THE ENGINEERING DESIGN GRAPHICS JOURNAL

ENGINEERING DESIGN GRAPHICS DIVISION ASEE

AUTUMN 1995
VOLUME 59
NUMBER 3

ENGINEERING DESIGN GRAPHICS DIVISION
AMERICAN SOCIETY FOR ENGINEERING EDUCATION

Textbooks currently available:

General Engineering
Engineering Graphics Workbook
An Introduction to Engineering Design

Rapid Prototyping
An Introduction to Rapid Prototyping
Rapid Prototyping Using the JP System 5

C Programming
An Introduction to Programming Using SilverScreen

SilverScreen - Introductory Level
Getting Started with SilverScreen
Computer Aided Design Using Solid Modeling
3D CAD & Solid Modeling Using SilverScreen

SilverScreen - Advanced Level
Animation, Presentation and Analysis Using Solid Modeling

Forthcoming Textbooks:

(The following books offer an introductory level of coverage of their respective topics.)

EXCEL for Engineers
SilverScreen for Engineers
AutoCad for Engineers

Please contact Stephen Schroff to receive examination copies of the above books.

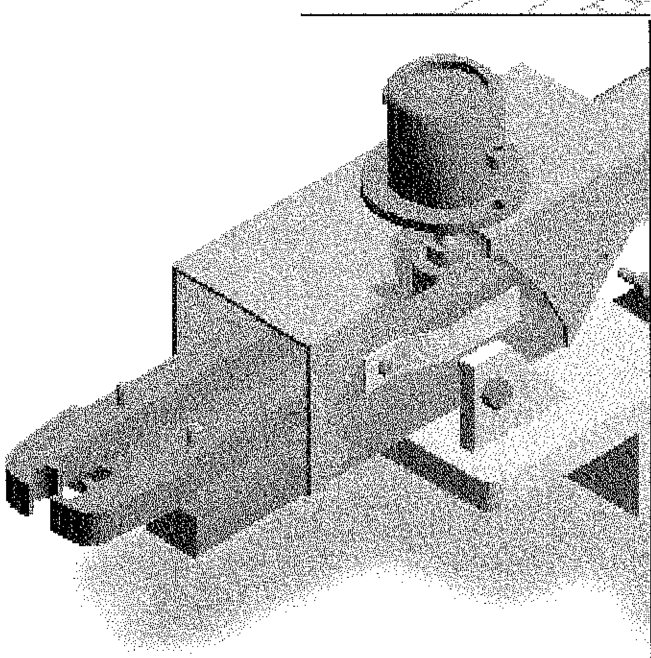
SCHROFF DEVELOPMENT CORPORATION
5424 Martway Drive
Mission, KS 66205
(913) 262-2664

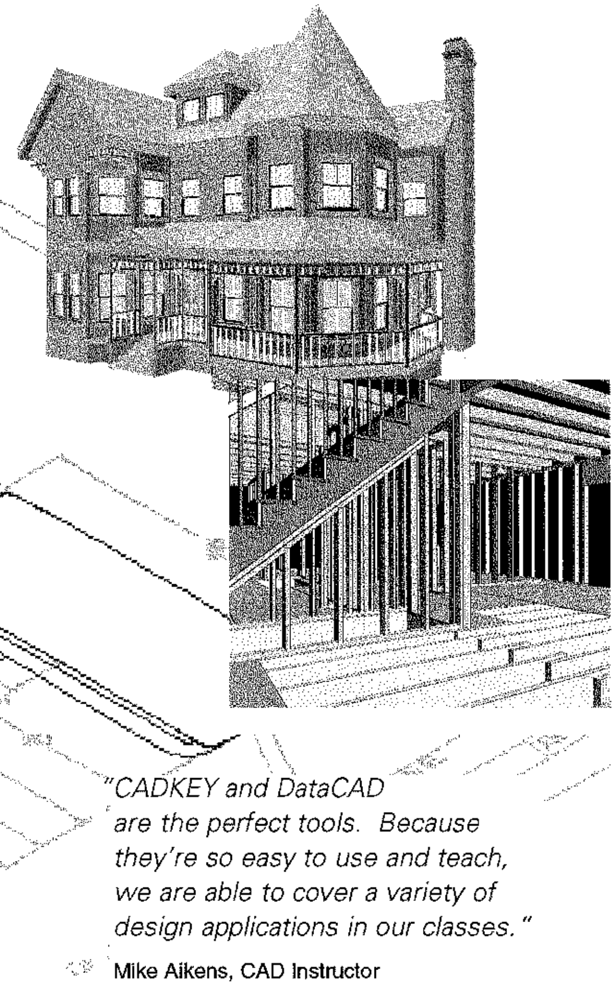
P.O. Box 1334
Mission, KS 66222
FAX (913) 722-4936

CADKEY® & DataCAD®
Winners by Design

"Being knowledgable in both AutoCAD® and CADKEY, Ryan chose CADKEY to earn the 1st Place Gold Medal."

Mark Platt, Drafting/CAD Instructor
and VICA Advisor to Ryan Mulder,
Post-secondary winner of the
1995 National VICA Technical
Drafting Competition.





"CADKEY and DataCAD are the perfect tools. Because they're so easy to use and teach, we are able to cover a variety of design applications in our classes."

Mike Aikens, CAD Instructor
Butler County Community College

CADKEY gives you the 3D modeling and drafting tools you need to bring innovative mechanical design to life.

DataCAD, designed by architects for architects, gives you powerful 3D CAD capabilities for all commercial and residential applications.

Ask about our new and exciting
EDUCAD America Discount Program

Call 1-800-338-2238

CADKEY

EDGD
ENGINEERING DESIGN GRAPHICS DIVISION
A S E E

THE ENGINEERING DESIGN GRAPHICS JOURNAL

Volumn 59 Number 3 Autumn1995

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.

ISSN 0046 - 2012

Congratulations are in order for the newly-elected Engineering Design Graphics Division officers for 1995-96. They are:

Division Chair: Mary J. Jasper
Mississippi State University
Phone: 601-325-3923
email: jasper@engr.msstate.edu

Vice Chair: Gary R. Bertoline
Purdue University
Phone: 317-494-4585
email: grbertol@tech.purdue.edu

Director of Programs: F. D. "Fritz" Meyers
The Ohio State University
Phone: 614-292-1676

Director of Liaisons: Holly K. Ault
Worcester Polytechnic Institute
Phone: 508-831-5498
email: hkault@wpi.wpi.edu

Each of these people would welcome your interest or your suggestions. Offer to serve on a committee, help with a conference or program at a conference. Remember, it is your Division. You only get as much out of it as you put into it. Your involvement is welcome.

Thanks to Judy Birchman, Technical Editor of the Journal, we now have an *Engineering Design Graphics Journal* Home Page. The address for all of you electronic surfers is:

http://www.tg.purdue.edu/edgd

You can get a preview of what the opening screen looks like if you turn to page 37 of this issue. After perusing it to your heart's delight, feel free to contact either Judy or myself with suggestions or additions. We will try to keep it as current as possible.

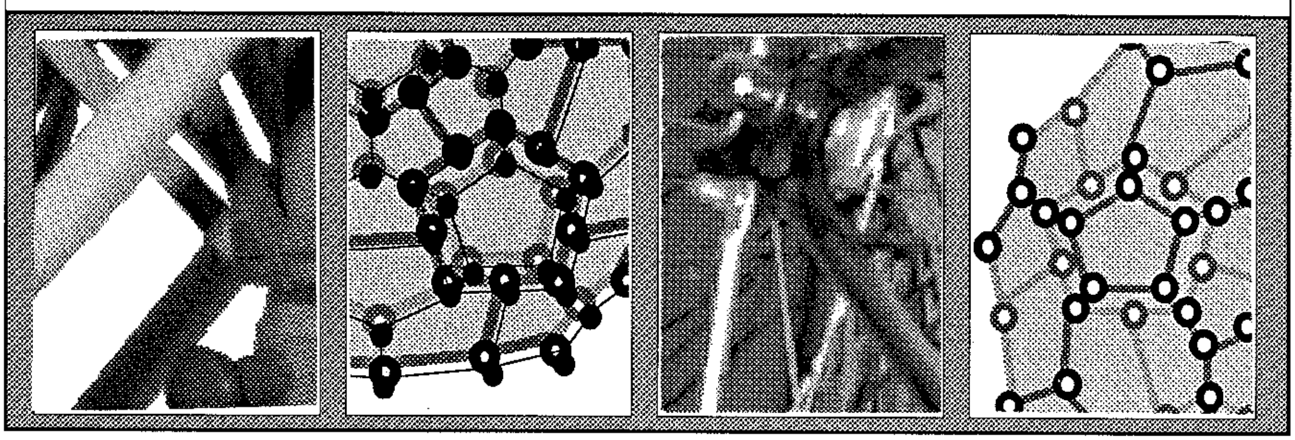
Judy is currently putting together the design and information for the Engineering Design Graphics Division Home Page. It will have a link to the *Journal*, so you will be able to find it as soon as we put it out there in space. Once again, we welcome your suggestions and information.

Mary A. Sadowski

Contents

PAPERS

EDG NEWS



Coming in December!

Autodesk® Press

Full-function Autodesk software plus design-driven exercises & projects for students, faculty, & staff.

Three special "LINKS" packages—containing Autodesk software and design-driven texts—give your students the tools and instruction they need to produce professional-quality engineering designs, projects, and visualizations:

for engineering design graphics courses

LINKS TO DESIGN GRAPHICS & SOLID MODELING: AutoCAD® Release 12

PACKAGE INCLUDES:
- AutoCAD Release 12 (DOS and Windows 3.1), AME 2.1 (DOS and Windows 3.1), AutoVision 1.0 (Windows 3.1), AutoVision 1.01 (DOS), and AutoSurf 2.0 (DOS), on MS-DOS CD-ROM
- Stewart/Bolluyt/Oladipupo, MODELING FOR DESIGN USING AUTOCAD 12, AME, AND AUTOSURF
- Duff/Ross, FREEHAND SKETCHING FOR ENGINEERING DESIGN

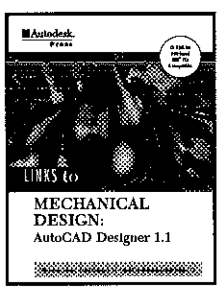
Order #: 0-534-95629-7; $249.95 suggested list price

for engineering graphics, art, graphic design, and architecture courses

LINKS TO PRESENTATION GRAPHICS: 3D Studio® Version 3

PACKAGE INCLUDES:
- 3D Studio Version 3 (supports file sizes to 25,000 vertices, with instructions on how to combine files to create larger designs), on MS-DOS CD-ROM, plus World-Creating Toolkit™ CD-ROM
- Reference Manual, Installation Guide, and Tutorial
- Duff/Ross, MASTERING 3D STUDIO
- Bousquet, 3D STUDIO TECHNICAL TIPS

Order #: 0-534-95126-0; $149.95 suggested list price



for mechanical engineering and design

LINKS TO MECHANICAL DESIGN: AutoCAD Designer® 1.1

PACKAGE INCLUDES:
- AutoCAD Designer 1.1 (DOS), on three MS-DOS disks
- Howell, INTRODUCTION TO AUTOCAD DESIGNER

Order #: 0-534-95630-0; $69.95 suggested list price

Above packages may be ordered by accredited students, teaching faculty, and staff through their college bookstore. **Note to bookstore managers**: To place bookstore orders, call International Thomson Publishing Customer Service at 800-487-5510.

For more information, please contact:
Nathan Wilbur, Market Development Manager,
PWS Publishing Company, 20 Park Plaza, Boston, MA 02116.
Tel: 617-348-8148; Fax: 617-338-6134
Email: nathan_wilbur@pws.com

Autodesk Press & PWS Publishing Company are divisions of International Thomson Publishing.

The Relationship of Previous Experiences to Spatial Visualization Ability

John A. Deno
Department of Industrial Technology
Ohio University
Athens, Ohio

Abstract

This study examined whether variations in performance on a measure of spatial visualization were related to prior spatial experiences, and to the developmental period when the prior experiences occurred. Analysis was conducted to determine whether specific experiences discriminated among subjects on the basis of spatial visualization ability.

The sample, consisting of 324 men and 72 women enrolled in a beginning engineering graphics course at The Ohio State University, were administered the Mental Rotations Test (MRT) and a Spatial Experience Inventory (SEI). The SEI subscales of formal academic courses, non-academic activities, sports, and developmental period served as predictor variables in this research. The main statistical approach used in this study examined variability in performance on the MRT.

The findings revealed that non-academic activities had the most positive significant relationship to spatial visualization ability for men, but not for women. It was also found that non-academic activities differentiated men when grouped by spatial ability and that experiences during high school accounted for the most variance in spatial ability.

Building activities differentiated between high and low spatial ability groups for men and women. Courses taken in junior high school using hands-on laboratory-based activities such as metalworking and manufacturing significantly differentiated women when grouped by spatial ability.

A significant sex-related difference in performance on the MRT was also found in this study.

Further experimental, causal-comparative, and longitudinal research using the findings of this study should be very useful in the design of curricula to enhance spatial ability.

correlations of the Mental Rotations Test with other tests using samples of 456 and 5,435 individuals tested in Hawaii range from r=.36 for the Elithorn Mazes Test, to r=.68 for the Identical Blocks Test (Vandenberg & Kuse, 1979). Vandenberg and Kuse also point out that the Mental Rotations Test was most often associated with other tests of spatial visualization and, in general, showed only low correlations with tests of verbal ability.

The Spatial Experience Inventory (SEI) was developed by this author by compiling a list of previously validated spatial activities from research formerly done at Purdue University (Guay, 1977, Guay and McDaniel 1979, 1982, and McDaniel, Guay, Ball, and Kolloff, 1978), Pennsylvania State University (Newcombe, Bandura, and Taylor, 1983) and University of Maryland (Olson, 1985).

The SEI, containing 12 categories or stages of life experiences with 480 spatial activities, was developed for use in two pilot studies conducted to determine which activities should be included in the final version of the Spatial Experience Inventory.

The final version of the SEI was administered using a computer answer sheet and scored electronically. Each activity item had four choices:

- ***(a) Frequently participated in the activity, scored as a 4,***
- (b) Occasionally participated in the activity, scored as a 3,
- (c) Seldom participated in the activity, scored as a 2, and
- (d) Never participated in the activity, scored as a 1.

Each formal academic subject item also had four choices:

- (a) Have taken more than two courses in this subject, scored as a 4,
- (b) Have taken two courses in this subject, scored as a 3,
- (c) Have taken one course in this subject, scored as a 2, and
- (d) Have never taken a course in this subject, scored as a 1.

The developmental time period, in which each activity was experienced, was also recorded and tabulated by dividing the SEI into five separate sections representing five different time periods, each containing a list of activities and academic courses appropriate for that time period. The five time periods were:

- (a) pre-school,
- (b) elementary school,
- (c) middle or junior high school,
- (d) high school & vocational school, and
- (e) postsecondary.

The subjects were asked to indicate the frequency of participation for each activity and academic course in each time period.

The time periods were further broken down into sub-scales describing the type of spatial experience, which made a total of 10 time period sub-scales. The Pre-School time period was sub-divided into two sub-scales: Pre-School Demographics (6 Items) and Pre-School Activities (12 Items). The Elementary time period was sub-divided into the Organized Activity scale (8 Items) and the Non-organized Activity scale (11 Items). The Junior High School time period was further divided into the Formal Academic Subjects scale (12 Items), the Non-academic Activities scale (55 Items), and the Sports scale (45 Items). The High School time period was divided into the same three scales into which the Junior High time period was divided, the Formal Academic Subjects scale (12 Items), the Non-academic Activities scale (55 Items), and the Sports scale (45 Items). The Postsecondary time period included only Formal Academic Subjects in a technical college or a university (39 Items)

The main predictor variables of the SEI were Formal Academic Subjects, Non-Academic Activities and Sports. The Formal Academic Subject Scale was tabulated by summing the Formal Academic Subject sub-scales found in the Junior High School period, the High School period, and the Postsecondary period, for a total of 81 items. The Non-Academic Activities scale was tabulated by summing the Pre-School Activities sub-scale, both the Elementary Organized and Non-Organized Activities sub-scales, and both the Junior High School and the High School Non-Academic Activities sub-scales for a total of 141 items. The Sports scale was tabulated by summing the Junior High School Sports sub-scale and the High School Sports sub-scale for a total of 90

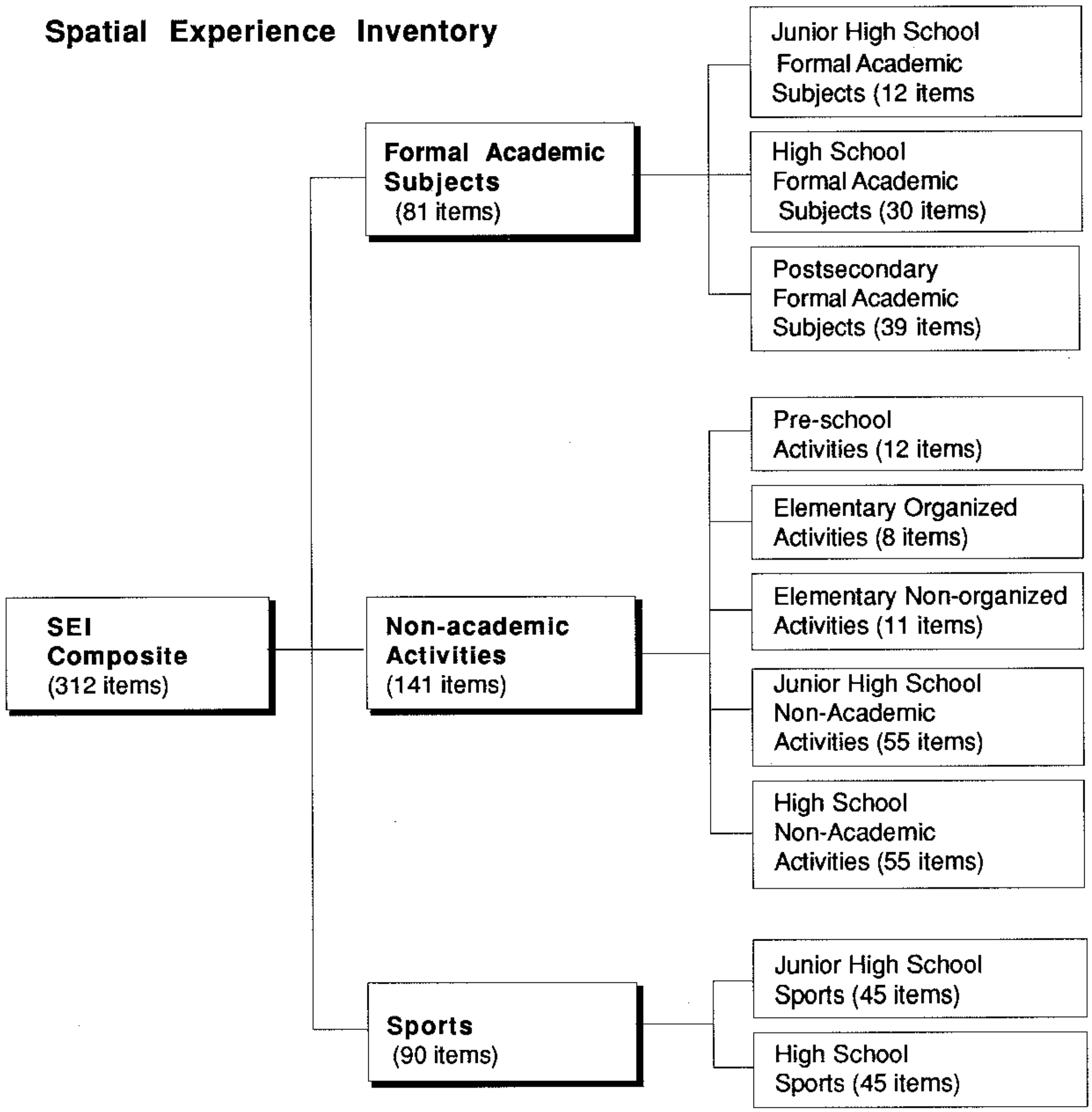


Figure 1. Layout of Spatial Experience Inventory

items. The Composite or total score of the SEI was tabulated by summing the three main variables: Formal Academic Subjects, Non-Academic Activities and Sports for a total of 312 items. The Demographics subscale in the pre-school period did not contribute to the score of any main variable but was used separately for correlational analysis.

