Phase 1A between scores on the paper and pencil MRT and MRT Computer.

A Pearson Correlation Test was used to determine the correlation between mean scores on the paper and pencil MRT and MRT Computer. A (xy-value of .777 indicated the paper and pencil MRT was positively correlated to the MRT Computer. The (2xy .60 indicates 60% of the variance in the paper and pencil MRT was related to the variance in MRT Computer.

Hypothesis 2 was tested using a paired sample T test within Phase 1B, at a level of significance equal to .05. Table 4 shows the T-value was calculated at 2.198and a critical T of 2.145 (T.025,(.05)) was needed to reject the Hypothesis 2 at the .05 level. There was a probability of .045 that the differences observed between the subjects times on the paper and pencil MRT and the MRT Computer occurred by chance alone. Null Hypotheses 2 was rejected at the .05 level. Therefore, there was a significant difference on Phase 1B between time required to complete the paper and pencil MRT and MRT Computer.

Phase 2

Phase two was conducted to compare the MRT Computer and MRT Memory tests. Hypothesis 3 was tested using a paired sample T test within Phase 2, at a .05 level. The T value was calculated at 2.142. A critical T of 2.0 (T.025,(.05)) was needed to reject the Hypothesis 3 at the .05 level. There was a probability of .037 that the differences observed between the subjects scores (Figure 5) on the MRT Computer and the MRT Memory occurred by chance alone. Null Hypotheses 3 was rejected at the .05 level. Therefore, there was a significant difference on Phase 2 between scores on the MRT Computer and MRT Memory.

Table 6 shows a paired sample T test was used to test Hypothesis 3A, at a level of significance

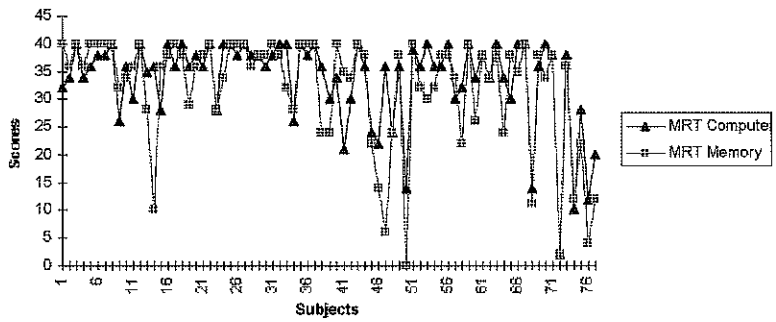

***Figure 5** Phase 2, Score distribution*

equal to .05. Null Hypotheses 3A was rejected because the results showed a P value of .000. Therefore, there was a significant difference between discrimination on the MRT Computer and MRT Memory.

Item difficulties for the twenty questions are shown in Figure 3. The mean difficulty for the MRT Computer was 0.82 while the mean difficulty of the MRT Memory was 0.73. The lower mean difficulty indicates lower scores on the MRT Memory.

The Pearson product moment formula was used to determine the coefficient of equivalence between mean scores on the MRT Computer and MRT Memory. The coefficient of equivalence was .77 indicating the MRT Computer was correlated to the MRT Memory.

The test of Hypothesis 4 using a paired sample T test, at a level of significance equal to .05, resulted in rejecting the null hypothesis as shown in Table 7. It was rejected because of the results showed a P value of .000.

Paired discrimination differences								
	Mean	Std. Deviation n	Std. Error Mean	95% Confidence Interval		t	df	Sig. (2-tailed)
				Lower	Upper			
P - RHO_PBIS	.1500	.1590	3.556E-02	7.557E-02	.2244	4.218	19	.000

