An Integrative Approach to Computer Graphics for Freshman

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ABSTRACT: The paper describes a multi-disciplinary computer graphics course with a final project whose basic intentions are 1) to provide motivation through creativity and cooperation for the study of engineering and 2) to develop the graphical communication and visualization skills of the student via the use of pencil-and-paper sketching supported by appropriate computer software. A majority of the course content was designed around a report, *Proceedings of the NSF Symposium on Modernization of the Engineering Design Curriculum*, 1990, Mechanical Engineering Department, University of Texas at Austin, and uses the Barr/Juricic model of the curriculum. Electrical, Civil, and Mechanical Engineering freshman develop a "sketch-as-plan" approach to their creation of images that vitalize design ideas. Image content is manipulated and re-worked in pencil and with AutoCAD Release 13 or MicroSim PSpice. A common final project for Civil and Mechanical Engineering revolves around solid model construction. An Electrical Engineering project involves designing, building, analyzing and testing a milled printed circuit board for a regulated power supply chip. The paper describes the history of the content and implementation strategies for all disciplines.

Course General Description

EGR 112, Engineering Design Graphics, is the third course in the sequence of common engineering courses given at the University of Portland School of Engineering. The first two courses in the sequence introduce basic concepts and practices in Civil, Electrical, and Mechanical Engineering. EGR 112 is a three semester-credit hour class, with a one hour lecture and two hours of back-to-back lab periods, given one day a week. Approximately three to four hours of homework are assigned each week of the semester. There is a project which has milestone due-dates spread over the entire semester. The main computer system used is Unix/X Windows run on Sun SPARCstations and X-terminals.

Basic Philosophy

In order to formulate a unique motivating strategy for students at the beginning of their engineering educational experience, two fundamental approaches have developed. First, the creative aspects of their normally routine in-class work and homeworks are emphasized by keeping the worked examples and exercises open-ended. For example, a given architectural elevation drawing can lead to any number of generated plan views that the student is allowed to invent on her own. All submitted work suits the particular individual esthetic and appeals to the student's talents, common-sense, and notion of what is appropriate. Second, subject matter is specialized according to the discipline of interest. For example, the class is tracked into Civil, Electrical, and Mechanical Engineering, where lecture, labs, homeworks, and project are different for each discipline. This leads to a greater sense of satisfaction with the focus of the class. This is a move towards teaching to the individual and her interests.

These two fundamental approaches are guided by a vision of the engineering design process seen as “an integrative blend of technical knowledge, creative abilities, analytical and communicative skills, and practical and social awareness.” [1] By emphasizing creativity within the domain of their discipline-specific technical subject matter, engineering practice is not seen as a scattered application of bits and pieces of technical knowledge, but begins to be viewed as part of a larger expression of the person as a responsible member of a benign and creative society.

Historical Perspective

Traditionally at the University of Portland, graphics for all engineering freshman was a drafting class centered around typical 2-dimensional mechanical engineering drafting topics. There was no discipline-specific subject matter, i.e. no electrical, electronic or computer-track graphics, and no civil engineering or architectural graphics. At the time, the perceived drawbacks to the traditional approach were:

- There was a total lack of development of 3-dimensional visualization skills.
- Students had an inability to execute pictorial drawings, particularly isometrics.
- There was no motivation for freshman interested in Electrical or Civil Engineering.

This traditional approach was modified in 1982 with the introduction of computer drafting. At the time, the perceived advantages of this approach were:

- In follow-up classes, drafting work was greatly expedited via use of CAD techniques.
- Training was contemporary with modern engineering practice.
- Elimination of the traditional approach drawbacks listed above.

This changed in 1992 with the introduction of the Barr/Juricic model of the curriculum. [2] At the time, the perceived advantages of this approach were:

- The new paradigm yielded stronger 3-dimensional visualization skills.
- Students gained familiarity with the construction and editing of a virtual solid model.
- The habit of using the sketch as a plan for the final product or system developed.

Further refinement of the above approach was attempted in 1997, when the syllabus for a single course was split into three divisions according to engineering discipline, i.e. Civil, Electrical, and Mechanical. Additionally, Electrical Engineering freshman moved partly away from the Barr/Juricic model. At the time, the perceived advantages of this approach were:

- Higher motivation levels became evident because of discipline-specific subject matter.
- Enhanced creativity was allowed in weekly work and the final course project.
- Allowed the students to have an interdisciplinary experience.