To aid the reader in comprehending the complex design of the SEI, Figure 1 graphically shows the layout of the SEI displaying the three main variables and the sub-scales from which they are tabulated.

Data Collection

The data were collected by the administration of two instruments, the Mental Rotations Test (MRT) developed by Steven G. Vandenberg and Allan R. Kuse and the Spatial Experience Inventory (SEI) developed by the researcher. The MRT and the SEI were administered personally by the researcher and taken voluntarily by 396 beginning engineering and technology students enrolled in the course Engineering Graphics & Problem Solving (Engineering Graphics 166) during the first and second week of the Winter Quarter, 1993, at the Columbus, Ohio, campus of The Ohio State University. The 396 students were made up of 324 men and 72 women.

Data Analysis

The means, standard deviations and variance on scale items for all the independent and dependent variables were calculated. ANOVA's were used to test for statistical significance of group mean differences.

Reliability analysis was conducted on the SEI. Cronbach's alpha coefficients were computed for all the instrument scales and for the composite score.

Correlation analysis was conducted using Pearson Product-moment correlations between predictor variables and spatial measures. Multivariate regression analysis was conducted with the effects of all predictors and spatial criteria examined simultaneously. All the analyses were done on the total sample and on the sample divided by spatial ability, determined by the top and bottom 50% scores on the MRT, and sex.

Results of the Study

Cronbach's Coefficient Alpha, a measure of internal consistency was used to analyze the reliability of the composite and the separate scales of the predictor variables on the SEI for the total sample by spatial ability group.

Table 1 shows that the alpha coefficients obtained for the composite, and the various scales of the SEI, were highly reliable for the total sample and by spatial ability group.

Table 2 shows that all the sub-scales of the Developmental Period scale had adequate levels of reliability for a research instrument with the exception of the Elementary Organized Activities scale.

Findings and Discussion

The relationships between spatial visualization ability and the main predictor variables were analyzed by calculating the Pearson product-moment correlation between the score of the measure of spatial visualization ability (MRT) and the composite and the

Table 1.
Reliablity Analysis of the Spatial Experience Inventory (SIE): Cronbach's Coefficient Alpha for the Total Sample and for Spatial Ability Groups.

Cronbach's Coefficient Alpha			
SEI Scales	**Total Sample** *n=396*	**Low Ability** *n=209*	**High Ability** *n=187*
Composite *312 items*	.9651	.9714	.9572
Formal Academic Subjects *81 items*	.9475	.9371	.9543
Non-academic Activities *141 items*	.9432	.9568	.9205
Sports *90 items*	.9337	.9398	.9278

three spatial experience variables, (a) Formal Academic Subjects, (b) Non-academic Activities, and Cc) Sports, which were measured by the SEI for the total sample and by sex group. These coefficients are displayed in Table 3.

Table 4 shows the correlation coefficients of sub-scales of the fourth variable, Developmental Time Period, that were significantly correlated.

For the total sample, the composite, which is the summation of the three sub-scale scores, and two of the three variables displayed on Table 3 had significant positive correlations with the exception of Formal Academic Subjects, which was negative. Also for the total sample, two of the Developmental Time Period sub-scales, displayed on Table 4, had significant positive correlations. The SEI composite score for the total sample had a correlation of r=.09 (p<.05). Non-academic Activities had the highest and most significant correlation for the total sample (r=.12, p<.01) with Sports having the only other positive significant correlation of r=.08 (p<.05).

The correlational analyses for the men were similar to those for the total sample. The highest and most significant correlation of the main predictor variables was Non-academic Activities with a coefficient of r=.12 (p<.01). The men also had a positive and significant correlation for High School Non-academic Activities (r=.13, p<.01), like that of the total sample but failed to have a significant relationship at the junior high time period.

There were no significant relationships observed between the MRT score and any of the main predictor variables for women.

In order to find out what type of academic subjects, activities, sports, and work-related experiences encountered by the subjects have a significant relationship with the subjects' level of spatial visualization ability, a more micro analysis was conducted. This analysis was done by looking at the Pearson product moment correlation between the measure of spatial visualization ability (MRT) and each item or

Cronbach's Coefficient Alpha			
Developmental Period Scales	**Total Sample** *n=396*	**Low Ability** *n=209*	**High Ability** *n=187*
Pre-School Activities *12 items*	.6840	.7006	.6777
Elementary Organized Activities *8 items*	.5494	.4920	.5933
Elementary Non-Organized Activities *11 items*	.6855	.7321	.6532
Junior High Formal Academic Subjects *12 items*	.7843	.7700	.7972
Junior High Non-academic Activities *55 items*	.8952	.9185	.8622
Junior High Sports *45 items*	.8753	.8886	.8635
High School Formal Academic Subjects *30 items*	.8714	.8645	.8777
High School Non-academic Activities *55 items*	.9034	.9245	.8683
High School Sports *45 items*	.8812	.8879	.8746
University & Technical College Formal Academic Subjects *39 items*	.9465	.9391	.9507

Table 2. Reliability Analysis of the Developmental Period Sub- Scales of the SEI: Cronbach's Coefficient of Alpha for the Total Sample and for Spatial Ability Groups

Cronbach's Coefficient Alpha			
SEI Scales	**Total Sample** *n=396*	**Low Ability** *n=209*	**High Ability** *n=187*
Composite *312 items*	.9651	.9714	.9572
Formal Academic Subjects *81 items*	.9475	.9371	.9543
Non-academic Activities *141 items*	.9432	.9568	.9205
Sports *90 items*	.9337	.9398	.9278

Table 3 Correlation Cooefficients Between Scale and Composite Scores on the Spatial Experience Inventory and Mental Rotations Test (MRT) for the Total Sample and by Sex Group

Mental Rotations Test (MRT)			
Developmental Period Scale	**Total Sample** *n=396* r	**Males** *n=324* r	**Females** *n=72* r
Elementary Organized Activities *n=8 items*		.10*	
Elementary Non-organized Activities *n=11 items*		.12*	
Junior High Non-academic Activities *n=55 items*	.12**		
High School Non-academic Activities *n=55 items*	.14**	.13**	
Note. * p<.05 ** p<.01			

Table 4 Significant Correlation Coefficients Between Developmental Period Scale Scores on the Spatial Experience Inventory (SEI) and Mental Rotations Test (MRT) for the Total Sample and by Sex Group

question of each of the 10 Developmental Time Periods of the SEI. Table 5 displays the Developmental Time Period sub-scale and the significant positive correlations of each time period for the total sample and by sex group.

An examination of the findings reveals that, of the Spatial Experience Inventory's (SEI) main predictor variables (i.e., Formal Academic Subjects, Non-academic Activities and Sports), Non-academic Activities (NONACAD) seemed to be the strongest predictor of spatial visualization ability, which was measured by the subjects' performance on the Mental Rotations Test (Vandenberg & Kuse, 1978).

The reliability for the Non-academic Activities scale of the SEI was extremely high (alpha = .94 for the total sample, alpha = .95 for men, and alpha = .93 for the women).

Non-academic Activities had the highest and most significant correlation with performance on the MRT for the total sample ($r=.12$, $p<.01$) and for men ($r=.12$, $p<.01$). There was a positive correlation between the women's score on this sub-scale and women's MRT scores ($r=.04$), but it was not statistically significant.

This finding is somewhat different from Olson's (1985) study in which she found *academic courses* to be the best predictor. However, Olson's study, at the University of Maryland, used a sample of 53 women and 45 men who were introductory psychology undergraduates, unlike the sample in the present study, who were 92% engineering majors.

Almost every major requires an introductory psychology course, the students of which will create a sample that is enrolled in several dissimilar programs, whereas an introductory engineering course consists of mostly students who have taken the same courses and therefore lack diversity. Olson's activity scale, which combined spatial activities and sports, did not correlate significantly with a measure of spatial ability that was derived from the same study (Shepard & Metzler, 1971) from which the MRT was developed. This was true for the total sample, as well as men and women sub-groups.

When performing correlational analysis on each non-academic activity item, a micro analysis approach shown in Table 5, the following items on the Preschool Activities subscale had significant positive correlations for the total sample: Played with Legos (.14, $p<.01$) and played with log building sets (.13, $p<.01$). For the men, the items that had significant positive relationships to their spatial visualization ability were: Played with Legos (.18, $p<.001$), played with log building sets (.13, $p<.01$), participated in art activities (.11, $p<.05$) and organized gymnastics (.10, $p<.05$). The women had significant positive correlations with watching educational TV (.25, $p<.05$) and watching *Sesame Street* (.26, $p<.01$).

In the Elementary School Non-Organized sub-scale, three items had significant relationships with MRT scores. For the total sample, playing with Legos (.17, $p<.001$) and repairing toys or bicycles (.17, $p<.001$) had significant positive correlations. The men had the same two, played with Legos (.19, $p<.001$) and repaired toys or bicycles (.09, $p<.01$) with the addition of *played with building blocks* (.14, $p<.01$). There were no significant positive item correlations for women in this developmental period.

If any one item stands out to have had a powerful influence or relationship to the spatial ability of men later on in life it seems to be playing with Legos. It was highly statistically significant at both periods of development ($p<.001$ for pre-school and elementary) and correlated higher than any other item in both periods.

In the Junior High School Non-academic Activities sub-scale for the total sample, items with $p<.001$ significance levels were: Repaired automobiles (.17), repaired equipment (.18), built race-car sets (.25), used power tools (.17), built train sets (.19), played with building sets (.25), and built models (.30). It seems that all building activities had a very strong relationship with the subjects spatial visualization ability when analyzing the total sample. The men had seven items in this developmental period that had significant positive correlations with their MRT score. Like the total sample analysis, all building type activities had significant correlations at the $p<.001$ level, (e.g., built race-car sets ($r=.18$), played with building sets ($r=.20$), and built models ($r=.20$). The women experienced two activities that correlated significantly and positively with their performance on the MRT (e.g., built train sets ($r=.30$), and navigated in car ($r=.28$).

Significant correlations between Non-academic Activities during the high school developmental time period and performance on the MRT, for the total sample, ranged from $r=.28$ ($p<.001$) for building models to $r=.09$ ($p<.05$) for assembling and/or repairing plumbing, using a compass and playing chess. There were 10 activities for the total sample that were at the $p<.001$ level, and again, as at the junior high school time period, all of these activities involved hands-on building or physically repairing things. The sole significant positively correlated high school non-academic activity for women was playing computer video games with a coefficient of $r=.28$ ($p<.01$).

Although previous studies did not investigate the time period in which spatial activities were experienced, these studies support the findings of the present study concerning spatial activities for men but not for women. This could be due to the measure of spatial ability used in the studies with the MRT discriminating against women more than the others, and the methods used to categorize high and low ability groups. One possible indication of the significant positive correlation between the amount of women's participation in video games and performance on the MRT is the learning style or processing style of women compared to that of men. It seems more visual forms of learning, such as educational TV, like *Sesame Street* at the Pre-School Developmental Period, and video games at the High School Developmental Period have more of an influence on women's spatial ability than the haptic style of learning, reported in Miller's (1992) study, that seems to correlate highly with men's spatial ability.

Table 5 Correlation Cooefficients Between Significant Item Scores on the Spatial Experience Inventory (SEI) and Mental Rotation Test (MRT) for the Total Sample and for Sex Groups

Mental Rotations Test (MRT)			
Item / Developmental Period	Total Sample (n=396) r	Males (n=324) r	Females (n=72) r
Preschool Demographics			
Stayed home with babysitter		.09*	
Preschool Activities			
QA7 Played with Legos	.14**	.18***	
QA8 Played with log building sets	.13**	.13**	
QA12 Watched educational TV			.25*
QA13 Watched "Sesame Street"			.26**
QA15 Participated in art activity		.11*	
QA18 Organized gymnastics		.10*	
Elementary School Non-Organized Activities			
QA30 Played with Legos	.17***	.19***	
QA32 Played with building blocks		.14**	
QA34 Repaired toys or bicycle	.17***	.09**	
Junior High School Formal Academic Subjects			
QA48 Manufacturing			.20*
Junior High School Non-academic Activities			
QA50 Repaired bicycles		.12**	
QA52 Repaired automobiles	.17***		
QA53 Repaired appliances	.15**		
QA54 Repaired equipment	.18***	.13**	
QA58 Built race-car sets	.25***	.18***	
QA62 Engaged in carpentry projects	.13**		
QA63 Construct/repair radios, stereo	.14**		
QA64 Sketched auto/vehicle designs		.16**	
QA65 Sketched house plans		.14**	
QA66 Used hand tools	.14**		
QA67 Used power tools	.17***		
QA74 Built train sets	.19***		.30**
QA77 Played with building sets	.25***	.20***	
QA79 Played computer video games	.10*		
QA81 Built models	.30***	.20***	
QA89 Tied various knots	.11*		
QA95 Read blue prints	.09*		
QA100 Operated machinery	.08*		
QA101 Created computer graphics	.11**		
QA103 Repaired motorcycles	.12**		
QA104 Navigated in car	.10*		.28**
Junior High School Sports			
QA105 Touch football	.16***		
QA106 Tackle football	.21***		
QA116 Archery	.15***	.13**	
QA117 Golf	.11**		
QA118 Hunting	.12**		

Item / Developmental Period	Total Sample (n=396) r	Males (n=324) r	Females (n=72) r
Junior High School Sports con't			
QA119 Target shooting	.16***		
QA120 Rock climbing	.10*		
QA121 Canoeing (shooting rapids)	.05*		
QA123 Skiing (slalom)	.16***	.18***	
QA131 Air hockey	.09*		
QA133 Softball		.10*	
QA138 Dodgeball	.14**	.09*	
QA149 Baseball	.18**		
High School Formal Academic Subjects			
QA163 Manufacturing technology	.05*		
QA164 Construction technology	.03*		
QA165 Mechanical drawing	.18***	.16***	
QA166 Architectural drawing	.11**	.11*	
QA168 Metal/metals technology	.10*		
QA174 Studio art (drawing)	.13**	.16***	
QA175 Studio art (painting)	.11**		
High School Non-academic Activities			
QB1 Repaired bicycles	.24***	.15**	
QB3 Repaired automobiles	.18***	.10*	
QB4 Repaired appliances	.14**	.11*	
QB5 Repaired equipment	.15**	.10*	
QB6 Remodeled a structure	.13**		
QB7 Built a structure	.14**		
QB9 Built race-car sets	.12**	.09*	
QB12 Assembled/repaired plumbing	.09*		
QB13 Engaged in carpentry	.21***	.15**	
QB14 Construct/repair radios, stereos	.18***	.11*	
QB15 Sketched auto/vehicle design	.18***	.15**	
QB16 Sketched house plans	.12**	.17***	
QB17 Used hand tools	.15***	.11*	
QB18 Used power tools	.21***		
QB20 Assembled electrical circuits	.16***	.11*	
QB25 Built train sets	.14**	.10*	
QB27 Used compass	.09*	.09*	
QB28 Played with building sets	.19***		
QB29 Played arcade video games	.10*		
QB30 Played computer video games	.10*		.28**
QB32 Built models	.28***		
QB40 Tied various knots	.11*	.10*	
QB41 Played chess	.09*		
QB46 Read blue prints	.15**	.13**	
QB52 Created computer graphics	.11*		
QB54 Repaired motorcycles	.10*		
High School Sports			
QB56 Touch football	.09*		
QB57 Tackle football	.17***		
QB68 Golf	.21***	.14**	
QB69 Hunting	.16***		
QB70 Target shooting	.14**		
QB71 Rock climbing	.11**		
QB72 Canoeing (shooting rapids)	.09*		
QB74 Skiing (slalom)	.17***	.18***	
QB100 Baseball	.12**		

Note: *p<.05 ***p<.01 ***p<.001

Conclusions

Of the main variables reported on the Spatial Experience Inventory (i.e., Formal Academic Subjects, Non-academic Activities and Sports) experiences in Non-academic Activities (NONACAD) seem to have the strongest relationship to spatial visualization ability, which was measured by the subjects' performance on the Mental Rotations Test (Vandenberg & Kuse, 1978). This, however, can only be stated for the men, for the correlation between previous non-academic experiences and spatial visualization ability was positive and statistically significant for men, but not for women.

Non-academic Activities experienced by men, in the High School Developmental Period, have the most positive and statistically significant relationship of any time period. The Elementary Developmental Period had the only other significant correlation between men's activities and spatial visualization ability, for both organized and non-organized activities.

The specific kinds of activities, during the preschool and elementary period, that had a positive statistically significant relationship to spatial performance for the men were experiences with building type toys such as playing with Legos, playing with log building sets and organized gymnastics. The women had significant positive correlations between spatial performance and activities that were more visual and less tactile such as watching educational TV and watching *Sesame Street*.

During junior high school and high school the frequency of the men's participation in all building type activities had high correlations and were significant at the $p<.001$ level with their MRT score (e.g., built race-car sets, played with building sets, and built models).

Also during the junior high school period, the frequency of the women's participation in more masculine type, tactile activities such as building train sets and navigating in a car had significant positive correlations with their MRT score. But the sole significant positively correlated high school activity for women was playing computer video games. Again it seems that experiences in visual activities have more of a relationship to spatial performance than physical activities for women.

Recommendations

Since this research demonstrated that differential patterns of experiences exist for the sexes, and for those grouped by spatial ability, and these experiences were correlated with performance on a spatial visualization test, then knowledge about these differences could be used to design interventions or develop training programs which facilitate spatial skills. Efforts in the design of curriculum materials for spatial skills seems warranted, particularly since such skills are correlated with performance in technical hands-on courses.

Building, constructing, repairing, and assembling type toys such as Legos should be investigated in future experimental research studies for possible implementation into the curriculum at pre-schools and elementary schools. Technology education at the elementary level can play a key role in this curriculum development.