Table 6

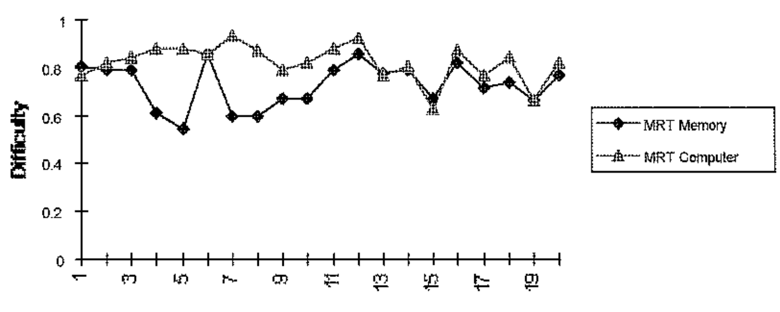

***Figure 6** Difficulty distribution*

Paired time differences									
	Paired Differences	Mean n	Std. Deviation	Std. Error Mean	95% Confidence Interval		t	df	Sig. (2-tailed)
					Lower	Upper			
Pair 1	**COMPUTER - MEMORY**	-1.6299	3.2958	.3756	-2.3779	-.8818	-4.339	76	.000

Table 7

Therefore, there was a significant difference between time required to complete the MRT Computer and MRT Memory.

Discussion

The primary purpose of this study was to establish if a computerized version of the MRT was a parallel test to the paper and pencil version of the MRT for spatial visualization. If the two forms of the test are parallel, can the computer be utilized to enhance the ability of the MRT to measure spatial visualization ability?

The results of this study indicate that a visuo-spatial working memory loading significantly impacts scores, completion times, and discrimination values on the MRT visualization test. These results would be expected if visuo-spatial working memory is a critical component of spatial visualization ability. The effect of adding any type of working memory component to spatial visualization testing has received very little attention within the engineering graphics related literature. Attention within the discipline to this oftentimes ignored and underutilized component of spatial visualization is the contribution of this study to the body of knowledge.

The results of Phase 1 revealed that the paper and pencil MRT and MRT Computer forms of the test resulted in similar test scores and were not significantly different. The scores between the pencil and paper MRT and the MRT Computer were significantly correlated. Based on scores alone, the pencil and paper MRT and the MRT Computer are parallel tests. The two forms of the test derive the same scores but the time required to complete the two forms of the MRT may not be similar. The difference in time may be attributed to one or more factors such as a group effect, learning effect, reporting methods, or perhaps an unidentified factor. While a time difference may exist, the relevance of the difference may be insignificant for a non-power test. The efficiency which may be lost in test completion time is more than made up for in test administration efficiency. Should the test be timed using Vandenberg's suggested time limit of six minutes, different scores might be expected.

The MRT Computer is recommended as an adequate test for spatial visualization among subjects in engineering graphics related disciplines. Because the MRT Computer is world wide web based, tracking of scores from multiple institutions would be simplified. Widespread use of this test would allow for comparisons of scores from other institutions and would enable educators to evaluate and improve their own curriculum.

The identification of a working memory component of spatial visualization ability can be supported. The addition of a visuo-spatial working memory component resulted in overall lower test scores on the MRT Memory test compared to the scores on the MRT Computer test. Discrimination values of the MRT Memory were significantly higher than the MRT Computer, indicating the MRT Memory may separate subjects with low ability from those with higher ability, more efficiently. The MRT Computer and MRT Memory forms of the test resulted in significantly different, but correlated, test scores. Subjects performed significantly lower on the MRT Memory test.

The addition of a visuo-spatial working memory component may be the cause of the lower scores and the greater time requirement needed to complete the MRT Memory test. The feedback from the spatial abilities survey supports the belief that the addition of a visuo-spatial working memory component is the cause of significantly different test scores and times. Many subjects stated the addition of a visuo-spatial working memory component made the test more difficult and they made references to the greater usage of short-term memory.

Because the literature identifies working memory as a vital component of spatial visualization ability a test which utilizes working memory such as the MRT Memory test should help in identifying students who are strong or weak in spatial visualization.

Recommendations

During the process of conducting this study and analyzing the data, the following recommendations were identified for future research. Based on the sample study, it may be possible to make inferences to the population of the study. There is a need to continue research in the area of spatial visualization and the effects of a working memory loading on it. The recommendations for future research are:

1. This study should be replicated using shorter time limitations, similar to Vandenberg's proposed time limitations.

2. The MRT Memory should be compared to other forms of tests for spatial visualization.

3. The use of a computer to improve existing tests has been illustrated. The addition of further subject interaction such as objects which can be dynamically rotated may improve the test further. The incorporation of true 3D objects into tests of spatial visualization may result in better tests to examine what is inherently a 3D process (CAD Modeling, orthographic projections, etc. ...).