Curricular Objectives

In the sequence of courses presented to freshman, EGR112 normally comes in the Spring semester, following Fall semester classes EGR110, Introduction to Engineering, and EGR111, Introduction to Engineering Laboratory. The engineering graphics content of the Fall semester classes is supportive of the design content contained in them, but it was decided to put a majority of graphic communication and visualization skills training into a specialized computer graphics class given in the Spring.

The major curricular objectives of EGR112 are to:

- make the beginning of learning engineering a positive, exciting, and pleasant experience.

• amplify the creative dimension of personal work.
• establish a foundation for cooperative behavior within the sphere of individual achievement.
• foster effective graphical communication skills and the sketch-as-plan methodology.
• develop 3-dimensional visualization skills, using manual techniques followed-up by CAD techniques.
• motivate by using example graphics from the discipline of interest to the student.

Course Outline

The organization of the class is based upon the weekly curriculum outline proposed by Barr/Juricic, and "assumes that each week has time allocated for a lecture period, a manual lab assignment, and a CADD/SM assignment." [3] Class time is broken down into:
• a one-hour lecture covering the manual drawing assignments for Civil ,Electrical , and Mechanical Engineering and the CADD/SM assignments due the following week,
• a one-hour manual drawing assignment for Civil (CE), Electrical (EE), and Mechanical (ME) Engineering done in class following the list of topics shown in Figure 1. below, and
• a one-hour CAD lab period where the homeworks for Civil, Electrical, and Mechanical Engineering, following the list of topics shown in Figure 2. below, are started under faculty and lab assistant supervision.

Figure 1. Manual Drawings (Done in pencil on prepared plates)

Civil	Electrical	Mechanical
A Basic CE Drawing	A Basic EE Drawing	A Basic ME Drawing
CE Scales and Rulers	EE Diagram Symbology	ME Engineering Diagrams
Geometric Constructions	PSpice "Schematics" Introduction	ME Scales and Rulers
Orthographic Projection 1	Orthographic Projection 1	Geometric Constructions
Orthographic Projection 2	Orthographic Projection 2	Solids into Shapes
Architectural Sections 1	Block Diagrams	Isometric Sketching
Architectural Sections 2	Schematic Diagrams 1	Model Sketching/CAD Building
Site, Plot Plans	Schematic Diagrams 2	Orthographic Projection 1
Architectural Elevations	Wiring Diagrams	Orthographic Projection 2
Structural Steel Detailing	Cable and Harness Drawings	Missing Lines Drawing Exercises
Concrete Detailing	Logic Diagrams	Sections and Auxiliaries
Electrical and Piping Details	Printed Circuit Board Layout	Design Revision - Tolerances/Fits

Figure 2. CAD Homeworks (Done Using AutoCAD Release 13 and PSpice A/D Version 8)

Civil	Electrical	Mechanical
AutoCAD Drawing Setup	AutoCAD Drawing Setup	AutoCAD Drawing Setup
AutoCAD Drawing Aids	AutoCAD Drawing Aids	AutoCAD Drawing Aids
2-D Geometry Creation	2-D Geometry Creation	2-D Geometry Creation
Advanced 2-D Geometry	Advanced 2-D Geometry	Advanced 2-D Geometry
2-D Shape/ Constructions	2-D Shape/ Constructions	2-D Shape/ Constructions
Viewing and Text	Viewing and Text	Viewing and Text
Basic Editing Commands	Basic Editing Commands	Basic Editing Commands
Automatic Editing	PSpice DC Node Voltage Analysis	Automatic Editing
Layers and Dimensions	PSpice Transient Analysis	Layers and Dimensions
3-D Coordinates	PSpice Digital Simulations 1	3-D Coordinates
ACIS Primitives	PSpice Digital Simulations 2	ACIS Primitives
Extrusion and Revolution	PSpice Analog/Digital Simulation	Extrusion and Revolution
Solid Model Analysis	PSpice PCBoards Tutorial	Solid Model Analysis

The manual drawing assignments shown above in Figure 1. are done in class, and are a collection of prepared plates that have partially-completed exercises on the facing side and complete instructions printed on the reverse side. Many of these plates contain a CAD component, which is done in the CAD lab directly following the completion of the manual drawing. This CAD component is different according to discipline, e.g. as shown in Figure 1., the pencil-and-paper component of Orthographic Projection plates 1 and 2 are the same for Civil, Electrical, and Mechanical, but their CAD components require discipline-specific AutoCAD drawings. The student either re-works or completes the graphics on the plate according to instructions, lecture examples, and her own esthetic. This is normally accomplished with pencil, straight-edge and scale. No traditional drafting instruments are required save plastic templates for electrical/electronic/computer symbology.