Courses containing hands-on laboratory activities such as manufacturing technology, which differentiated women on the basis of spatial ability in this study, and also correlated with spatial performance, should be examined in future research to determine if participation in these courses causes an increase in spatial ability. If so, these courses should be recommended for all men and women, especially if their career plans include areas in engineering, technology or the physical sciences.

It is hoped that engineering and technology educators will continue research efforts in the area of visualization in order to build a substantial research base on the effects of hands-on laboratory-based activities and instruction on spatial visualization ability.

References

Arnheim, R. (1986). *New essays on the psychology of art*. Berkeley, CA: University of California Press.

Bertoline, G. R. (1988). The implications of cognitive neuroscience research on spatial abilities and graphics instruction. *Proceedings of the International Conference on Engineering Design Graphics*, Vienna, 1, 28-34.

Guay, R. B. (1977). Factors affecting the development of two spatial abilities basic to technical drawing. *Journal of Industrial Teacher Education*, 14(3), 38-43.

Guay, R. B., & McDaniel, E. D. (1979). *Toward explaining sex differences in spatial ability: An investigation of selected cultural and neurophysiological factors. Arlington, VA: Army Research Institute. for the Behavioral and Social Sciences.* East Lansing, MI: National Center for Research on Teacher Learning. (ERIC Document Reproduction Service No. ED 185 071)

Guay, R. B., & McDaniel, E. D., & Angelo, S. (1978, August). *Analytic factor confounding spatial ability measurement.* Paper presented at the annual meeting of the American Psychological Association, Toronto, Canada.

Guay, R. B., & McDaniel, E. D. (1982). The relationship between spatial abilities and social-emotional factors. (Lafayette, IN: Purdue University.) East Lansing, MI: National Center for Research on Teacher Learning. (ERIC Document Reproduction Service No. ED 224 810)

Heinrich, V. L. S. (1989). The development and validation of a spatial perception test for selection purposes. Unpublished master's thesis, The Ohio State University, Columbus, OH.

McGee M. G. (1979). *Human spatial abilities: Sources of sex differences.* New York: Praeger.

Miller, C. L. (1992). *Effects of field independence & dependence on the acquisition of visual spatial mental rotational skills through solid models and wire frame video presentation.* Unpublished doctoral dissertation, The Ohio State University, Columbus, OH

Newcombe, N. (1982). *Sex-related differences in spatial ability: Problems and gaps in current approaches. In M. Portegal (Ed.), Spatial Abilities: Development and Physiological Foundations,* New York: Academic Press.

Newcombe, N., & Bandura, M. M., & Taylor, D. G. (1983). Sex differences in spatial ability and spatial activities. *Sex Roles*, 9, 377-386.

Olson, D. M. (1985). *The influence of sex, experiential factors and cognitive processing on spatial aptitude performance* (Doctoral dissertation, University of Maryland, 1985). Dissertation Abstracts International, 47, 05A.

Salthouse, T. A., Babcock, R. L., Skovronek, E., Mitchell, D. R. D., Palmon, R., & Skovronek, E. (1990). Age and experience effects in spatial visualization. *Developmental Psychology*, 26(1), 128-136.

Sexton, T. J. (1991). *Teaching engineering graphics: A comparison between manual/two dimensional computer aided drafting traditional methods and three dimensional computer aided drafting nontradional methods with respect to spatial visualization ability.* Unpublished doctoral dissertation, Ohio University, Athens, OH.

Shute, V. J., Pellegrino, J. W., Hubert, L. R., & Reynolds, R. W. (1983). *The relationship between androgen levels and human spatial abilities. Bulletin of the Psychonomic Society*, 21(6), 465-468.

Shephard, E. N., & Metzler, J. (1971). Mental rotation of three dimensional objects. *Science*, 171, 701-703.

Vandenberg, S. G., & Kuse, A. R. (1979). Mental rotations: A group test of three-dimensional spatial visualization. *Perceptual and Motor Skills*, 47, 599-604.

Wiley, S. E. (1989). Advocating the development of visual perception as a dominant goal of technical graphics curriculum. *Engineering Design Graphics Journal*, 53(1), 1-12.

Zavotka, S. (1985). *Three dimensional computer graphics animation: A tool for spatial skill instruction* (Doctoral dissertation, The Ohio State University, 1985). Dissertation Abstracts International.

An Algorithm for Evaluating Team Projects

Frank M. Croft, Jr.
Frederick D. Meyers
Audeen W. Fentimen
The Ohio State University
Columbus, Ohio

Introduction

Open-ended design or conceptual design is becoming more and more a part of freshman engineering programs. Nee (1992) reports that nearly 50% of the respondents to a survey on open-ended design use open-ended design problems in their freshman level graphics courses. Furthermore, he reports that 60% of the respondents believe that open-ended design should be used in freshman level technical graphics classes. The National Science Foundation has encouraged the use of design projects to teach engineering concepts through the Engineering Education Coalition Programs (NSF 93-58a). The ECSEL coalition includes "Design Across the Curriculum" in all of their freshman engineering programs (NSF 93-58c). The application of this philosophy was reported to the Engineering Design Graphics Division by Calkins in 1992, and by Sathianathan in 1993.

We at Ohio State did a survey in 1992 which confirmed reports from industry that new graduates were competent in technical specialties, but poor at integrating information and at working in teams (6). We introduced team projects into EG166, our basic engineering graphics course, and found problems in determining a project grade for each student. The most difficult problem in evaluating an individual's performance on a team project is the amount of effort that the individual has contributed to the team. There was a fear that an individual could do little but would reap the benefit of being associated with a dynamic group and thus receive a grade that he/she might not really have earned. This paper presents an algorithm that has been used at Ohio State over the past two years to evaluate individual performance on team projects.

Evaluation of Criteria

An individual grade on a team project is determined by a team component and an individual component. The team component is composed of the written report grade and the team oral report grade. The criteria used in evaluating the written report include: cover and appearance; title page and table of contents; introduction; statement of problem; concepts considered; refinement/selection/justification; analyses; and final design.

Each section of the report is graded on content and clarity. Neatness, spelling, grammar, and punctuation are important. A maximum of 50 points are associated with the written report. The criteria used to evaluate the team oral report include: Introduction, statement of problem; alternative concepts; refinement/selection/justification; analyses; and final design. Also evaluated are: Organization/transitions; use of visual aids; and use of allotted time.

The team oral report is worth a maximum of 20 points. The team component is simply the written report score plus the team oral report score (70 points maximum).

The individual component is composed of the individual oral report grade and the grade on the drawing(s) completed by the individual student. The individual oral report is evaluated on the student's speaking ability, organization, use of visual aids, and appearance (some instructor's require professional dress). This part of the individual effort is worth a maximum of 15 points. The drawing grade is determined by the student's ability to communicate his/her ideas through detail and assembly drawings that are produced to ANSI standards. Use of CADD was encouraged and is now required. The individual drawing grade is worth a maximum of 15 points.

The points that the individual student earns on the individual oral report and on the drawing(s) that he/she produces are not weighted; however, the team component (written report grade and team oral report grade) is weighted. The weight is determined by a secret ballot that each student is required to complete at the end of the project. Each student rates his/her teammates (including themselves) with regard to the percentage of the project that they believe their individual teammates contributed. For example, an individual would rate each member of a five-person team 20% if all contributed the same effort. With this scenario, each member of the team would have a weighting factor of 100%, which means that they would receive 1.0 times the team component (70 points max.). On the other hand, the percentage could vary with respect to each member's contribution. An individual could receive a weighting factor in excess of 100% or one less than 100%. The weighting factor is multiplied times the team component score to establish the individual student's team score. The team grade plus the individual oral report grade and the drawing grade yields the student's final numerical grade. An example of how the algorithm works is illustrated below. Three students, Andy, Bob, and Claire worked together as a design team. Each component of their grade is illustrated in Figure 1.

Andy's Ballot		Bob's Ballot		Claire's Ballot	
Andy	40%	Andy	35%	Andy	35%
Bob	30%	Bob	30%	Bob	35%
Claire	30%	Claire	35%	Claire	30%
Total:	100%	***Total:***	100%	***Total:***	100%

Andy's contribution 40+30+35= 110%
Bob's contribution 30+30+35= 95%
Claire's contribution 30+35+30= 95%

Figure 1. An example of how the Algorithm works.

The team, as a whole, received 65 out of 70 possible points.

Scores for team members are calculated as in Figure 2.

	Drawing	Oral Report	Team Grade	Total
Andy	12	14	65 x 1.1	97.5
Bob	11	10	65 x .95	82.75
Claire	12	12	65 x .95	85.75

Figure 2. Team member calculations.

Effectiveness of the Weighted Components

This algorithm has been used in computing student project grades over the past two years at OSU with a great deal of success. The secret ballots that the members of each team complete have worked better than most of us expected. For example, a student could rate his/her contribution excessively high in relation to the rest of the team but this has not happened. The students, in general, are brutally honest with one another. If a student is rated low on one ballot, he/she is generally rated low on the other ballots (including their own!).

Conclusions

The experience that we have had at Ohio State has shown the algorithm to be very effective in evaluating individual performance on a team project. Individual grades vary within a team, which is highly desirable since the contribution of each member of the team is variable. The weighting factors work well and the general feeling among the students is that their grade is fair and based on their individual performance. They learn a lot about teamwork and dependence on others to complete a task with this type of evaluation.

References

Nee, J. G., (1992). Freshman Engineering Design Problem Status: A National Pilot Study. *Proceedings of the 1992 ASEE Annual Conference*, pp. 1423-1428.

National Science Foundation, *Engineering Education Coalitions*. (NSF 93-58 a).

National Science Foundation. *ECSEL Engineering Education Coalition*. (NSF 93-58c).

Calkins, D. E. (1993, June). ECSEL-Freshman Engineering Design at the University of Washington, *Proceedings of the 1993 ASEE Annual Conference*. pp. 192-201.

Sathianathan, D., Engle, R., & Foster, R. (1993, June). A Freshman Engineering Design Course. *Proceedings of the 1993 ASEE Annual Conference*.

Meyers, F. D., Britton, R. & Fentiman, A. (1993, December). The Engineering Core Courses: Are They Preparing Students for the Future?, *Proceedings of the First International Conference on Graphics Education*. Alvor, Portugal, pp. 208-217.

7th International Conference on Engineering Computer Graphics and Descriptive Geometry

July 18-22, 1996

Cracow University of Technology (CUT), Cracow, Poland

ICECGDG Organizing Office
Cracow University of Technology, A-9
Warszawska St. 24
31-155 Cracow, Poland
E-mail: icecgdg@oeto.pk.edu.pl
Fax: +48 12 233212

Scope

This conference will be a continuation of the International Conferences in this series held in Tokyo '94, Melbourne '92, Miami '90, Vienna '88, Beijing '84 and Vancouver '78. It will provide a forum for the discussion of both academic and industrial research which would involve the application of geometry, computational methods in modern technology and education in related fields.

Organized by

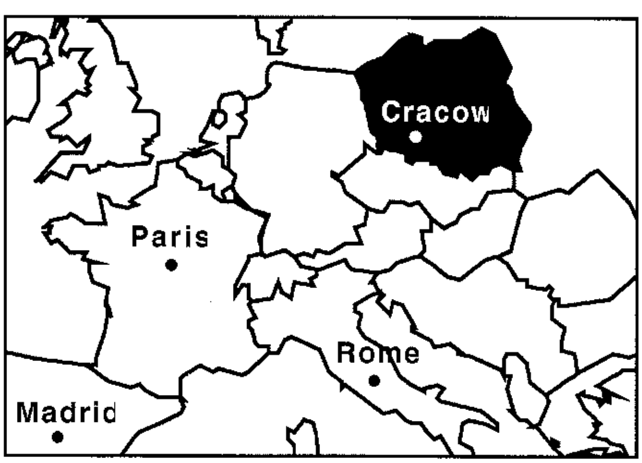
Cracow University of Technology, Poland Faculty of Architecture, Division of Descriptive Geometry and Engineering Graphics

In co-operation with

International Society for Geometry and Graphics
Polish Society for
Geometry and Engineering Graphics
Division of Descriptive Geometry and Engineering Graphics, Silesian Technical University

Sponsored by

Engineering Design Graphics Division of the American Society for Engineering Education



Conference Chair: J. Tadeusz Gawlowski
Cracow Univ. of Technology, Poland
Vice Chair: Lidia Zakowska
Cracow Univ. of Technology, Poland

Conference topics

1. Theoretical graphics and applied geometry; descriptive geometry; kinematic geometry; computational geometry; geometric and solid modeling; geometry in arts and sciences; other applications of geometry,
2. Engineering computer graphics; CAD; Computer Aided Geometric Design; computerized descriptive geometry; product modeling, graphics standards and user-interface methodology; scientific and technical visualization; image synthesis, image processing and remote sensing,
3. Graphics education; graphics teaching techniques; computers in engineering graphics education; evaluation of graphics courseware; evaluation of student's spatial abilities; impact of computers on engineering graphics education and society,
4. Women and graphics education; using computer graphics education to recruit women into engineering; gender balance for graphics education; computer graphics, technology and young women; widening women access to engineering computer graphics; encouraging women into ECG.

For more information contact:
Dennis R. Short, Purdue University
1419 Knoy Hall, RM 363
West Lafayette, IN 47907-1419, U.S.A.
Fax: (317) 494-0486
E-mail: short@vm.cc.purdue.edu

Cost Estimate: $450-US.
Students & accompanying persons, $ 150-US.
For participants from the weak currency countries registration fee may be adjusted, if requested.

Visualization of 4-Space Through Hypersolid Modeling

Josann Duane
Department of Engineering Graphics
The Ohio State University
Columbus, Ohio

Abstract

This paper views 4-space through a window for visualization opened by hypersolid modeling. Hypersolid modeling methods are briefly described. Polytopes are defined. The 120-cell 4-polytope is constructed from dodecahedron cells beginning with a single dodecahedron. As construction proceeds, patterns and symmetries are described that enable the reader to visualize four-dimensional space. These patterns are related to patterns generated in three-space generated during construction of 3-polytopes giving the reader an intuitive understanding of the similarities and differences between 3-space and 4-space.

Introduction

We imagine that we live in a three-dimensional Euclidean world. However, several other spaces are essential in analyzing and modeling the world that we live in. For example, the three-dimensional world is viewed on a two-dimensional picture plane. Even though two-dimensional space is not "real" in the sense that objects in two-dimensional space have no volume, we find it useful in representing the three-dimensional world. The same is true of four-dimensional space. The physical model of the universe, general relativity, developed by Albert Einstein (1961) and others is based on space-time that is represented by four-dimensional non-Euclidean geometry. The four-dimensional model of the universe is required to explain phenomena observed in our three-dimensional world. This paper describes a new method for forming a mental image of four-dimensional space.

Regular Polytopes in Four-dimensional Space

Each space, whether it be one, two, three, four or N dimensional, is defined by the geometric and topological elements comprising the space. This paper describes space using topology, thus topological elements are used to model entities in space. Topological elements for spaces of dimension one through four are as follows: one-dimensional space (vertex and edge), two-dimensional space (vertex, edge and face), three-dimensional space (vertex, edge, face and body), and four-dimensional space (vertex, edge, face, body and hyperbody).

Polytopes are modeled by the highest order elements in the space. For example, a 2-polytope (polygon) is two-dimensional and modeled using topology by the elements: face, edge and vertex. A 3-polytope (polyhedron) is three-dimensional and modeled by the elements: body, face, edge and vertex. Likewise, a 4-polytope is four-dimensional and modeled by the elements: hyperbody, body, face, edge and vertex. A set of regular polytopes is defined in each order of Euclidean space. In two-dimensional Euclidean space regular 2-polytopes are polygons. In Euclidean 3-space there are five regular 3-polytopes (polyhedra), the regular tetrahedron, regular hexahedron (cube), regular octahedron, regular dodecahedron and regular icosahedron. In 4-space there are six regular 4-polytopes. Three are built from regular tetrahedrons (5-cell or simplex, 16-cell and 600-cell); one is built from regular hexahedrons (8-cell or tessaract); one is built from regular octahedrons (24-cell) and one is built from regular dodecahedrons (120-cell).

The author has modeled four of the smaller 4-polytopes (Duane 1994 and 1995) and demonstrated the utility of her modeling method for visualization. Modeling and visualization of the 120-cell 4-polytope are the challenges of this paper.

Visualizing Four-Dimensional Space

The approach taken to understanding four-dimensional space depends on experience and expertise. Many mathematicians realize 4-space through the algebraic and topological relationships governing operations in 4-space. Coxeter (1963) devotes his book to algebraic methods that prove the existence of regular polytopes in higher order spaces. Coxeter solves for the coordinates of all regular 4-space polytopes and shows projections of the 4-space coordinates onto 2-space. Coxeter counts topological elements of the polytopes listing tables of vertices, edges, faces and bodies. However, little attention is given to connectivity. Another mathematician, Grunbaum (1967) describes connectivity of polytopes and relates connectivity to Euler's equation. Yet, his treatment is still mathematical in nature and little help is given in visualization.

Designers and engineers are, in general, more visually oriented than mathematicians. Even before extensive use of computer graphics, descriptive geometry extended into the fourth dimension (Ernesto, 1968) proved to be a useful tool for engineers in understanding the fourth dimension. Descriptive geometry permits objects to be constructed and manipulated in four-dimensional space according to rules governing their projection onto two-dimensional space. As a result, engineers can work with objects in four-dimensional space in a way that is familiar to them in working with objects in three-dimensional space.

Computer graphics has opened new possibilities for visualization of 4-space entities through animation of the projection of 4-space objects into 3-space as they rotate in four space. By projecting the 4-space model onto a two-dimensional picture plane at two slightly different angles, stereo pairs result that can be viewed so that a three-dimensional image is formed in the mind of the observer. When Noll (1978) used rotation of 4-space objects as a visualization tool, observers were "puzzled by the strange distortions of rigid four-dimensional object." Even though Noll believed that little insight into the geometry of a four-dimensional world was gained through this visualization tool, these "strange distortions" are a key to understanding 4-space.

Wan (1994) also uses projection as a method for 4-space visualization. Instead of rotating the object in 4-space and observing changes in the 3-space projection, Wan developed a method for finding the optimum viewing angle for objects in 4-space.

Sectioning provides another technique for visualization of 4-space. Banchoff (1978) demonstrates the method of "slicing" two, three and four-dimensional objects. He observes that slices of two-dimensional objects are one-dimensional, slices of three-dimensional objects are two-dimensional and slices of four-dimensional objects are three-dimensional. If a cube is sliced parallel to one of its bounding faces, the result is a family of square slices of the same size and shape as the bounding face of the cube. If a hypercube is sliced parallel to one of its bounding bodies (i.e., cubes), the result is a family of cubes the same size and shape as the bounding body of the hypercube.

Diagonal slicing of cubes and hyper cubes yields a more interesting set of geometric shapes. If a cube is sliced by a plane perpendicular to the diagonal of the cube, halfway through the cube, the slice is a regular hexagon with each edge of the hexagon a section of the six bounding squares of the cube. If a hypercube is sliced by a hyperplane absolutely perpendicular to the diagonal of the hypercube, halfway through the hypercube, the slice is a regular octahedron with each face of the octahedron a triangular section of the eight bounding cubes of the hypercube.