4. Create tests of spatial visualization which are more "realistic". By reducing the abstractness of visualization tests through incorporation of 3D objects, application of materials to surfaces, or the use of true to life objects.

5. The adaptation of this test to computer adaptive testing practices would result in a generally accepted test, which could be used throughout the engineering graphics discipline to monitor and improve the curriculum.

6. The MRT Computer test should be used as a measure of spatial visualization in the engineering graphics discipline. Further research should be done to more adequately determine the role of the added visuo-spatial working memory component in tests of spatial visualization.

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The Effectiveness of Using the Successive Perception Test I to Measure Visual-Haptic Tendencies in Engineering Students

Nancy E. Study
Purdue University

Abstract

Since spatial abilities have been attributed to success in many fields including engineering, and visual-haptic learning styles have been shown to influence instruction of spatial tasks, it is important to have effective means of measuring these learning styles. Individually administered tests have proved both reliable and valid, but are time consuming to administer to a large population. Group administrable tests have had their reliability and validity questioned. The results of the group-administered Successive Perception Test I (SPT) for the study population of freshman engineering students were compared to their results on the group-administered Purdue Spatial Visualization Test: Visualization of Rotations (PSVT) and the individually administered Haptic Visual Discrimination Test (HVDT). In contrast with the theory that haptic subjects are not visual, the mean score for the population on the HVDT, a test of haptic ability, was one standard deviation above the norm, while 95% of the population scored as "visual" on the SPT. The test scores for the entire population on the SPT and HVDT were significantly positively correlated. These results suggest that either visual and haptic abilities are not mutually exclusive or the SPT score classifications of visual and haptic tendency are not appropriate for the population of freshman engineering students.

Introduction

Spatial visualization ability can be developed through instruction (Branoff, 1998; Deno, 1995; Gardner, 1983) and Miller (1992) found that learning style differences may influence an individual's performance on spatial tasks. These styles should be considered when creating materials designed to develop and enhance spatial abilities. Learning styles are usually identified by testing individual students, but individually administered tests can be time consuming and group administrable tests such as Lowenfeld's Test of Integration of Successive Impressions and the Successive Perception Test I have questionable reliability and validity (Miller, 1992).

Cognitive science has investigated spatial visualization abilities, the creation of mental images, and the coding of these images into memory. Some theorists hold that all information is ultimately represented verbally and others believe that information is coded both verbally and non-verbally depending on how it was perceived by the senses. The learning style of the subject, whether haptic or visual, also has an affect on how the visual information is coded. Haptic subjects rely predominantly on nonvisual sensory stimuli to orient themselves with their environment while visual subjects tend to prefer optical experiences to other sensory input (Lowenfeld, 1945). The use of different media can also affect the coding of information and with the increasing use of computer-based instruction and testing, it is important to assess their reliability and validity compared to traditional methods of testing and instruction.

Many tests in various formats have been developed to measure different aspects of subjects' spatial abilities without specifically testing their verbal abilities including the Purdue Spatial Visualization Test: Visualization of

In particular, the department has embarked on a plan that emphasizes downstream applications of solid modeling technology and includes the use of numerical manufacturing analysis, or finite-element-analysis (FEA). Teaching FEA to Technology majors can be challenging due to the competency and skill levels of students in that a relatively high theoretical knowledge base (particularly linear algebra, calculus, and material failure theories) is generally needed for understanding and applying FEA principles. In general, the exacting theoretical skills required to study and learn FEA in great depth are beyond the scope of technology majors. However, an introductory exposure to this powerful analysis tool can be accomplished through hands-on problem solving and application oriented projects (Cole, 1999; Logue & Hall, 2001). This paper describes the development of an FEA course in NIU's manufacturing engineering technology (MET) curriculum. In this paper, both the content and the methods used to instruct are discussed. In addition, the authors present the modules and design oriented projects which were utilized in this first generation course, and the outcomes which the students experienced after graduation based upon this course.