A fourth technique for visualization of objects in hyperspace, also introduced by Banchoff (1988), involves decomposition of hypersolids into tori. Banchoff decomposed the 24-cell polytope into four tori. Each torus is formed from six tetrahedrons of the 24-cell. The connectivity of the tetrahedrons forming the 24-cell can be seen as the structure is pulled apart revealing four interlocking tori. Duane (1995) also demonstrated the decomposition of the 24-cell into tori using a method based on topology.

The approach taken to visualization presented in this paper is based on hypersolid modeling (Duane, 1994), making it fundamentally different from the methods described in the preceding paragraphs where the basis for visualization is decomposition rather than composition of hypersolids. The method of hypersolid modeling enables us to generate a mental image of 4-space by following the construction of hypersolids from bodies, faces, edges and vertices. Hypersolid modeling opens yet another window into four-dimensional space by permitting individuals from a variety of backgrounds to visualize objects in 4-space.

Euler's Formula

Euler's formula (Grunbaum, 1967) has been used extensively in in the development of boundary representation solid modelers. Incorporating Euler's formula in the algorithms for construction of solids ensures that the resultant models represent valid solids. In simple terms, valid solids are solids that could be built physically. They have no self intersecting surfaces such as those found in a Klein bottle or non-orientable surfaces such as the surface of a Mobius strip. Euler's formula applies to all spaces and ensures the topological validity of the entities being modeled in any given space.

Euler's formula in n-dimensional space is give by equation 1.

$$\sum_{m=0}^{n}(-1)^{m}K_{m}^{n}=1 \qquad (1)$$

In equation 1, **n** is equal to the dimension of the space, **m** is an element index that is incremented from 0 to n, and **K** is the number of topological elements of order **m** in n-dimensional space that are used to construct the entity being modeled.

In three-dimensional space equation 1 is written as,

$$K_0^3-K_1^3+K_2^3-K_3^3=1 \qquad (2)$$

and in four-dimensional space equation 1 is given by,

$$K_0^4-K_1^4+K_2^4-K_3^4+K_4^4=1 \qquad (3)$$

where K_0^n is the number of vertices, K_1^n is the number of edges, K_2^n is the number of faces, K_3^n is the number of bodies, and in four-dimensional space K_4^4 is the number of hyperbodies in the entity being modeled.

Symbol	Definition	Value 1-space	2-space	3-space	4-space
v_e	number of vertices bounding an edge	**2**	**2**	**2**	**2**
v_f	number of vertices bounding a face	NA[3]	δ[4]	δ	δ
v_b	number of vertices bounding a body	NA	NA	δ	δ
e_v	number of edges adjacent to a vertex	**1**	**2**	δ	δ
e_f	number of edges bounding a face	NA	δ	δ	δ
e_b	number of edges bounding a body	NA	NA	δ	δ
f_v	number of faces adjacent to a vertex	NA	**1**	δ	δ
f_e	number of faces adjacent to an edge	NA	**1**	**2**	δ
f_b	number of faces bounding a body	NA	NA	δ	δ
b_v	number of bodies adjacent to a vertex	NA	NA	**1**	δ
b_e	number of bodies adjacent to an edge	NA	NA	**1**	δ
b_f	number of bodies adjacent to a face	NA	NA	**1**	**2**

Table 1. Element adjacencies for a single instance of the highest order entity[2] in the space (Duane, 1994).

Modeling and Visualization of the 120-cell 4-polytope

The 120-cell 4-polytope is a hyperbody constructed from 120 regular dodecahedron bodies. The rules for constructing the 120-cell follow from Euler's formula. Since this paper is on visualization and not on modeling, details of the construction procedure based on Euler's formula will be omitted. The reader is referred to two earlier papers by the author that supply the details omitted here (Duane 1994 and 1995).

Element ratios give information about adjacency of topological elements. In 3-space there are sixteen different adjacency relationships among 3-space elements nine of which are used in solid modeling (Weiler, 1985). In 4-space there are 25 adjacency relationships (Duane, 1994). Table 1 defines the cross element adjacencies1 for elements of entities in 1-, 2-, 3-, and 4-space. Some of the element adjacencies[1] are fixed and some depend on the topology of the entity being constructed.

Table 2 shows the element ratios computed for the six regular polytopes in 4 - space. Regular polytopes by definition have the same adjacencies for every element. For example, every vertex in a regular dodecahedron has exactly three edges adjacent to it and every face in a regular dodecahedron has exactly five edges adjacent to it. Using Euler's formula, the element adjacencies that are dependent on topology can be computed (Duane, 1995).

Figure 1 shows the conventions that are used in illustration of the element adjacencies of the 120-cell as it is modeled. Two element ratios are given in Figure 1:

Regular 4-Polytope	v_e	v_f	v_b	e_v	e_f	e_b	f_v	f_e	f_b	b_v	b_e	b_f
5-cell (simplex)	2	3	4	4	3	6	6	3	4	4	3	2
8-cell (hypercube or tessaract)	2	4	8	4	4	12	6	3	6	4	3	2
16-cell	2	3	4	6	3	6	12	4	4	8	4	2
24-cell	2	3	6	8	3	12	12	3	8	6	3	2
120-cell	2	5	20	4	5	30	6	3	12	4	3	2
600-cell	2	3	4	12	3	6	30	5	4	20	5	2

Table 2. Element adjacencies ffor the six regular polytopes in Euclidean 4-space (Duane, 1994).

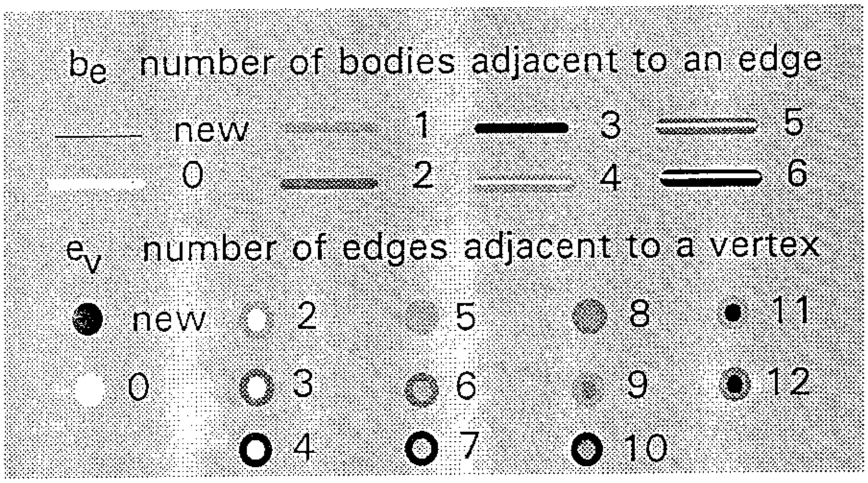


Figure 1. Element adajecency symbols and symbols for new elements added during polytope construction (Duane,

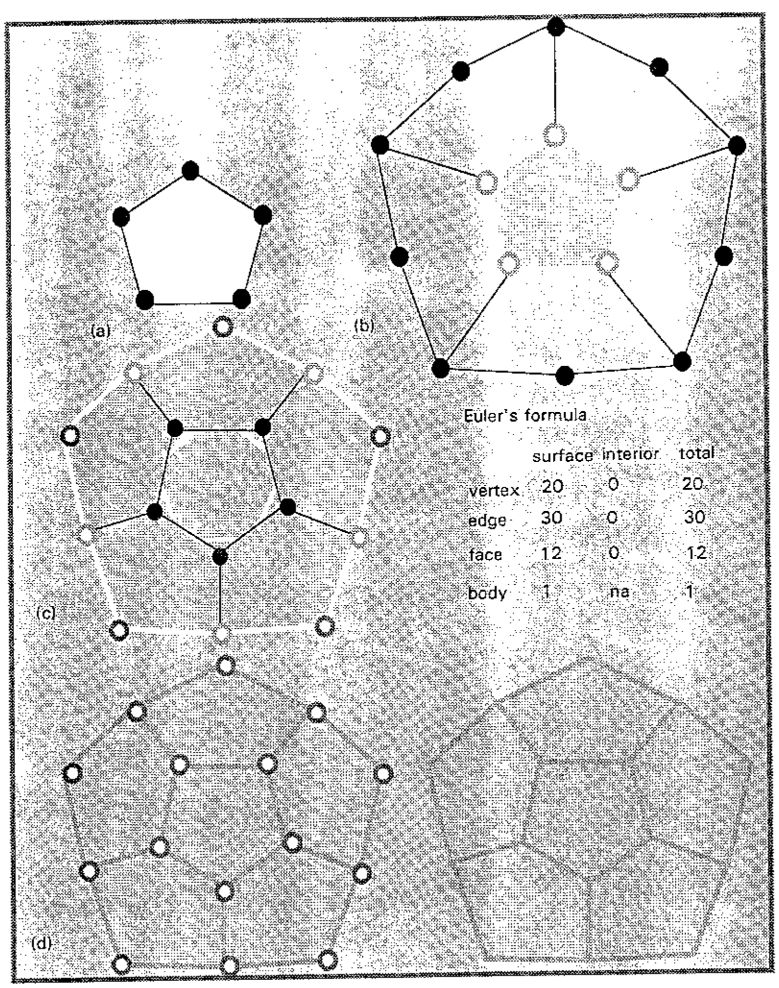


Figure 2. Creation of the initial dodecahedron from 12 pentagons

1. Element adjacency b_e is the number of bodies that are adjacent to (i.e. are connected to) an edge; and
2. Element adjacency e_v is the number of edges that are adjacent to a vertex.

When completely constructed, the 120-cell has 3 bodies adjacent to every edge ($b_e = 3$), and four edges adjacent to each vertex ($e_v = 4$) as listed in Table 2.

Figure 2 shows a graph of the surface of a dodecahedron under construction. The graphs use the symbols given in Figure 1 to illustrate the connectivity of the polytope. In Figure 2a each of the edges and each of the vertices are shown in black as a new entity. Even though each of the vertices is adjacent to two edges and each edge is adjacent to one face, symbols for adjacencies are not shown until the face is depicted as a completed face in Figure 2b. Figure 2b shows the addition of 5 faces to the initial face, with each added face adjacent to the initial face. The vertices of the initial face in Figure 2b are white circled in light gray indicating that they are adjacent to two edges and the edges are white indicating that they are adjacent to one face. New edges and new vertices shown in black are not considered in the adjacency relationships.

The addition of five more faces creates a graph as seen in Figure 2c where some of the vertices (in white circled in light gray) are adjacent to two edges and some (in white circled in dark gray) to three; and some edges (in white) are adjacent to one face and some (in light gray) to two faces. Upon completion of the dodecahedron (Figure 2d) all vertices are adjacent to three edges and all edges are adjacent to two faces.

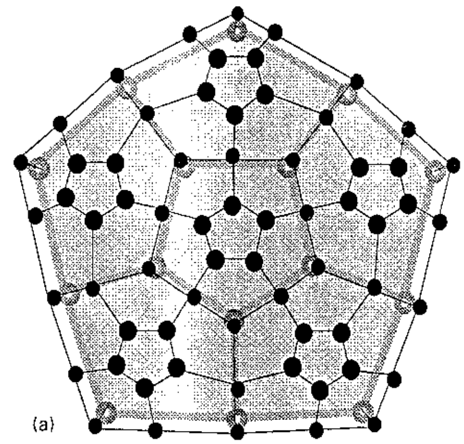
$$K_0^3 - K_1^3 + K_2^3 - K_3^3 = 20\,vertices - 30\,edges + 12\,faces - 1\,body = 1 \qquad (4)$$

Each of the figures contains tables giving Euler's formula for the construction stage illustrated. The table in Figure 2 shows that Euler's formula is balanced for the initial dodecahedron.

Taking a second look at Figure 2 we notice the form of the projection of the three-dimensional dodecahedron onto 2-space. The construction of the dodecahedron begins with a pentagon, (Figure 2a), that is then surrounded by five pentagons, (Figure 2b), one on each side of the initial pentagon. Next, 5 pentagons (Figure 2c) are placed one above each vertex of the initial pentagon. Finally, a single pentagon, (Figure 2d), is added above the initial pentagon. The sum of the interior angles of three pentagons as they meet at a vertex is less that 2π radians causing the polyhedron to fold around and close.[5]

Notice that the projection of the dodecahedron construction onto two-dimensional space begins as a pentagon. Next, the pentagon is surrounded by five pentagons and the projection onto 2-space increases in size. The addition of five more pentagons covers the first set of five pentagons that were added. The final pentagon is adjacent to all the pentagons added in the previous stage and its projection onto 2-space covers the initial pentagon. The projection onto 2-space of the dodecahedron grows in size and then shrinks as we construct the polyhedron. We will find the projection of the 120-cell onto 3-space initially grows in size and then shrinks as we construct the polytope.

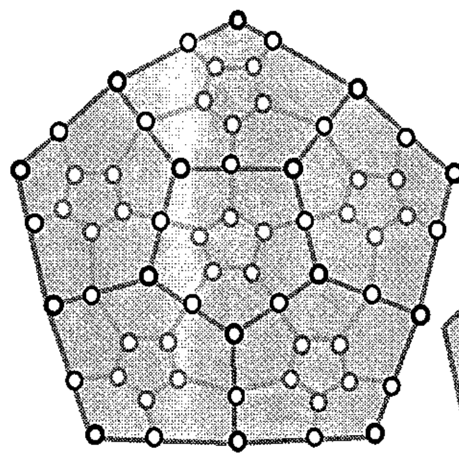
The key to the observed growth and shrinkage of the projection of the 120-cell onto 3-space is found in the sum of the interior solid angles of bodies as they meet at a vertex. The sum of the interior solid angles of the dodecahedrons is less than 4π steradians causing the polytope to curve in 4-space and finally close.[6] The modeling of the 120-cell begins with a single dodecahedron. Adjacent dodecahedrons are added causing the projection of the model onto three-dimensional space to become larger and more complex. As the midpoint in four-dimensional space is passed, the projection of the polytope onto three-dimensional space becomes

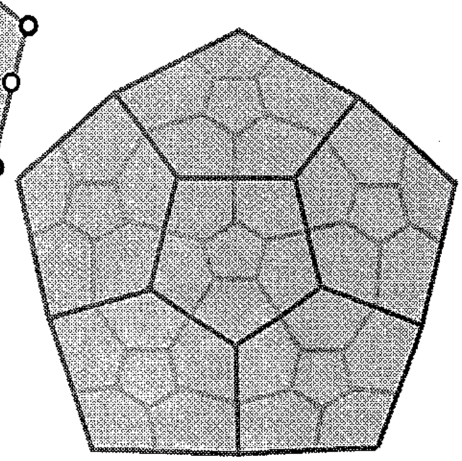


(a)

Euler's formula

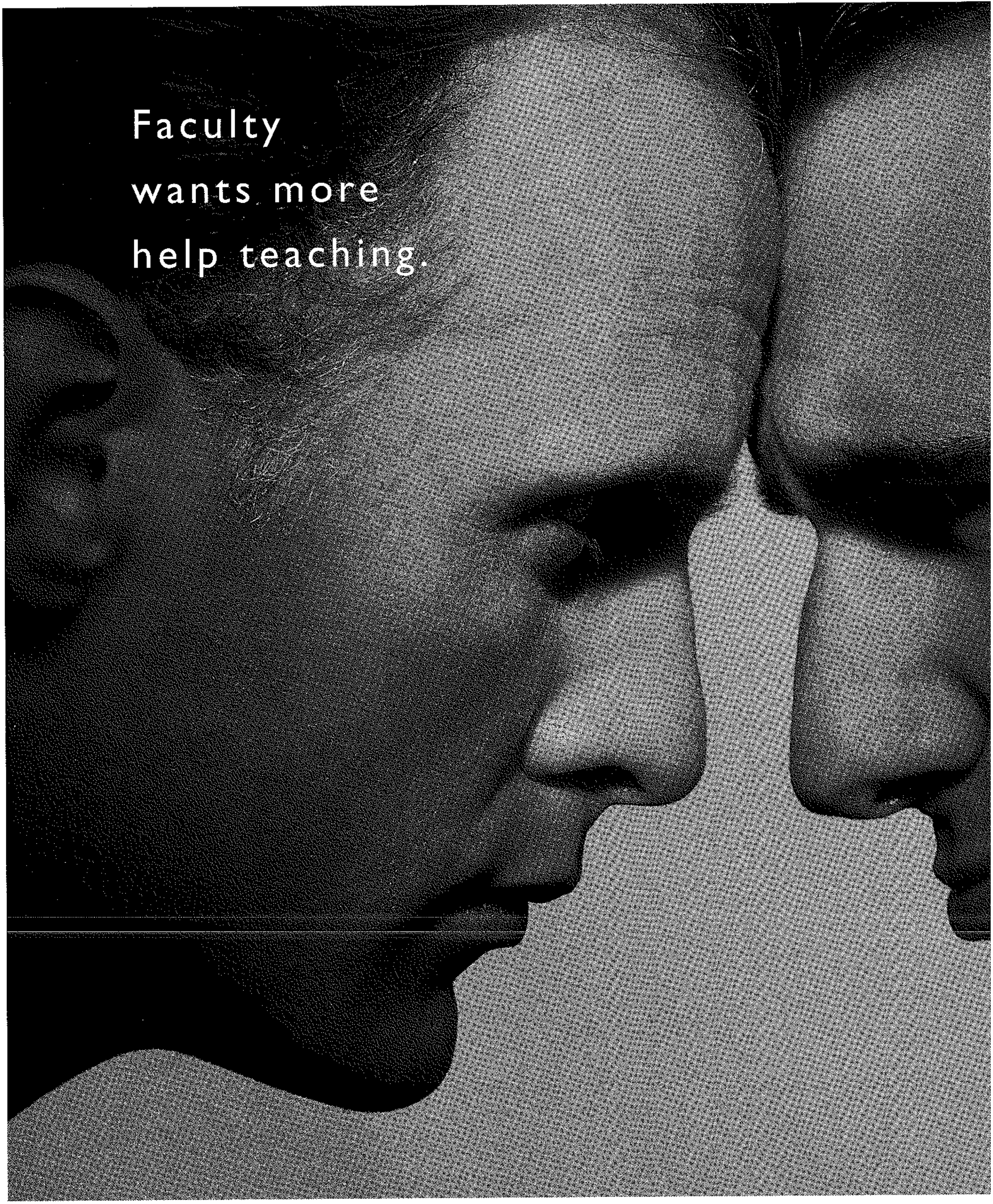
	surface	interior	total
vertex	110	20	130
edge	180	50	230
face	72	42	114
body	na	na	13

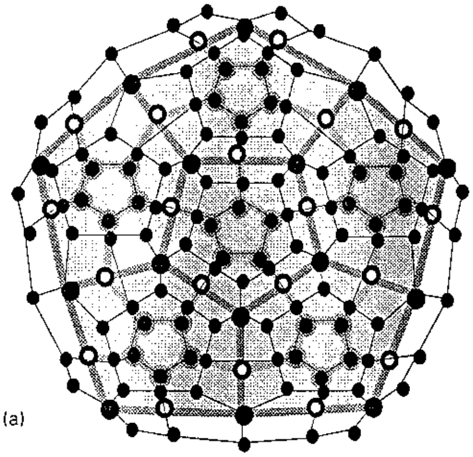




(b)

Figure 3. Addition of 12 bodies, one on each of the 12 faces of the initial dodecahedron.