Motivation for Curricular Change

The Department of Technology at NIU enjoys a long history of successfully preparing graduates in engineering technology and industrial technology. The department has maintained an excellent relationship with the rich industrial base in the Northern Illinois region, and thus, in Year 2000, current members of the Industrial Advisory Board panel were invited to share perspectives on curricular revision and reform. Thus, the faculty members of the Technology Department and advisory members met at a joint session that reexamined objectives and desired outcomes of our undergraduate manufacturing engineering technology (MET) program.

The MET curriculum contained a blend of the traditional manufacturing skills such as the creation and interpretation of legacy 2-D drawings, metallic processes, non-metal processes, quality, metrology, plant layo work measurement and project manageme However, our graduates were lacking in t applications of computer-aided design, spec ically, the usage of solid modeling and eng neering analyses. In addition, the departme tal review of the program outcomes pointed an increased need for student instruction the area of automation processes, such vision, robotics, sensors, and plc's. Therefor the department embarked on a concert effort to augment our program in the areas computer and automation applications. One the implementations made in response to th departmental review was the inclusion finite element analysis (FEA) into the man facturing curriculum.

Why teach FEA in Engineering Technology?

Arguably, FEA is one of the more modern an visually powerful modes of engineering analy sis that has proven its utility in produc designs that address a wide array of huma needs ranging from agriculture to aerospac and sport to medicine (Boronkay & Dav 1997; Jensen & Pramono, 1998). Until a fe years ago, this powerful mode of analysis wa an exclusive tool, understood and used only b a select group of structural engineers. Toda FEA has evolved and continues to mature as logical downstream application of solid mod eling with new uses being discovered almos on a daily basis. The analysis is no longe restricted to expensive workstations running the UNIX operating system, instead very complicated analysis can now be completed from a wide variety of relatively inexpensive PC-based software packages (Jensen & Pramono, 1998).

Over the past decade, FEA has made significant new strides in technical problem solving and visual communication of design stresses (Robinson, 1994). Prior studies have supported that engineering technology graduates are expected to possess at least a working knowledge of FEA and be familiar with one or more related software packages (Boronkay & Dave, 1997; Logue & Hall, 2001; Szaroletta et al, 2001). Although embodying complex engineering analysis, FEA can be understood and appreciated by engineering technology students provided appropriate instructional techniques are invoked (Cole, 1999; Balamuralikrishna & Mirman, 2001).

The Implementation Challenge

The Department of Technology offers degree programs in the areas of engineering technology (electrical and manufacturing options) and industrial technology. Having decided that the Technology department should embrace FEA as a downstream application of CAD, the fundamental questions that needed to be addressed at the beginning were:

a. Who will be the target audience that will be introduced to FEA techniques?
b. How can FEA be presented to the audience to satisfy the desired goals?

The target group selected was the manufacturing engineering technology (MET) majors as opposed to industrial technology (IT) majors. As will be explained later, MET majors are required to complete more rigorous Mathematics and Engineering Mechanics requirements and hence better prepared to understand FEA as a problem solving tool. The second question addressing "how to" was much more difficult to answer and the rest of this article essentially elaborates on this issue. Intuition, past experiences in teaching and conducting FEA projects, and suggestions provided by peers in the discipline served as the basic guidelines in developing a strategy for teaching (Mirman & Tym, 1998). A practice-based curriculum was preferred in contrast to "theory-based" or "strong fundamentals" approaches (Hansen, 1998; Logue & Hall, 2001).

Based upon the program structure and the employment potential, the broad learning objectives for this FEA course were:

- Simple analysis
- Complex analysis
- Knowledge of FEA on-line support to permit self-learning
- Knowledge of FEA to interact with vendors
- Knowledge of available FEA analysis techniques

The authors decided that the proposed FEA course would initially be offered as a manufacturing elective, specifically, as Tech 497 (Special Topics in MET ñ Manufacturing Analysis). Following the successful implementation of the pilot course on FEA, the Department would alter the curriculum to include Manufacturing Analysis - FEA as a course which is required of all MET students.

Establishing the Content and Structure of the Course

Teaching finite element analysis can pose considerable challenges in terms of both selection of content and methods used to deliver instruction. The treatment of subject matter in engineering programs tends to be mathematical with more emphasis placed on theory where it usually takes weeks before the students are exposed to practical problems. At the other extreme, the authors were aware of courses where FEA was covered in a rather cursory manner, involving nothing more than a Microsoft PowerPoint slide show, covering the subject matter in very general terms. Both these extremes have very limited potential in terms of helping students with restrictive backgrounds in mathematics and mechanics of materials such as students majoring in Technology. Limited documented experiences that relate to the teaching of FEA specifically in technology degree programs have favored a middle-of-the-road practical approach with emphasis on the use of software tools in real world problem solving situations as opposed to the derivation of mathematical equations and relations (Cole, 1999; Logue, 2001).

In any advanced course, the student's prior preparation, and their ability to both comprehend the presented material and integrate that

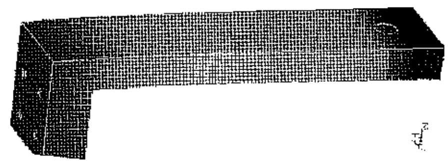
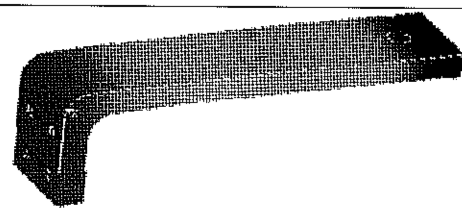
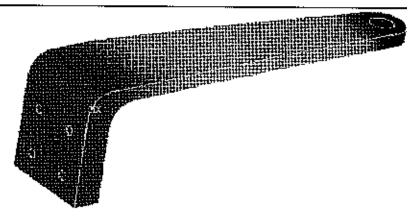
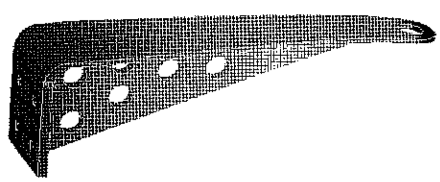
Iteration	3-D Solid Model of Part
# 1	
# 2	
# 3	
# 4	

Figure 9 *Solid models of design project 2 iterations*

Results

At the start of this course, the authors were not certain of the outcome. FEA using any software program is computationally intensive, hence the hardware and network capabilities of our computer laboratory were tested to the maximum. Computer system crashes occurred at regular intervals while the course was in session, however, the students excelled, and thoroughly enjoyed the new concepts which were covered in this course. In fact the students enjoyed the concepts so much that they spent extra hours in the lab working on homework and the projects, and far exceeded the requirements which were placed on them. Since then, our computers and network have been upgraded and the students' reaction to learning FEA is now even more positive. It was interesting to note that our students' positive experience with the FEA course much resembled the observations reported by Logue & Hall (2001) in working with their students. The modules which were introduced in this initial class worked very well, and the students took time to learn the concepts and use the knowledge in design projects.

The use of the two design projects served as a focal point of the course. The projects integrated the various topics that were introduced during the lecture/lab sessions. The instructors realized that this activity was successful in instilling confidence among the students, and they were inspired to think in terms of more complex projects. In fact one of the students used the concepts on his senior project.

Several of the students in the class where hired by regional companies where they are either using FEA in a design capacity or they interface with vendors who present data developed with FEA. During the departmental advisory board meeting, the members emphasized the need to include this course permanently in the curriculum. Within the next year, this course will be taught again, to the same level of students, and then it will be added to the curriculum.

Conclusion

The need for continuous reengineering of the curriculum is particularly relevant in this era of downsized engineering staff and industry's desire to reduce costs in a globally competitive economy. Generally speaking, employers would prefer to recruit a multi-functional graduate rather than hiring several other employees having limited individual skills. Many industries continue to address the challenges of compressed product life cycle and development times. Similarly, in an era of explosion of knowledge educators have to teach more and students have to learn more without extending the duration of a typical four-year undergraduate program. Creativity, innovation and experimentation are the vital keys in discovering new approaches that enhance efficient and effective preparation of engineering and technology graduates (Lunt & Helps, 2001).