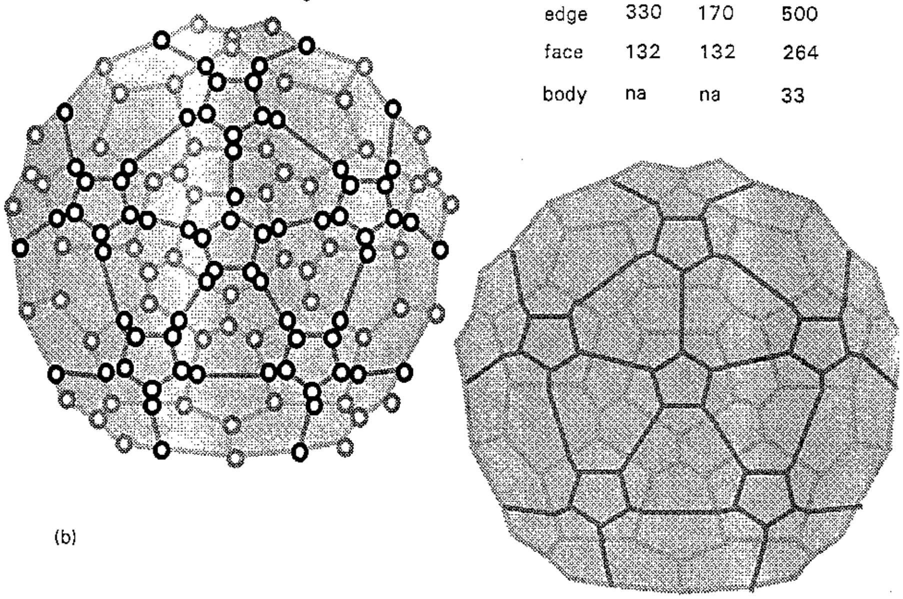

Faculty
wants more
help teaching.



(a)

Euler's formula

	surface	interior	total
vertex	200	70	270
edge	330	170	500
face	132	132	264
body	na	na	33



(b)

Figure 4. Addition of 20 bodies, one over each of the 20 vertices of the initial body, creating the 140 new vertices, 270 new edges and 140 new faces.

less complex and smaller. Finally, it is closed by a single dodecahedron adjacent to all dodecahedrons added in the previous stage of construction.

Figures 3 through 9 illustrate the construction of the 120-cell 4-polytope. Graphs similar to the ones used to illustrate the surface of the dodecahedron will be used to illustrate the construction of the 120-cell 4-polytope. Since the 120-cell is symmetrical, each figure shows a graph of either one-half, or one-half plus 20 faces. Each stage of construction is illustrated by a graph of the most recently constructed surface of the polytope. When the line of symmetry falls along an edge, the figure illustrates one-half of the most recently constructed faces (Figures 2, 3, 8 and 9) When the line of symmetry falls on a face, the figure illustrates one-half of the most recently constructed faces plus 20 faces in order to represent the 20 shared faces (Figures 4, 5, 6 and 7).

In each of Figures 2 through 9 every figure part (a) shows edges that have been added to the previous construction stage using thin black lines and vertices added using filled black circles. Every figure part (b) shows the polytope under construction after faces have been attached to the edges. New faces cover the old faces of the polytope under construction. Every figure (b) shows two graphs of the polytope under construction, one with vertices and one without. Vertices are eliminated from the second graph to aid in visualization.

The patterns formed by the light and dark gray edges illustrate the topology of 4-space. Light gray lines represent edges adjacent to a single body and dark lines represent edges adjacent to two bodies (see Figure 1). In 3-space, each edge must have two and only two faces attached to it to form a valid solid. In 4-space each edge must have at least three faces attached to it to form a valid hypersolid. Using equation 1, it can be shown that for the 120-cell each edge must have exactly three bodies adjacent to it (Duane, 1994). Although the derivation of this result is beyond the scope of this paper, the result itself is a useful visual aid for construction of the 120-cell. You will notice that as we construct the 120-cell the edges are usually initially light gray. Before being covered by another layer of polyhedra during construction, an edge must have two bodies adjacent to it and hence be represented by a dark gray line.

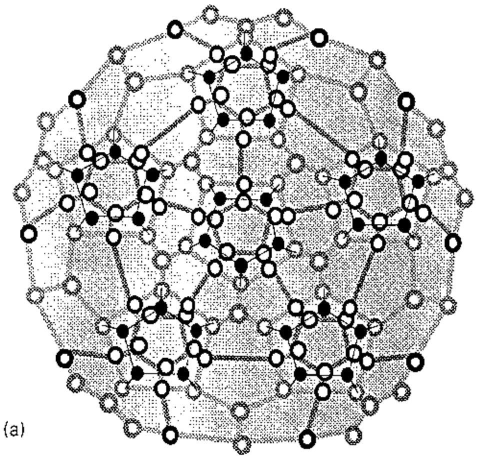
The symmetry in the patterns of light and dark gray edges is described during each stage of the construction beginning here with the first stage. Comparing Figure 2d and Figure 9b, we see that the edges in the first figure are all light gray and the edges in the last figure are all black. All the edges of the initial dodecahedron (Figure 2d) are adjacent to a single body and hence colored light gray. The final dodecahedron in the construction (Figure 9b) encloses the entire polytope. Each of its edges are shared by three dodecahedrons, two from the construct shown in Figure 9a and the final dodecahedron that encloses the entire polytope projection into 3-space.

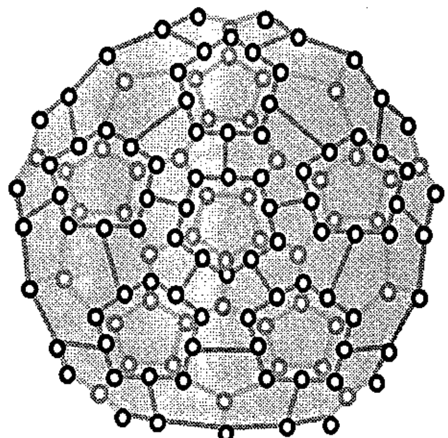
In addition to the symmetry in patterns of light and dark gray edges in corresponding pairs of figures throughout, there is also a symmetry in the number of vertices, edges, and faces. Although the connectivity varies, the number of vertices, edges, faces, on the surface of corresponding pairs is always identical (see Figures 2d and 9b, Figures 3b and 8b, Figures 4b and 6b, Figures 5b and 6b).

Figure 3 illustrates the second stage in construction of the 120-cell. In this stage (Figure 3a) we place 12 bodies, one body on each of the 12 faces of the initial body (the dodecahedron shown in Figure 2), creating the 110 new vertices, 200 new edges and 102 new faces shown in Figure 3b. The surface of the partially constructed hyperbody is a complete and valid surface and Euler's formula (column 1) holds here and throughout the construction of the 120-cell hyperbody (*110 vertices - 180 edges + 72 faces - 1 body =* 1)[7].

Each of the bodies share a common face. The edges of the common faces are shown in dark gray. Adjacent to each dark gray edge is the common face plus two adjoining bodies. The edges of the initial dodecahedron that were covered during the first stage of construction are adjacent to three bodies. At this stage of construction and throughout the entire construction all interior edges are adjacent to three bodies and can be considered to be colored black. All the interior vertices are adjacent to four edges.

Figure 3b shows the partially constructed polytope with and without vertex symbols. In the diagram without vertex symbols, dark gray lines outline added bodies. Note that the coloring of the edges and vertices in Figure 3b is exactly opposite of the coloring of the edges in Figure 8b.


(a)


(b)

Euler's formula

	surface	interior	total
vertex	200	130	330
edge	330	290	720
face	132	204	336
body	na	na	45

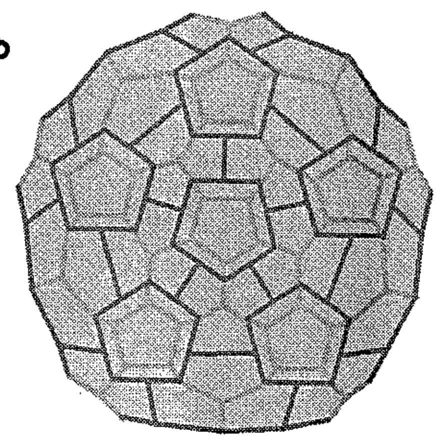
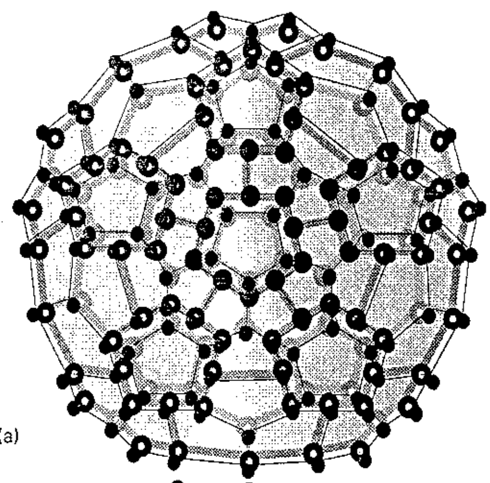


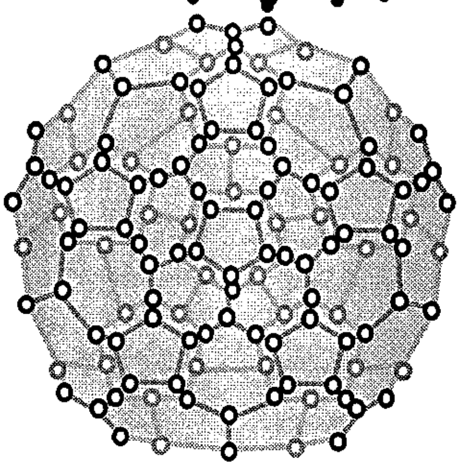
Figure 5. Addition of 12 bodies, one over each of the 12 faces of the initial body, creating the 60 new vertices, 120 new edges, and 72 new faces.

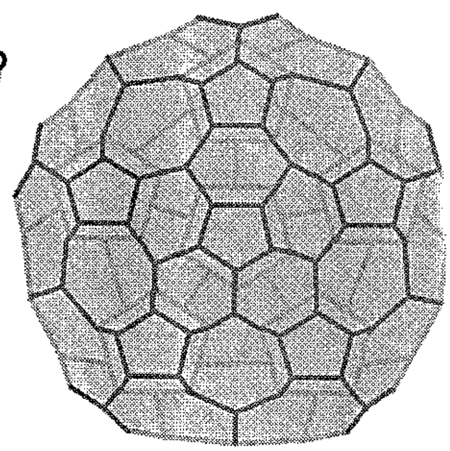


Euler's formula

	surface	interior	total
vertex	200	270	470
edge	330	580	910
face	132	384	516
body	na	na	75

(a)





(b)

Figure 6. Addition of 30 bodies, one body over each of the 30 edges of the initial body, creating the 140 new vertices, 109 new edges and 180 new faces.

The bodies added at this stage (Figure 3) form a continuous shell completely enclosing the initial dodecahedron in 3-space. Before we continue with construction, note that, although the initial body is completely enclosed in the projection onto three-dimensional space, it actually is not enclosed at all in 4-space. The void in three-dimensional space becomes a passageway in four-dimensional space. One way to understand how a void in 3-space becomes a passage in 4-space is to visualize the two-dimensional analog. Consider a face with a hole in it. In 2-space, a two-dimensional creature is trapped in the hole. If the face is placed in 3-space the creature can jump over the face. The hole in the face becomes a passage through it when the face is moved from 2-space to 3-space. Analogously, the initial body in four-dimensional space is not completely enclosed even though its projection onto three-dimensional space is.

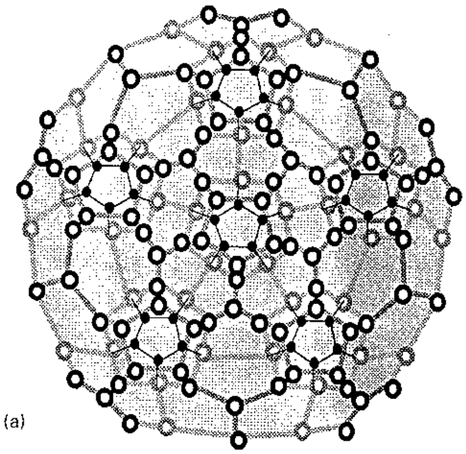
In the next step, we place one body over each of the 20 vertices of the initial body (Figure 4a), creating the 140 new vertices, 270 new edges and 140 new faces shown in Figure 4b. Note that the added edges are connected to the vertices adjacent to three edges. At this stage the surface of the partially constructed hyperbody contains 200 vertices, 330 edges and 132 faces. In this and the next three stages of construction the number of vertices, edges and faces on the surface remains constant. In the last two stages, the number of faces, vertices and edges on the surface declines in a manner analogous to the increase in the number of faces, vertices and edges on the surface in the first two stages of construction.

Each of the bodies added at this stage (Figure 4) is in contact with three other newly added bodies sharing a common face and a common edge shown in dark gray. Again the outline of the added bodies is shown in Figure 4b by dark gray lines. The bodies added at this stage form a network with holes over each of the faces of the initial body. Note also that: (1) the edges over the faces of the initial body are colored dark gray and thus can be covered by bodies in the next stage of construction; and (2) the pattern of dark and light edges and vertices is exactly opposite that of the partially constructed 120-cell in Figure 7b.

Proceeding with construction, we add 12 new bodies, one over each face of the initial body (Figure 5a), creating the 60 new vertices, 120 new edges and 72 new faces shown in Figure 5b. The 12 new bodies added are not connected to each other. However, they do fill in the holes in the network created in the previous stage of construction. The outline of the added bodies is shown in Figure 5b by the six dark gray pentagons. Together the bodies added in this stage and the previous one form a complete shell enclosing the bodies from the first two stages of construction.

The coloring of the surface pattern created in Figure 5b is the exact opposite of that found in Figure 6b. At this stage and throughout construction, column 1 representing the entities on the surface of the partially constructed hyperbody remains balanced (200 vertices-330 edges + 132 faces -1 body = 1).

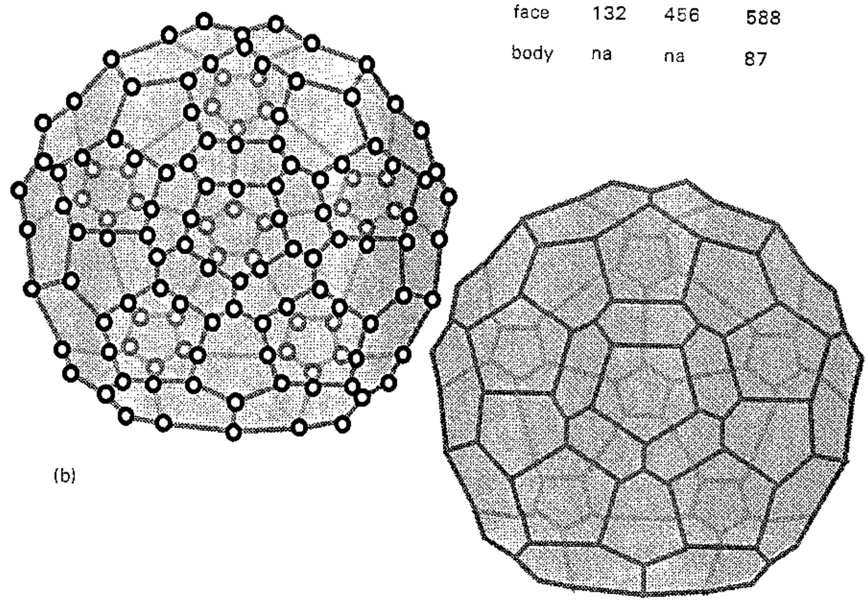
In this stage of construction, we proceed through the midpoint of the polytope by placing 30 bodies (Figure 6a), one over each of the 30 edges of the initial body, creating the 140 new vertices, 190 new edges and 180 new faces shown in Figure 6b. The bodies added at this stage are outlined in dark gray lines in Figure 6b. The added bodies added at this stage are all in contact with each other and form a network enclosing the partially constructed polytope. The number of bodies at this stage is 75, representing one half of the total number of bodies (120/2 = 60) plus one half of the number of bodies added (30/2 = 15).



(a)

Euler's formula

	surface	interior	total
vertex	200	330	530
edge	330	700	1030
face	132	456	588
body	na	na	87



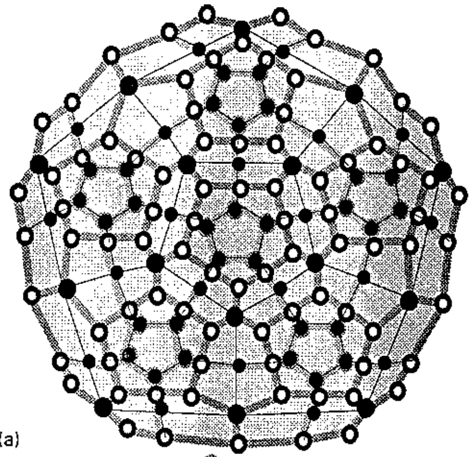
(b)

Figure 7. Addition of 12 bodies. one over each of the 12 faces of the initial body, creating the 60 new vertices, 120 new edges and 72 new faces.

The pattern of light and dark gray edges is exactly opposite of that shown in the previous Figure 5b and the arrangement of surfaces is exactly the same as in the previous figure. As we pass through the midpoint we reverse the symmetry in patterns observed during the first four stages of construction.

As we begin modeling the second half of the polytope, 12 bodies are placed one body over each of the 12 faces of the initial body (Figure 7a), creating the 60 new vertices, 120 new edges and 72 new faces shown in Figure 7b. The added bodies are outlined by the dark gray pentagons shown in Figure 7b. The added bodies are not connected to each other. However, in combination with the network of bodies to be added in the next stage, they form a complete shell.