By nature, engineering technology majors are keen on witnessing practical applications of concepts very early on in the learning process; this inherent characteristic of the target student audience was exploited in introducing a FEA course in the Technology department at Northern Illinois University. Although deeply rooted in theory and computations, FEA can be taught in a manner that emphasizes its practical utility. The authors experiences teaches that it is not necessary for students to go through an entire sequence of courses in structural analysis to develop a significant working knowledge of FEA. It appears that a number of technology programs have not embraced this topic due to the complex nature of subject matter. Our experience has proved to be positive and should encourage interested others to initiate similar activities in the design component of their academic programs.

The skills required to export/import solid models and prepare them for use in a finite element module are fast becoming an important required skill for engineering technology graduates. The ability to use one or more popular FEA packages (such as ANYSYS, COSMOS, Nastran, and DESIGNSPACE) and interpretation of stress plots are useful skills that increase the employability of technology graduates who desire to work in the CAD area. Higher compensation, variety, and more challenging job assignments are some of the rewards that could well be on its way to technology majors who learn basic engineering analysis. The students who completed our new course in manufacturing analysis (FEA) gained significant skills in modeling FEA geometry, performing required analysis, and interpretation of results. The industrial advisory board applauded our decision to promote engineering analysis in the Technology curriculum, and concurred that this change provided our majors with a desirable edge over competing graduates coming from similar departments based at other universities.

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Appendix I

Rating form for GIT 439 Technical Publishing

Purpose: This form is used to give you the opportunity to rate the contributions of yourself and your fellow team members. The results will be used to determine each individual's performance grade. This page will not be shared with anyone else on the team, so think carefully and be open and honest with your evaluations. Evaluate each person in your group and rate them on a scale of 1 to 5 in each of the categories. Five means 'top notch" this person was really good in this area. One means that the person hardly performed in this area.

A. Quality of work - Value and quality of contributions, suggestions, opinions, ideas
B. Quantity of participation - Sharing of responsibility, willingness to do his/her share of the work, prepared for meetings
C. Timeliness - Attendance at meetings, classes and work sessions. Met deadlines, had work finished and ready on time,
D. Level of work - Final work was professional and ready to be used.
E. Contribution to the group (in percent). The total for this must add up to 100%

	A	B	C	D	E
Team member	quality	quantity	timeliness	level	contribution %
1. Kelly	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	*_____
2. Joe	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	*_____
3. John	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	*_____
4. Steven	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	*_____
5. Cheng K	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	*_____

* *total for all five must = 100%*

Give a brief written evaluation of yourself and each team member. Explain problems, conflicts, and confrontations as well as great work, leadership, willing to pick up slack etc. If you gave someone a 1 or 2 please explain why.

1. Kelly

2. Joe

CAD Interoperability

David Kelley
Purdue University

Abstract

Computer-aided design systems (CAD) are the tools of choice for communicating product design intent. The ability to vertically and horizontally share CAD data is an increasing concern for original equipment manufactures. This paper explores issues related to CAD interoperability and emerging technologies that are influencing the ability to share CAD data. CAD interoperability methodologies are detailed and discussed.

Introduction

Competition and increasing demands from consumers for product customization necessitates the timely sharing of product data throughout organizational design structures. Likewise, modern approaches to design and manufacturing dictate the sharing of data concurrently in an environment that facilitates communication and information flow. Computer-aided design (CAD) applications are the tools of choice for communicating product design intent. Correspondingly, the ability to share CAD data is extremely important during product design and manufacturing. With the exception of small, less complicated products, original equipment manufactures (OEM) usually outsource at least some of the components or sub-parts of a design. In an ideal world, companies that manufacture various components of an end-product would be able to seamlessly transfer CAD data up and down the organizational structure. Unfortunately, there is no established standard for CAD model formats. Due to this, the interoperability of CAD systems is a major concern within manufacturing industries.

This paper explores issues related to CAD interoperability and emerging technologies that are influencing the ability to share CAD data. This topic is important for industry professionals, students, and other individuals that have to use CAD models throughout design and manufacturing processes. This paper will discuss sources of interoperability problems and possible solutions to these problems.

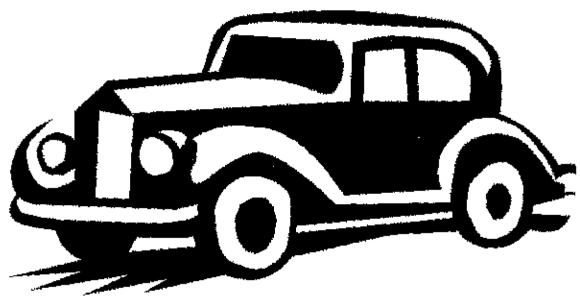
Interoperability Issues

There are two categories of CAD interoperability: inter-company and intra-company. Inter-company CAD interoperability relates to the need to share CAD data between companies that represent different levels of components within a design. OEMs typically have first tier companies that produce major subcomponents of their design, while first tier companies have sub-tier supplies that produce even smaller parts and sub-assemblies. As an example, Textron-Lycoming, a first tier company, might provide power plants for new Piper single engine aircraft. In turn, Lycon Aircraft, a sub-tier organization, might supply pistons to Lycoming. It is possible that companies within this structure, or any other similar relationship, might use different CAD systems (such as CATIA, Pro/ENGINEER, and AutoCAD), making the ability to share model data difficult (see Figure 1).

The automotive industry is another good example where inter-company CAD interoperability is an issue. According to a recent study (Brunnermeier & Martin, 1999), CAD interoperability issues and problems cost automotive companies a combined $1 billion per year. Before the 1980s, the automotive manufacturing process was based on mass production utilizing a sequential linear design process with little outsourcing of components (Womack, Jones, & Roos; 1991). Quality movements of the 1980s and 1990s, especially concurrent engineering and lean manufacturing philosophies, focused on the reduction of manufactur-

[2003 EDGD Design Contest]

Unlike the precisely propelled projectiles of the past, this contest is earthbound... in fact you will lose points if the project leaves the ground. The contest is to see which team can design an air-powered car that traverses a 50' long x 8' wide serpentine course. The car will earn points by passing thru gates that are slightly offset from a straight line in a gently curving serpentine. Extra points will be granted if the car is able to demonstrate a controlled 360° spin at the start or along the course. Power for the car must be self-contained and is limited to 4 AA batteries.



For safety, the propeller must be guarded and the vehicle may not leave the ground. Past experience with spinning propellers tells us to have plenty of Band-Aids handy, but the students love the project anyway.

A new wrinkle for us from previous years... For the 2003 contest, points will added for the design aesthetics. So get out the spray paint, heavy chrome, and whitewall tires to make yours a real showpiece. Major points will still come from the graphics and written report that is submitted.

Information will be posted on the EDGD contest web page this summer along with the names of the four, $500 scholarship winners from this year. If this source is not convenient, please feel free to contact contest coordinator, Dr. Jerry Vinson at 979-845-1633 or email him at "vinson@entc.tamu.edu".

Watch those fingers...
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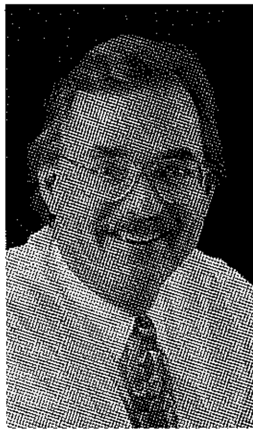

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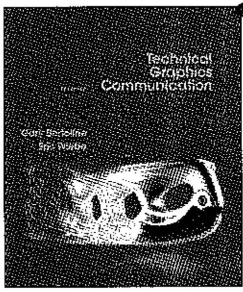

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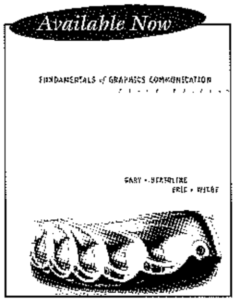

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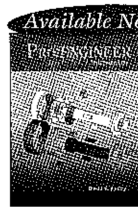

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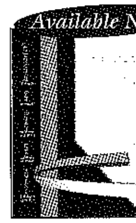

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