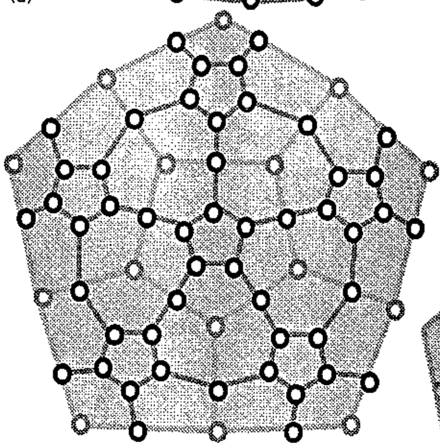
The polytope begins to close as we place 20 bodies, one body over each of the 20 vertices of the initial body (Figure 8a), creating the 50 new vertices, 120 new edges and 90 new faces shown in Figure 8b. The bodies form a network as described in the previous stage of construction. Also, as

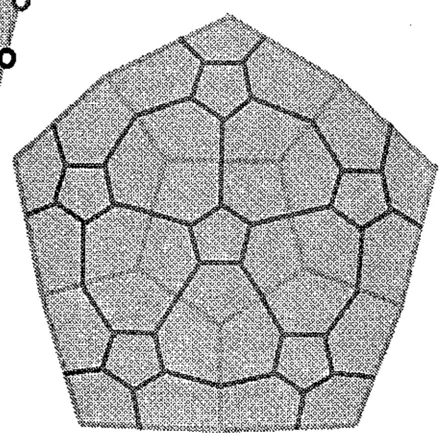


(a)

Euler's formula

	surface	interior	total
vertex	110	470	580
edge	180	970	1150
face	72	606	678
body	na	na	107





(b)

Figure 8. Addition of 20 bodies. one body over each of the 20 vertices of the initial body, creating the 50 new vertices, 120 new edges and 90 new faces.

previously noted, dark gray lines outline the added bodies and the pattern of light and dark gray edges and vertices created is exactly opposite of that shown in Figure 3b.

The polytope is completed by performing the following:

1. placing 12 bodies, one body over each of the 12 faces of the initial body, creating the 20 new vertices, 50 new edges and 42 new faces (Figure 9a); and
2. enclosing the partially modeled in a dodecahedron, creating a new body shown in Figure 9b.

The final shape of the polytope is the same as the initial dodecahedron shown in Figure 2d. All the edges are black indicating that all edges are adjacent to (i.e., attached to) the required three bodies and all vertices are white circled in black indicating that they are all adjacent to four edges, also as required.

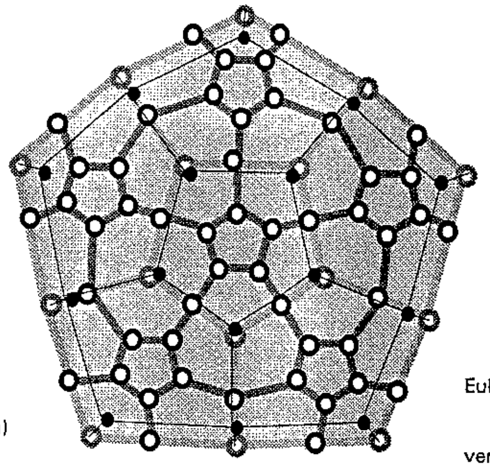
With completion of the polytope, Euler's relation for four-dimensional space (*600 vertices-1200 edges+720 faces-120 bodies+1 hyperbody* = 1) is balanced, showing that a valid topological model of a hyperbody has been constructed. Note that, at this stage and throughout construction, column 1 representing the most recently constructed surface of the partially constructed hyperbody remains balanced (*20 vertices-30 edges + 12 faces -1 body* = 1).

Conclusions

Hypersolid modeling of entities in four-dimensional space gives us an understanding of how entities fit together in four-dimensional space. The 120-cell polytope has been solved algebraically and represented geometrically by Coxeter (1973). A physical model of the projection onto 3-space of the 120-cell has been constructed by Miyazaki (1982). Neither of these two representations model the topological properties or provide an understanding of how the topological entities comprising the polytope determine the final configuration of the polytope.

By following the topological patterns created by the connectivity of vertices, edges and faces as construction progresses we can detect symmetries in the polytope and begin to understand how its constituent bodies fit together in 4-space. The symmetrical graphs created as construction progresses show us the symmetry of the polytope in 4-space. If we begin construction, as we did in the case of the 120-cell 4-polytope, with a single body, the final entity added is a single body.

(a)



Euler's formula	surface	interior	total
vertex	20	580	600
edge	30	1170	1200
face	12	708	720
body	na	na	120

(b)

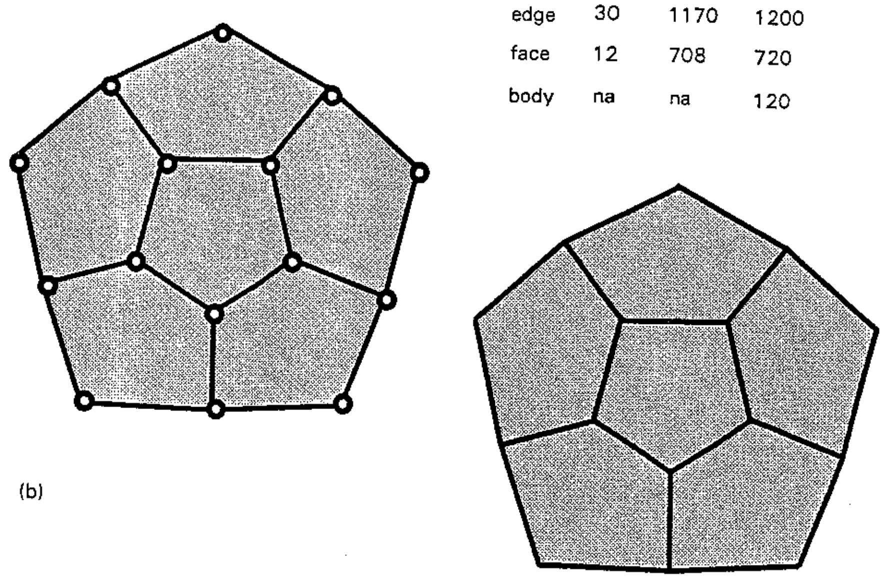


Figure 9. Addition of 12 bodies over each of the 12 faces of the iitial body and one body enclosing the entire model, creating the 20 new vertices, 50 new edges and 42 new faces. Addition of the final body completes construction of the 120-cell polytope.

Essentially we visualize 4-space in the same way that we visualize 3-space. In visualizing 3-space we use two-dimensional images of 3-space to formulate a mental model of where objects in 3-space must be located in order to appear as they do in the two-dimensional image. The same process is used in visualizing 4-space. From studying the graphs of the surfaces of the polytope under construction we form a mental model of where in 4-space the entities must be located in order to produce the graphs.

In contrast, verification of 3-space and 4-space mental models are two different processes. We verify 3-space mental models simply by reaching out and touching the entities imaged on the retinas of our eyes. Verification of 4-space models is an abstract process performed using one or more of the following methods: (1) A 4-space mental model can be verified by comparing where we imagine an entity in 4-space is located with the geometric coordinates of the entity. (2) Following the construction of a 4-space entity, as we did in this paper, is another way of verifying a mental model of 4-space. (3) Finally, by studying time sequence images of object rotation in 4-space, we can refine our mental model of entities in 4-space.

The "strange distortions" of the projection into 3-space of rigid 4-dimensional objects observed by Noll (1978) are actually exactly what should be observed. This phenomenum can be understood by considering the projection onto 2-space of rigid 3-dimensional objects. The projection of a cube onto 2-space changes from a square to a hexagon as the cube is rotated. Although the cube itself remains rigid, its projection onto 2-space is "strangely distorted." The same holds true of rigid 4-space objects projected into 3-space. The object itself in 4-space remains rigid but its projection into 3-space is "strangely distorted." Although geometry is distorted by projection into a subspace, the topology remains unchanged, making it possible to construct topological models in a subspace of the actual space in which the object exists, as the author has shown in this paper.

References

Banchoff, T. & Strause, C. (1978). Torus Decompositions of Regular Polytopes in 4-Space. *Hypergraphics: Visualizing Complex Relationships in Art, Science and Technology*, Westview Press, Boulder, CO, pp. 159-168.

Banchoff, T. (1988). Torus Decompositions of Regular Polytopes in 4-Space. *Shaping Space: A Polyhedral Approach*, Birkhauser, Boston, MA, pp. 221-230.

Duane, J. W., (1994). Hypersolid modeling fundamentals. *Engineering Design Graphics Journal*, 58, (3), pp. 30-40.

Duane, J. W. (1995) Hypersolid modeling topology." submitted to *Journal of Theoretical Graphics and Computing.*

Coxeter, H. S. M. (1973). *Regular Polytopes*, Dover Publications, New York.

Einstein, A., (1961). *Relativity*, Crown Publishers, New York.

Ernesto,C. S., Lindgren, & Slaby, S. (1968). *Four-Dimensional Descriptive Geometry*, McGraw-Hill Co., New York.

Grunbaum, B. (1967). *Convex Polytopes*, Wiley, New York.

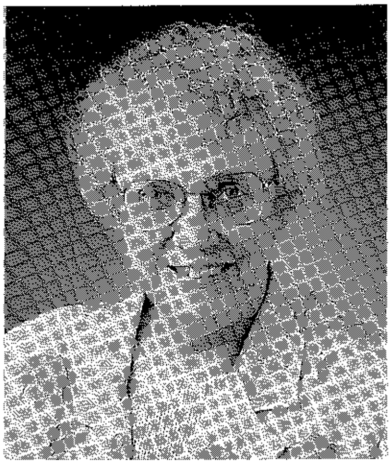
Miyazaki, K. (1982). A model of the 120-cell and some spatial arrangements derived from four kinds of pentagons. *Structural Topology*, (7), pp. 2-10.

Noll, M. A. (1978). Displaying n-dimensional hyperobjects by computer. *Hypergraphics: Visualizing Complex Relationships in Art, Science and Technology*, Westview Press, Boulder, CO, pp. 147-158.

Wan, Z., Liu, Z., Lin, Q. & Duane, J (1994). An orthographic axonometric mapping method for dimetric drawings of four-dimensional objects. *Journal of Theoretical Graphics and Computing*, 7, (1),. pp. 1 -11.

Footnotes

1. Cross element adjacencies are adjacencies between unlike elements. For example, the number of edges surrounding a face is a cross adjacency but the number of neighboring faces surrounding a face is not.
2. The highest order entity in 1-space is a line; in 2-space it is a face; in 3-space it is a body, and in 4-space it is a hyperbody.
3. NA = not applicable
4. δ = the quantity is not constant and depends on the topology (connectivity) of the entity being represented.
5. An interior angle sum of exactly 2π produces a honey comb; whereas, an interior angle sum greater than 2π does not allow the shape to close.
6. In four-dimensional space an interior solid angle sum of exactly 4π steradians produces a four-dimensional honey comb; whereas, an interior angle sum greater than 4π steradians does not allow the shape to close.
7. The most recently constructed surface is a complete boundary. Interior faces of the hyperbody are not included. The surface can be considered to be the surface of a body rather than the most recently constructed part of the hyperbody surface. Thus, Euler's formula for a 3-space body applies.



Chair's Message III

Mary Jasper

The difference between LIGHTNING and the LIGHTNING BUG is nature's way of demonstrating the value of picking precisely the right word.

Mark Twain

As I sit at my desk and write this, it seems to me that I have always done work under the pressure of *The Last Minute*...It is possible, of course, that preceding chairs of this division have felt the same way when confronted by the Director of Publications who wants their *Message* for the *Journal*,...what can I say, exhort, or persuade you, as a member, to do, or to refrain from doing, that has not been said, exhorted, or delivered before?

One aspect of my own career has been foremost in my thoughts, lately, and that has been my teaching effort. As chair of the University Instructional Improvement Committee (UIIC) at Mississippi State, I am aware that this is one aspect of our respective careers which may be lost in the shuffle for tenure, academic advancement, and , of course, the old "bug-a-boo," **PUBLISH OR PERISH**.

Some folks say that the best researchers are (always, sometimes, never) the best teachers. (Here the reader is allowed to select the correct modifier.) Others proclaim that the best teachers do nothing else (but teach) to add to the prestige of the university, college, or department. Conundrums such as these constantly assail the average faculty member – and this is mainly because we want to be liked and respected by our students – at least, I do.

I would like to see more forums in the EDGD on teaching technology; balancing publications with classroom innovations; teaching to different learning styles; the small class vs. the large class; and, basically, how different educators solve problems of teaching three-dimensional graphic skills to two-dimensional minds. With the diversity of our student population (more women, more ethnicity, etc.) we need to address these teaching/learning needs. Many of us teach entering freshmen who maintain most of the *baggage* left over from their pre-college instruction. I would like to know how other faculty deal with students who may be described as *the pampered, the pitiful, and the prosaic*, and how EDGD faculty comply with ever-expanding technology in the lecture/lab setting.

Given the presence of the ERM (in which many of us claim membership), I believe that there is a difference in teaching electrical and mechanical theory and teaching visualization skills. Do you think divisional meetings and /or the *Journal* should furnish such a forum? If you have any comments, suggestions, and/or exhortations of your own, please feel free to email (jasper@engr.msstate.edu), call (601-325-3922 [O] or 601-263-4032 [H]), FAX (601-325-8753), or write me at:

Mary A. Jasper
Department of
Industrial Engineering
Mississippi State University
Box 9542
Mississippi State, MS 39762

EDGD 1995 Distinguished Service Award

Presented to
Arvid R. Eide

June 27, 1995
Anaheim, California
ASEE Annual Conference

Introduction by Rollie Jenison

The Distinguished Service Award of the Engineering Design Graphics Division of ASEE is the highest honor we can bestow upon a fellow member. This year, 1995, the award goes to Arvid R. Eide, Professor and Associate Dean, College of Engineering, Iowa State University. It is an equal honor for me to be asked to introduce Arv and present the award to him.

I could stand before you and review Arv's vita: instead I will try to give a more personal perspective of your DSA awardee.

Arv is a colleague of mine at Iowa State, was my boss for thirteen years, has been a great mentor, and a long-time personal friend. I first met Arv as an undergraduate engineering student in the 1960s but did not get to know him well until he hired me into the Freshman Engineering Department in 1975. This opportunity to return to Iowa State in 1975 was the best thing to happen to me in my career, and I will be forever grateful to Arv for providing that opportunity.

Arv was born and raised on a farm outside Huxley, Iowa, which is less than ten miles from the Iowa State campus. Eide, as you might have guessed, is a Norwegian name. Some say that it means "An ability to teach trolls the elements of orthographic projection," while others believe it is Norwegian for an integer somewhere between 79 and 81. According to Arv, he excelled in academics and athletics throughout high school. Further investigation through contacts with some Huxley old timers revealed a slightly different story. It seems that baseball was the only sport where he got much playing time and that was because: 1) there were only 9 boys in the school at that time, and 2) when his sister, Donna, had to go with the debating team, the coach let him play right field in her place.

Arv went up the road to Iowa State and graduated in 1962 with a B.S. in Mechanical Engineering and a commission in the U.S. Army. He spent the next two years at Fort Polk, Louisiana, one year as a company commander and one year as a teacher for commissioned officers. Upon leaving the military, he returned to Iowa State to pursue an M.S. in Mechanical Engineering, supporting himself by teaching in the Engineering Graphics Department. Jim Rising was the department head and Gordon Sanders was a professor. Both are prior recipients of the Distinguished Service Award. Paul DeJong, another DSA recipient from Iowa State came on board a few years later.

After completing his M.S., Arv worked for the Trane Company in LaCrosse, Wisconsin, for two years as a sales engineer for HVAC equipment. He returned to Iowa State in 1969 as an assistant professor in engineering graphics and as a Ph.D. was completed in 1973, he was promoted to associate professor, and one year later he was promoted to professor and named chair of the newly created Freshman Engineering Department. Arv was charged with developing and growing a teaching-oriented department with responsibilities in graphics, introductory problem solving, advising, and service. The department became nationally known for its freshman emphasis and innovative teaching practices.

In 1988, the new dean of engineering asked Arv to step up to the position of associate dean for academic affairs, a position he is giving up officially this coming Friday. At that time he will return to his old department, now called the Division of Engineering Fundamentals and Multidisciplinary Design, to teach and conduct research in his interest areas of instructional technology, educational theory, and multimedia. After 22 years in administration he is looking forward to the classroom environment again. In fact, one of my assignments this coming fall term is to team teach a section of our graphics course with him and help him get back into the teaching activity as painlessly as possible after his long absence.

Because of the team teaching assignment, he has been frequently stopping by my office asking various questions, such as, "Will the department buy me a new set of ruling pens? A couple of the nibs on mine are bent." Just last week he really confused me when he walked in with this dry-clean pad and asked for a new one, telling me that he had heard the department was upgrading the drafting "software"!

Arv has many significant accomplishments in his career as a teacher, mentor, administrator, author, and leader. In addition to his success with the Freshman Engineering Department, he has been a leader in our college of engineering in the development of outstanding computing facilities for undergraduate students. He was the driving force behind the development of a student services program which provides academic advising, tutorial services, orientation programs, and numerous other services to hundreds of lower division engineering students each year. He is the college leader in bringing TQM into the various service units. He was the Iowa State principal investigator for the charter NSF Engineering Coalition, the Synthesis Coalition.

Arv's involvement with EDGD and ASEE has been and continues to be significant. He was director of programs, vice-chair, and chair for EDGD; vice-chair and chair for freshman programs where he was a major player in establishing this program as an ASEE committee and later as a division. He was chair of the North Midwest Section and hosted a meeting at Iowa State. He is completing a three-year term as chair of Zone III and as a member of the ASEE Board of Directors.

Arv's many accomplishments in engineering education can be attributed to his organizational ability, his people skills, and his work ethic. He believes in doing a job right and leads by example. As an administrator he assigns responsibility and allows his people to achieve their potential. For example, as a new faculty member in Freshman Engineering in 1977, I was named by Arv to be the program chair for the annual meeting in Vancouver. I did not know anyone in EDGD, but with Arv as program director, I soon had contacts and was able to put together the program and meet the deadlines. It is because of this mentorship and opportunity that I was able to meet all of you, serve the division, and remain active to this day. Numerous other faculty at Iowa State have benefitted similarly from Arv's leadership.

Arv does manage to find time outside of work for service and recreation activities. He is an active Rotarian. He has a Ford tractor, with which he pretends to farm his large lawn. He also fishes occasionally and, according to a fishing buddy, he has adopted the catch and release method. His fishing buddy says he has mastered the release part quite well.

During his career in engineering education, many honors and awards have been bestowed upon Arv, including the Dow Outstanding Faculty Award, Oppenheimer Best Paper Award (twice), AT&T Foundation Award, Iowa State University Faculty Citation, and the ASEE Centennial Medallion for Outstanding Service. Although Arv has been involved over the years in many aspects of engineering education, his roots remain in EDGD and he treasures the professional relationships and friendships he has developed with all of you over the years.

It is my distinct pleasure and honor to now present the 1995 Engineering Design Graphics Distinguished Service Award to you, Arv.

The inscription reads:

Distinguished Service Award
Arvid R. Eide

Arvid R. Eide is hereby recognized by the *Engineering Design Graphics Division* of the American Society for Engineering Education for his outstanding contributions to the Division and to engineering education. He has served the Division in many capacities including director of programs, vice-chair, and chair. His leadership and organizational skills have benefited the Division and its membership for more than 20 years. This award, the highest that can be awarded by the Division to one of its members, acknowledges the efforts made by Arvid R. Eide on behalf of the Division and recognizes his distinguished career at Iowa State University as an educator, author, and administrator.

Presented this day
June 27, 1995
at the ASEE Annual Conference

Acceptance by Arvid Eide

I am indeed honored and frankly humbled by this special recognition. As I reflect over the list of Previous Distinguished Service Award recipients it is honestly quite difficult for me to imagine that I merit or deserve this prestigious award. I am, however, extremely pleased to receive this special recognition, and I am also proud that I am the fourth faculty member to receive this award from Iowa State being preceded by Jim Rising, Gordon Sanders and Paul DeJong.

I recall a few years ago when Larry Boss received this well deserved recognition. He provided a very comprehensive review and personal perspective of many past recipients who have made significant contributions. I will not attempt to provide a similar set of comments because Larry presented an excellent summary designed to remind each of us that a great number of outstanding people proceeded all of us and managed to forge a most remarkable division.

As I recently sat down to formalize my comments for this evening, I decided to review a number of past presentations given by others. As you are aware, their comments have been recorded in the Engineering Design Graphics Journal. What I discovered was a range or diversity of approaches. They reflected individual personalities, historical perspectives, suggestions for change, philosophies, advice, and sincere gratitude.

I have elected to focus on two of these areas as I outlined my brief remarks: Specifically, the EDG Division together with a set of principles that I have adopted over some twenty-five years of experience; a sort of check-list that I try to apply in most situations.

The Division

First the division,

I attended my first ASEE meeting at Penn State in 1969. I recall as a young Assistant Professor what it was like at that very first meeting. I recall how exciting it was to learn about new ideas, to meet other people who were working in the same field, and I recall very vividly that I did not know anyone other than two or three faculty for ISU. I also remember how very much enjoyment others (i.e., more senior members) seemed to derive from greeting friends, peers, and other professionals. It did, however, take two or three meetings before I began to look forward to seeing new friends. Now, after some 25 annual meetings, many section meetings, zone meetings, and a few Mid-Year EDG Division meetings, I am one of the senior members.

My initial interaction with the division started by preparing and presenting papers. As I began to get known by the Division leadership I was assigned to a number of committees. Over time, I was asked to assume more responsibility, being placed in charge of committees and eventually being elected to division leadership myself. During this process, I had the good fortune to get well acquainted with many EDGD members. By attending as many meetings as possible, I learned what other schools were doing, I learned about new methods or approaches, emerging directions and new techniques for better classroom teaching and how to help develop a stronger graphics program at Iowa State.

Although I have ventured into other ASEE areas during the past 25 years, the EDGD has remained my base or home division. I am proud to be a member of this division and hope to continue service in ways my limited talent may allow.

Ten Principles

In addition to these brief remarks about the EDG Division, I would also like to share with you some thoughts about a few important principles that I have learned in some 25 years of administrative experience.

Let me set the stage with a simple example. Gordon Sanders, a past recipient of the award, was my office mate when I first started teaching in the Engineering Graphics Department. Since the first day I met Gordon, he has been my mentor and long time personal friend, and example of someone that I truly have tried to emulate. He provided me a sage bit of advice one day as we pondered some significant subject. I was trying very hard at the time to convince him of my point of view. He said, "A man's mind changed against his will is of the same opinion still." I have found this to be absolutely true. It is precisely why we must engage people in the process of enlightenment. People will only truly commit themselves if they are part of the process, not innocent bystanders. This, by the way, applies to students as well.

This example is intended to demonstrate that over the years, I like each of you have stored successful bits f information. I have been involved in collecting and experimenting with such items, and I believe that I have learned a few simple lessons in both teaching and administration that I would like to share with you.

I decided that I would list the 10 most significant principles that I have learned in my years as a teacher and a list of 10 learned as an administrator. To my complete surprise, when I completed these lists they contained the very same, identical items. In fact, as it turns out, these are reasonably good principles for every thing we do.

Ten Basic Principles
by Arvid Eide

Honesty	Is it the truth? *Absolutely nothing more important*
Respect	Are we respectful of others?
Fair	Is you action fair to everyone"
Humility	Take the blame, distribute the praise.
Reliable	Can people depend on you?
Patient	Show patience, but be tenacious.
Listening	Listen more and talk less.
Work hard	Be prepared. *Nothing of value comes without considerable effort.*
Enthusiasm	Be enthusiastic about everything you do.
Humor	Above all else, maintain a sense of humor.

Calendar

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

1996 Illinois-Indiana Section Conference
March 22-23, 1996
Bradley University, Peoria, IL
Contact: John Francis at 309-677-3670
email: jef@bradley.edu

North Central Section Annual Conference
April 11-13, 1996
Ferris State University, Big Rapids, MI
Contact: Clare Cook at 616-592-2367
email: cookc@cot01.ferris.edu

1996 CIEC - ASEE
College Industry Education Conference
January 25-29, 1996
San Jose CA
Contact: Ken Gowdy at 913-532-5590
email kgowdy@ksuvm.ksu.edu

International Conference on Engineering Computer Graphics &Descriptive Geometry
July 18-22, 1996
Cracow, Poland
Cracow University of Technology (CUT)
ICECGDG Organizing Office
Cracow University of Technology, A-9
Warszawska St. 24
31-155 Cracow, Poland
E-mail: icecgdg@oeto.pk.edu.pl
Fax: +48 12 233212
USA contact: Dennis R. Short
E-mail: short@vm.cc.purdue.edu

1996-97 EDGD 51st Annual Mid-Year Conference
Location: North Carolina State University
General Chair: Eric N. Wiebe
Program Chair: Bob Chin
Graphic Communications Program
Department of Occupational Education
College of Education and Psychology
North Carolina State University
Box 7801, Raleigh, NC 27695-7801
(919) 515-2234
email: eric_wiebe@ncsu.edu

1997 Annual ASEE Conference
Milwaukee, WI, June 15-18, 1997
Frank Croft, EDGD Program Chair
email: croft.3@osu.edu

ICED '95 Praha
International Conference on Engineering Design
Aug. 22-24, 1995
Czech Technical University (CVUT), Prague, Czech Republic
Theme: Design Science for and in Design Practice
Contact: Czech Technical University (CVUT)
Faculty of Mechanical Engineering,
Technicikâ4, CZ-166 07 Praha 6,
Czech Republic
Tel: +42-2-311-1273
Fax: +45-2-311-1273

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

In Cooperation with the "International Society for Geometry and Graphics," these conferences will be held concurrently.
Contact: Harold P. Santo
Tel. + Fax : +351-1-848-2425
E-mail: chpsanto@beta.ist.utl.pt

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

LETTERS

Dear Readers:

Following is a set of letters which were written in response to "Modeling: Suggested Practices for Multiviews," written by Pat Kelso and found in the Winter 1995 issue of the Journal.

Dear Mary:

I have attached comments in response to Pat Kelso's offering, *Computer Geometric Modeling: Suggested Practices for Multiviews.* As you will note, I do not believe that these ideas have much merit.

You will note that copies are being sent to Pat Kelso, Pat McCuistion, and Jim Shahan. To Kelso, to give him a shot at rebuttal for the same issue. To McCuistion as Chair of the Standards Committee. To Shahan as background for a paper proposal for the Mid-Year Conference.

Sincerely,

Edward W. Knoblock

Following are my comments on the article *Computer Modeling: Suggested Practices for Multiviews,* by Pat Kelso, *The Engineering Design Graphics Journal,* Winter 1995, Pg 46-47.

I appreciate the fact that Prof. Pat Kelso is concerned with 3-D CADD modeling of descriptive geometry problems. However, there is nothing in his article that I find useful.

First,

Pat has used the term "orthodirectional" for some time. What does it actually-mean? What is its purpose? How does it differ from the term *orthographic* and/or"orthogonal". Where can one find a definition of this term? We don't need new terms to add to the techno-babble that already polluting our environment.

Second,

Pat also suggests a set of view line practices that serve no real purpose. CADD is used in three distinct environments: Totally computer-integrated environments have no need of a prescribed set of views.

Descriptive geometry is used to both create geometry and to validate or interrogate existing geometry. Remote viewers can call up any view of their choice, and interrogate the model at will. No need of new line practices here! When hard copy is required in either the partially CIM/CAD/etc., or for the 2-D drafting emulated environments (and these will exist for much longer than the "enlightened ones" wish to admit), views must adhere to accepted projection standards, or the costs resulting from misunderstood drawings will be unbearable. Over the last several years I have had too much exposure to cost overruns, law suits and failed ventures that happen because of the low level of visual literacy among technical and support personnel in this country.

The simple fact is that whenever a 2-D hard copy view is used, at least two ordinate lines must be available to completely interpret it. If not, the view is of little, or no, use to the viewer. Even interpreting views in CADD programs is aided by using the above basic principle of orthogonal projection. Computer graphics will create more problems than it solves if technical people accept pretty pictures as a substitute for good geometric data.

Third

I also have remarks on both problems that Prof. Kelso used as illustrations. The first example "to create/construct a line parallel to a given plane that connects given skew lines" is too general. There exists an infinite number of solutions to this problem. All of these solutions can be constructed in CADKEY using a single primary auxiliary view (the edge view of the plane.) Three views are overkill, and imply a single solution.

The second sample problem, "determine the shortest connecting line/distance between two skew lines" is also simpler than implied in the article. If only the distance is needed, interrogation of the database will provide the answer without additional views. If the actual connecting line is required, it can be created in CADKEY in the view that shows both lines true length (True size of a plane that contains one line and is parallel to the second line).

This oblique auxiliary view can be obtained without the need of the primary view. Once the connecting line is created, it is automatically established in all views derived from the database. The primary (edge view] auxiliary view can be easily created if 2-D drawings are needed.

Finally, as I see it, the real problem has been ignored. That problem is that too many people are still 2-D thinkers, indoctrinated/brainwashed in the drafting mechanics of folding and miter lines. Had the majority of our clan adopted Hiram Grant's and a few others use of the Reference Plane years ago when proposed [more than 4 decades ago], the transition to 3-D CADD as well as GDT would be much easier. Had that happened, the term Datum would be used as a synonym by now, and our students and industry would be better served. Placing appropriate 3-D datums in a CADKEY view is very easy, and flexible. The use of colors and levels is very helpful. The use of 3-D datum [reference planes] negates the need for the practices proposed by Prof. Kelso.

P.S. An active standards committee could be very useful for issues such as these. Any one interested, please contact Pat McCuistion, Ohio University, Athens Ohio, (614) 593-1457.

Ed Knoblock
Professor Emeritus,
UW-Milwaukee
Lecturer, Milwaukee School of Engineering

Pat Kelso's Response

I appreciate Ed copying me with his letter to allow a response in the same issue. I regret that he found nothing useful in my article.

Re: "orthodirectional." Mongé discovered that virtual space may be created on a plane surface by displaying (at least) two images of an object as (1) they are projected onto planes of projection, orthogonally, and as (2) they are projected into spatial directions which are serially orthogonal to one another. To (1) we have the word "orthographic" to describe; to (2) we have none, hence, "orthodirctional" The word "orthogonal" is too broad to describe either circumstance completely.

I was obliged to coin "orthodirctional" for the Autumn 1985 EDGJ paper titled, *Non-Orthodirctional Orthographic Projection.* The paper demonstrates that it is not necessary to project orthodirectionally in order to achieve the same results as does Mongé. But having demonstrated that, the paper acknowledges that "non-orthodirectional projections to achieve the same results, also does not require fewer projections. Since it does not improve on the Mongéan problem solving process, I presented it merely as a curiosity. However, the advent of computer virtual space requires we use the term (or any other of the same meaning) if we are to adequately describe the computer's spatial problem solving processes: computer virtual space often allows us to omit "Mongéan orthodirectional" steps in determining desired views.

I am afraid I don't follow Ed's reference to "ordinate lines." If this is a large point, perhaps he might elaborate and allow me to address it later.

My *Suggested Practices* article apparently mislead Ed, judging particularly from his comments on my second sample problem. Since the article addresses hardcopy presentations only, a reference to a database query does not apply. Not that both Ed's and my examples show (except in my example the parallel plane does not contain either of the given lines), to project the TL view of the connector requires one auxiliary; to locate the connector requires another auxiliary. The crux of the matter is that the true-shape of a plane parallel to the given lines is determined in one auxiliary and without having first to project the plane into an edge view. Similarly, to project the edge view of the plane (for a different solution) again requires only one auxiliary and without having first to determine the direction of a TL line on the plane. Both alternatives are required by Mongéan techniques.

I acknowledge and agree with Ed's points re solutions views in CadKEY. My article should be read as addressing only the hardcopy printouts of spatial solutions. My article suggests how hardcopies of multiviews may be presented without having to use explanatory notes to point out the exceptions to the usual Mongéan technique; the article suggests linetpye standards that will signal to a viewer of a multiview when a projection is and is not orthodirectional. If an old descript hand were to see a printout showing the true shape projection of a plane from anything other than an edge view, he is going to wrinkle his brow. My suggested practices preclude this and, hopefully, some of the cost overruns due to the visualization problems Ed speaks of.

With regard to my first example illustration, "Determine: The line parallel to the oblique plane that connects the given skew lines, "Ed's point is well taken; it should read, "Determine: The shortest line..." The solution shown is correct for this specification.

Ed is preaching to the choir when he talks (to me, at least) about Reference Planes. When I work on the board I resist drawing one line that represents the edge view of a plane in one view then have the same line to represent the edge view of a different plane in another view. Folding lines may be neater, but that is the only thing to recommend them. Notice, however, in my article examples, that serial Reference Planes, if applied, are not necessarily mutually orthogonal. But notice more importantly, that since measuring from Reference Planes, or folding lines, in computer virtual space has no function in the creation of views, that is, because they are now merely artifices to conveniently show the demarcation between views, a single set of double lines is recommended in the case of non-orthodirectional projection, and merely a single line for orthodirectional projection.

In passing, allow me to quibble with Ed's use of the term "descriptive geometry" as he applies it to computer modeling. Per my "Aurevoir Gaspard" letter of a year or so ago (and also in the past efforts of others, principally from the University of Texas-Austin) I argue that "descriptive geometry" applies only to creating Mongéan virtual space and not to the geometric analysis within virtual space I suggest that the term "spatial analysis" is the more descriptive.

While I have the floor: our good editor in order to make my prose more decipherable inadvertently changed the meaning of a paragraph in my original. Where it reads,

"The Second suggested practice is to use double lines between views. These double lines do not need to be orthodirectional."

should read:
"The second suggested practice is to use double lines between views which need not be orthodirectional."

Or in other words, it is the views that need not be orthodirectional, not the double lines notations

Also in the final paragraph,

"...true length-shape of a plane...".

should read:

"...true shape of a plane..."

To close, allow me to compliment Ed on his continued concern for the nuances of our discipline and his sharp eyes and brain. The computer has brought a new focus on our discipline from a theoretical stand point that in the past was not investigated completely or even especially needed to be. I hope Ed's rising to the occasion encourages the *Journal* and others to informally exchange views through letters in the *Journal*. This might alleviate some of the pent up frustration vis-a-vis, descript, Reference Planes vs. Folding Lines, visualization, how to keep up with software advances and also teach the basics (can parametric modeling and sectioning be covered in the same 2 or even 3 hour course?), teaching methodologies, per se (are tutorials the best or only way to teach modeling?), and others.

Best To All,

Pat Kelso

PS I trust (1) that CadKEY's capability to lay out the solutions in a "descriptive geometry-like" fashion and (2) that graphical error is a thing of the past, is properly appreciated.

A Simple Convenient Method of Constructing Ideal Perspective

Ding Zhong Kun

Department of Fundamental Courses
Shanghai Adult Construction University

Abstract

This paper offers a simple quick method to locate and draw the measuring points of the ideal perspective, even when the placement of the vanishing point is situated beyond the edge of the paper. It can still conveniently construct the measuring point, thus it manages to construct ideal perspective.

Principle

In order to make the two-point perspective up to self-ideal effect, architects, above all, may draw the perspective direction of two sides of perspective. In this case, the two vanishing points are determined, then if the position of the object relative to the picture plane is defined, the position of the measurement point can be refound. In this manner we can conveniently draw the perspective. In Figure 1, the angle formed by the frontal of the house with the picture plane is α, and the angle formed by the side of the housewith the picture plane is β (=90°-α). In the right triangle, $sf_2= \sin\alpha f_1f_2$, $sf_1=\cos f_1f_2$. As a rule, in two-point perspective, α=30°, so

$$\left.\begin{aligned} sf_2 &= \sin 30^\circ\ f_1f_2=0.5f_1f_2 \\ sf_1 &= \cos 30^\circ\ f_1f_2=0.866f_1f_2 \end{aligned}\right\} \quad (1)$$

with $sf_2 =F_2M_2$, $sf_1=F_1M_1$, $f_1f_2=F_1F_2$, Equation (1) becomes

$$\left.\begin{aligned} F_2M_2 &=0.5F_1F_2 \\ F_1M_1 &=0.866F_1F_2 \end{aligned}\right\} \quad (2)$$

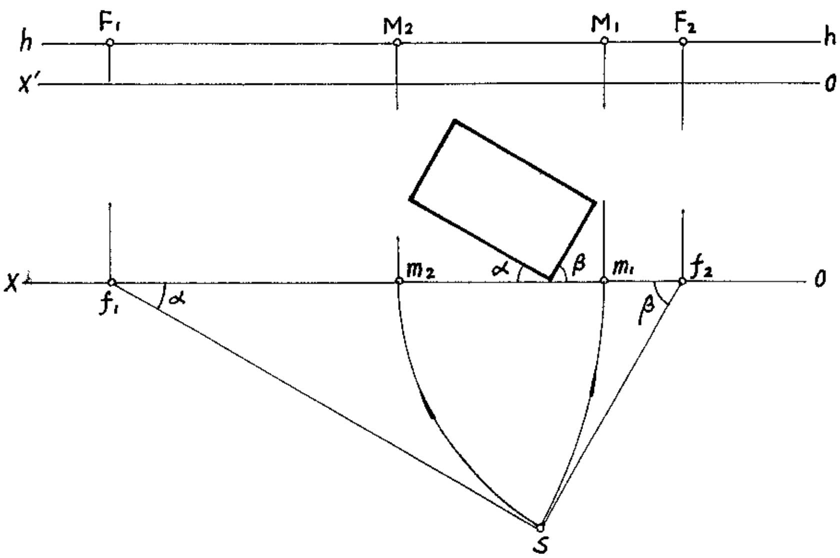


Figure 1. Construction principle

It follows that if we only take the middle point on the line F_1F_2, the measuring point M_2 can be obtained and take 0.866 length from point F_1 on line F_1F_2, the measuring point M_1 can be obtained. The measuring point M_1 may also be found by using the parallel line method.

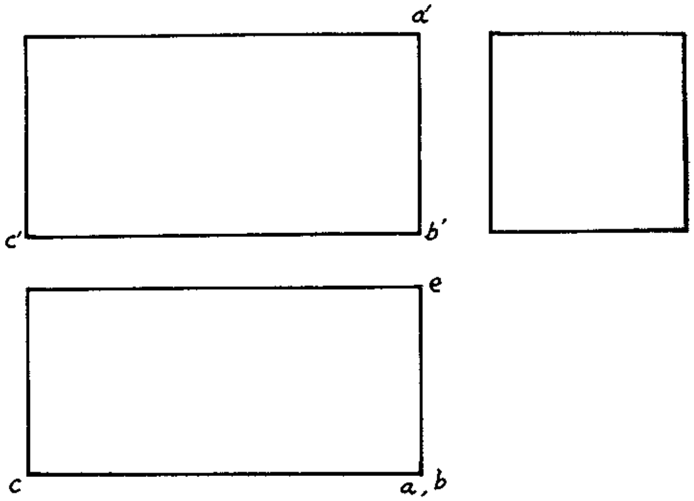


Figure 2. Given projection drawing

Construction

Figure 2 shows the given projection drawing of a house. The ideal perspective direction of the frontal and profile of views of the house is assumed in Figure 3. Two vanishing points F_1 and F_2 are situated beyond the edges of the paper. In this case the construction of the ideal perspective of the house is as shown in Figure 4.

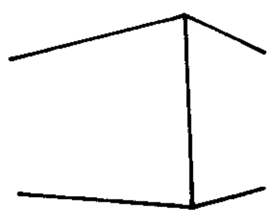


Figure 3.
Ideal perspective direction

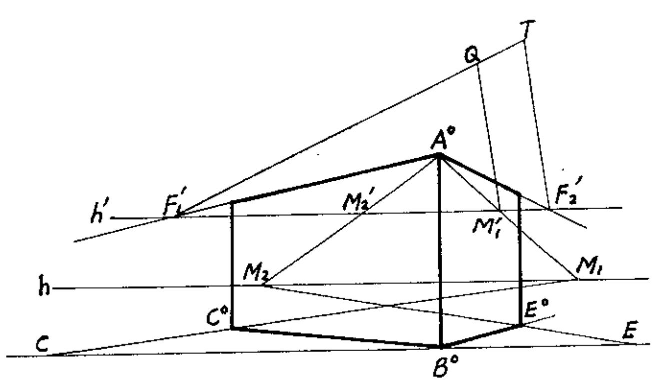


Figure 4. Construction

Figure 4. Construction

1. Drawing a random line h' h' parallel to the horizon line hh intersects perspective direction of frontal in point F_1' and intersects perspective direction of profile in point F_2'.
2. Middle point M_2' may be taken on line F_1'F_2'. A straight line can be connected with point A°,M_2 and lengthened to intersect the horizon line hh at the measuring point M_2.
3. By drawing a random line F_1'T from F_1' and taking a length equal to 10 units and measuring the length equal to 8.66 units from point F_1' on F_1'T, thus the point Q is obtained.
4. Line TF_2' can be connected. From point Q, draw a straight line parallel to TF_2' which intersects line F_1'F_2' in point M_1'. A line can be connected with point A°, M_1' and lengthened to intersect horizon line hh at the measuring point M_1.
5. Through point B°on the ground line, we measure respectively, the frontal length of the house B°C=bc and the profile lenth BE=be. A line can be connected with point M_1,C and intersects the frontal perspective direction line at point C°. A line can be connected with point M_2,E and intersects the profile perspective direction line in point E°.
6. Through point C°,E° we draw a vertical line. The perspective of the frontal and the profile of the house is accomplished.

NATIONAL DESIGN GRAPHICS COMPETITION

Date: 1 August, 1995

Dear Colleague,

On behalf of the sponsoring divisions of the American Society for Engineering Education (ASEE) and the corporate sponsors, I want to invite you to submit student design projects for the National Design Graphics Competition (NDGC). This event will be held in conjunction with the 1996 ASEE Convention, June 23-26, 1996, Washington, D.C.

Please find the enclosed guidelines and registration forms for this event. These documents should answer most of your questions. The project this year is a lawn mower jack. Servicing lawn mowers would be much easier if it wasn't so difficult to gain access to the under side of a mower. I hope you enjoy the project.

The graphic part of the project is a major component of the competition. The graphics must augment the written report and present a chronological graphic record of the project. Any graphic form is acceptable including concept sketches, photographs, graphs, detail drawings, assembly drawings, etc.

Please pay particular attention to the point values for each stage of the design for the written and graphic parts of the project. The judges of the 1995 projects suggested attention be focused on a well written abstract and adherence to the design sequence.

The main reason for this competition is for the students to gain a good understanding of the design process. Only 20 points are related to a workable design. With your help, your students have an opportunity to learn a design sequence that will stay with them for the rest of their lives. I hope to see you in Washington, D.C.

Sincerely,

Patrick J. McCuistion, NDGC Chairman

P.S. The winners in 1995 were: 1st Place, Virginia Polytechnic Institute & State University; 2nd Place, Miami University (Ohio), and 3rd Place, Colorado School of Mines. The winners and their schools won a considerable amount of AutoCAD software. Congratulations to <u>all</u> participants and many thanks to the judges, Addison-Wesley and Autodesk for providing guidance, software, and finances.

CORPORATE SPONSORS
ADDISON-WESLEY
AUTODESK

ASEE DIVISON SPONSORS
ENGINEERING DESIGN GRAPHICS
DESIGN IN ENGINEERING EDUCATION
FRESHMAN PROGRAMS

NATIONAL DESIGN GRAPHICS COMPETITION

1996 COMPETITION GUIDELINES

The National Design Graphics Competition (NDGC) will be held June 23-26, 1996, in Washington, D.C., in conjunction with the American Society for Engineering Education (ASEE) Annual Conference. In addition to the competition, a display of the entries will also be held.

I. Design Project:

The project is to design a lawn mower jack. The purpose of the jack is to allow easy cleaning of the housing and removal of the blade and oil plug. It must be designed for non-riding type rotary power mowers with cutting widths from 18" - 22". The jack must be able to securely position the mower at 6" intervals from 6" - 36" from level ground to the lowest part of the housing. None of the mechanism is allowed directly under the housing. There must be clear access to the underside of the mower. The mower must remain in a horizontal position at all times. Smooth, safe operation and conservative pricing are very important.

II. Project Contents:

Each project entry should contain the items in sections A-C. The possible point value for each part of the entry is noted after the description. The highest judged average point value will be used to determine the winners. One copy of the abstract, written report, and all graphics must be submitted for each entry.
- - Do not send original work - -

A. ***Abstract:*** An abstract page typed on 8.5" X 11" white paper shall accompany each report. It must include the project title, school name, participating student names, date completed, estimated time to complete, and a coherent narrative of no more than 250 words. The type font should be no less than 12 point size. 10 points

B. ***Written Report:*** The written report shall be type written on no more than 10 - 8.5" X 11" white paper pages. The print must be double spaced, on one side only, be 10-12 point font size, and not encroach on 1" borders on all four sides of each page. The report shall be a segmented narrative that completely describes the results of the activities of the team members in the following areas: 1) *Problem Statement*, 2) *Preliminary Ideas*, 3) *Refinement*, 4) *Analysis*, and 5) *Final Solution*. No graphics are permitted in the written report. Each section is worth 15 points. (75 points total)

C. ***Graphics:*** A chronological graphic record is an integral part of this competition. The graphics must be grouped separately from the written report. Pertinent graphics are required for each phase of the design project. Each graphic must include the minimum of a title, date, and name of the person who is responsible for it. The point values for the different sections are: 5 - *Problem Statement,* 20 - *Preliminary Ideas,* 20 - *Refinement,* 20 - *Analysis,* 35 - *Final Solution.* (100 points total)

D. Additional Scoring: A *Workable Solution* to the problem and the *Presentation Quality* of the entry are worth 20 points each.

III. Project Team/Entry Limitations:

A. The maximum number of students per project is 5. Each team member must be enrolled in the same Freshmen level class where this design project is introduced.

B. The maximum number of entries per school or branch campus is 3.

CORPORATE SPONSORS
ADDISON-WESLEY
AUTODESK

ASEE DIVISON SPONSORS
ENGINEERING DESIGN GRAPHICS
DESIGN IN ENGINEERING EDUCATION
FRESHMAN PROGRAMS

NATIONAL DESIGN GRAPHICS COMPETITION

IV. Project Interest and Registration Forms

Please find the entry forms on the back of this page. The Project Interest Form must be received no later than March 1, 1996. The Registration Form and entry fee for each design team must be received no later than June 1, 1996.

V. Entry Fee:

An entry fee of $10.00, in U.S. currency, must accompany each Registration Form. Entry fees are not refundable.

VI. Entry Submission Date and Time:

All project entries must be submitted at the judging session or at the main conference hotel registration area before 8:30 a.m. (Eastern Time Zone), June 23, 1996. Transporting the project(s) to the conference is the sole responsibility of the entering school.

VII. Judging:

Judging will be based solely on the items listed in sections I - VI. Each project will be judged by three judges. Judging will start on Sunday morning at 9:00 a.m. and be completed the same day.

VIII. Display Location and Schedule:

Location:	Sheraton Washington Hotel
Set-up:	June 23, between 2:00 p.m. and 4:00 p.m.
Display hours:	9:00 a.m. - 5:00 p.m. June 24 & 25 Project security is the responsibility of the entering schools.
Removal:	June 26 between 10:00 a.m. and 12:00 noon Removal and return of projects is the responsibility of the entering schools. Projects not removed will not be returned.

IX. Display contents:

The displays must include the written report and the graphics. An 8.5" X 11" placard with the school and advisor names will be provided for each entry. The displays may utilize any additional medium of communication but must fit on table space no larger than 36" wide X 30" deep.

VII. Awards/Prizes:

Team members from the First, Second, and Third place teams will receive an appropriate certificate and Autodesk software. All other students will receive certificates of participation. The award winning schools will receive plaques and one copy of the software.

Please direct questions to: Patrick J. McCuistion
124D Stocker
Ohio University
Athens, OH 45701-2979

Phone - 614-593-1457
FAX - 614-593-4684
e-mail - pmac1@ohiou.edu

CORPORATE SPONSORS
ADDISON-WESLEY
AUTODESK

ASEE DIVISON SPONSORS
ENGINEERING DESIGN GRAPHICS
DESIGN IN ENGINEERING EDUCATION
FRESHMAN PROGRAMS

1996 ASEE NATIONAL DESIGN GRAPHICS COMPETITION
PROJECT INTEREST FORM
Washington, D.C.

Our institution is considering submission of student design projects:

Number of Freshman projects ____ (3 permitted)

Contact person at your institution:

Full Name: ______________________________

Address: ______________________________

____

Phone #: ______________________ Fax #: ______________________

Please mail to: Patrick J. McCuistion, Ohio University, 124D Stocker Center, Athens, OH 45701-2979

This form due by March 1, 1996

-- CUT ALONG THIS LINE --

1996 ASEE NATIONAL DESIGN GRAPHICS COMPETITION
REGISTRATION FORM
Washington, D.C.

All the information on this form should be the same as you wish it to appear on any award.

Advisor(s): ______________________________

School: ______________________________

Address: ______________________________

____

Phone #: ______________________ Fax #: ______________________

Team Members: ______________________ ______________________
(limit of five)

______________________ ______________________

____

Please mail to: Patrick J. McCuistion, Ohio University, 124D Stocker Center, Athens, OH 45701-2979

This form due by June 1, 1996

NATIONAL DESIGN GRAPHICS COMPETITION

Date: 1 August, 1995

Dear Colleague,

On behalf of the sponsoring divisions of the ASEE and the corporate sponsors, I want to invite you to judge the 1996 National Design Graphics Competition. This event will be held in conjunction with the ASEE Convention, June 23-26, 1996, in Washington, D.C.

We will start on Sunday June 23, at 9:00 a.m. and finish with lunch about noon. We will first cover the judging criteria and then the judging sheets and projects will be assigned. When you complete the judging, you will hand in your score sheets for tabulation. The scores will be compiled and the results will be announced at the sponsoring division lunches and banquets.

If you will be in attendance and would like to help judge, please fill in the enclosed Judging Interest form and mail to the printed address.

Sincerely,

Patrick J. McCuistion, NDGC Chairman

- CUT ALONG THIS LINE -

JUDGING INTEREST FORM
1996 ASEE NATIONAL DESIGN GRAPHICS COMPETITION
Washington, D.C.

I am interested in judging the 1995 competition. Please contact me in March 1995 to confirm my availability. Please use single stroke gothic capitals.

Name: ______________________________

Address: ______________________________

____

____

Phone #: ____________________

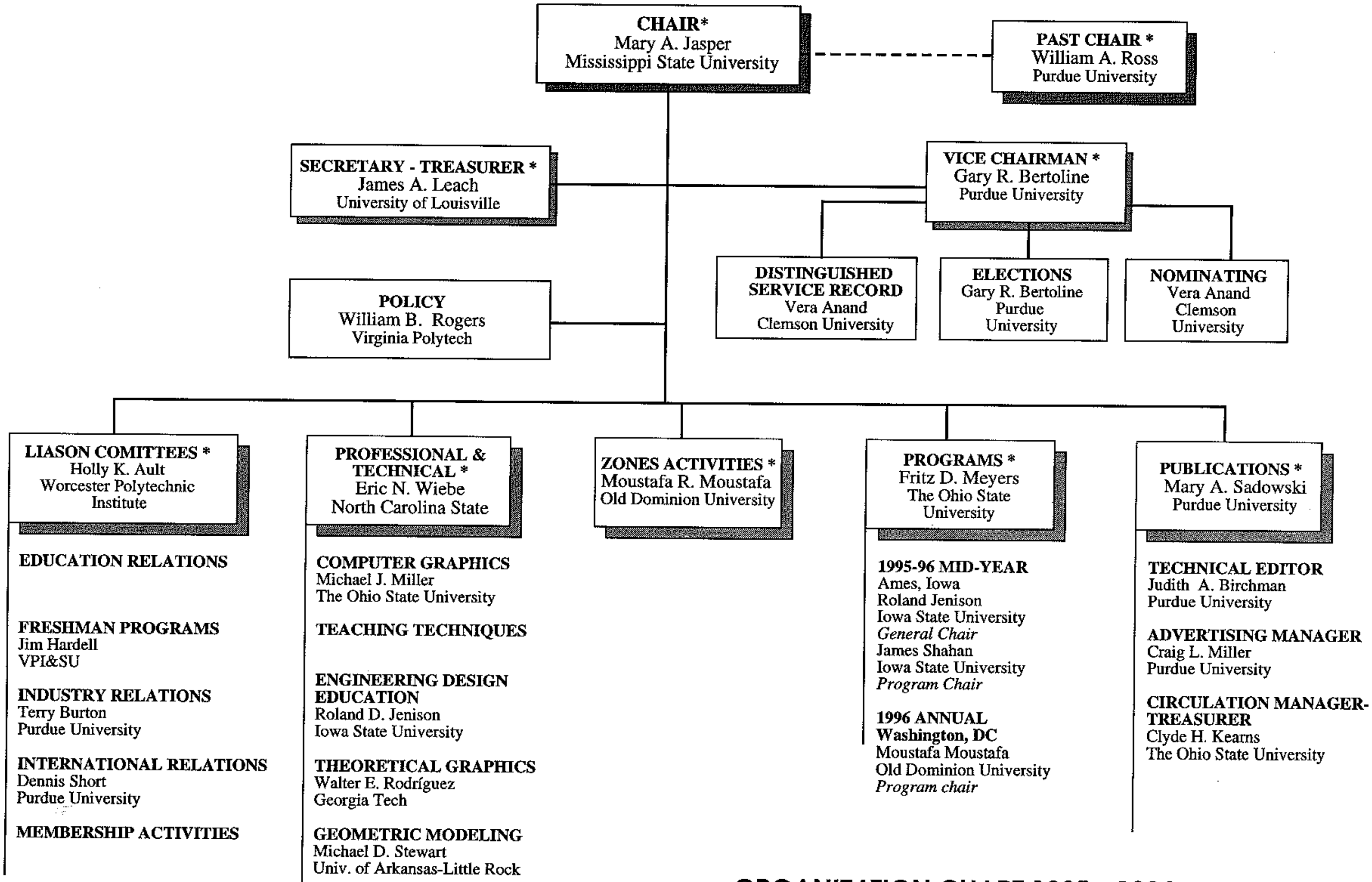
FAX #: ____________________

Please mail to: Patrick J. McCuistion, 124D Stocker Center, Ohio University, Athens, OH 45701-2979

CORPORATE SPONSORS
ADDISON-WESLEY
AUTODESK

ASEE DIVISON SPONSORS
ENGINEERING DESIGN GRAPHICS
DESIGN IN ENGINEERING EDUCATION
FRESHMAN PROGRAMS

ENGINEERING DESIGN GRAPHICS DIVISION of ASEE



ORGANIZATION CHART 1995 - 1996

* **Executive Committee member**

Submission Guidelines

The *Engineering Design Graphics Journal* is published by the Engineering Design Graphics (EDG) Division of the American Society for Engineering Education (ASEE). Papers submitted are reviewed by an Editorial Review Board for their contribution to Engineering Graphics, Graphics Education and appeal to the readership of the graphics educators. By submitting a manuscript, the authors agree that the copyright for their article is transferred to the publisher if and when their article is accepted for publication. The author retains rights to the fair use of the paper, such as in teaching and other nonprofit uses. Membership in EDGD-ASEE does not influence acceptance of papers.

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

Mary A. Sadowski, Editor
Engineering Design Graphics Journal
1419 Knoy Hall / Technical Graphics
Purdue University
West Lafayette, IN 47907-1419
FAX: 317-494-0486 PH: 317-494-8206

Cover letter should include your complete mailing address, phone and fax numbers. A complete address should be provided for each co-author. Use standard 8-1/2 x 11 inch paper, 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. All line work must be black and sharply drawn and all text must be large enough to be legible if reduced. The editorial staff may edit manuscripts for publication after return from the Board of Review. Upon acceptance, the author or authors will be asked to review comments, make necessary changes and submit both a paper copy and a text file on a 3.5" disk.

Page Charges

A page charge will apply for all papers printed in the *EDG Journal*. The rate is determined by the status of the first author listed on the paper at the time the paper is received by the Editor. The rates are as follows:

$5 per page for EDGD members
$10 per page for ASEE, but not EDGD members
$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.

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.
300 Zeeb Road
Ann Arbor, MI 48106

The *Engineering Design Graphics Journal* is published three times a year by the Engineering Design Graphics Division (EDGD) of the American Society for Engineering Education (ASEE). Subscription rates: ASEE/EDGD members, $6.00; non-members, $20.00. If you would like to become a member of EDGD/ASEE, write ASEE, Suite 200, 11 Dupont Circle, Washington, D. C. 20036, and request an ASEE membership application. Non-members can subscribe to the *EDG Journal* by sending their name, address, telephone number, and a $20.00 check or money order payable to Engineering Design Graphics. Mail to:

Clyde Kearns
The Ohio State University
2070 Neil Avenue
Columbus, OH 43210

PAPERS

Circulation Manager
The Engineering Design Graphics Journal
The Ohio State University
2070 Neil Avenue
Columbus, OH 43210-1275 USA

ADDRESS CORRECTION REQUESTED

Non-profit Organization
U.S. Postage
PAID
Permit No. 221
Lafayette, Indiana