The CAD homeworks for Civil and Mechanical are assignments from the class textbook.[5] These are sequenced to allow students to do the CAD components of the manual drawing assignments. The Electrical track spends the first half of the term doing AutoCAD from the Basics textbook, and then shifts to PSpice, using assignments taken from a PSpice lab book. [6]

The semester-long project is exactly the same for Civil and Mechanical Engineering. This involves working in groups of three to design a bicycle frame for a mountain bike. The semester-long project for Electrical Engineering is to design, build, and test a switching power supply circuit mounted on a printed circuit board (PCB).

Ideas for the mountain bike frame are first sketched within a set of geometry constraints imposed by safety and functional requirements. Then, a solid model is built of one selected sketch and analyzed. This follows a paradigm of sketch-model-analyze; *this is the "sketch-as-plan methodology, where the sketches serve as a plan for execution of the project.*

The switching power supply is first sketched, drawn and analyzed using MicroSim PSpice as an unregulated circuit within certain voltage/current constraints. Then, using "Switchers Made Simple" software from National Semiconductor Corp., a final configuration is detailed for placement on a PCB. The final configuration is then drawn in PSpice PCBoards and exported as Gerber files to LPKF CircuitCAM and BoardMaster software, which mills the traces and pads. Finally, after components are soldered onto the milled board, a test fixture and oscilloscope are used to compare output of the finished board to parameters submitted to the Switchers Made Simple software. This follows a paradigm of sketch-model-analyze-build-test, *again where the sketches serve as a plan for the execution of the project.*

Future Developments

At this time, the perceived strengths and weaknesses of the curriculum and pedagogy are:

Strengths-

• Students are more motivated because of the discipline-specific nature of the in-class work.
• The non-competitive and creative nature of the in-class, homework, and project components encourages cooperation and individual achievement.
• Given that incoming engineering freshman are more computer-literate now than at any time in

the past, they appreciate being trained on and working with the professional edition computer tools that they will actually be using when they practice engineering after graduation, *and this has strong motivating influence.*

• Civil and Mechanical students demonstrate more sophistication and facility with 3-dimensional models and their manipulation, and in their visualization skills.

• Electricals begin to demonstrate facility with graphics in the freshman year.

Weaknesses-

• When this class was initially run in the latest format in Spring 1997, there was not enough time to devote to each discipline during a one-hour lecture. Also, problems in the lab where students required discipline-specific help were difficult to address because of time constraints. This could be remedied by splitting the single class section into three discipline-specific class sections meeting at different times . The possible drawback of that remedy is that someone who enrolls in the Electrical track section as a freshman could transfer into Civil Engineering as a sophomore, and then will not have been exposed to 3-D AutoCad modeling.

• Non-parametric modeling does not allow for enough variability in the model and does not naturally fit the sketch-as-plan paradigm emphasized in the class. This can be remedied by switching to a parametric modeler, like AutoDesk Mechanical Desktop with Designer. [4]

• Not building and testing anything in the project leaves Civil and Mechanical tracks at a disadvantage, since in their practice of engineering, they deal very much with tangible (and testable) products and systems.

• The Electrical project is very ambitious and few students are able to complete it. A scaled-back version of it or an integrated, interdisciplinary project run in conjunction with Civil and Mechanical will be attempted in Spring 1998.There is no plan to repeat the same final projects within a given five-year cycle.

References

1 *Engineering Design as Research in a Senior Capstone Course: An Integrative Approach*, by Robert J. Albright, ASEE Conference Proceedings, 1995.

2 *The Engineering Design Graphics (EDG) Curriculum Modernization Project: A White Paper Summary*, by Ronald Barr and Davor Juricic, Pp.23-42 in Proceedings of the NSF Symposium on Modernization of the Engineering Design Graphics Curriculum, 1990, Mechanical Engineering Department, University of Texas at Austin.

3 Ibid , P.36 .

4 *The New Fundamentals of CAD* **-** *An Educator's Guide to Parametric, Feature-based Design*, by Steven K. Howell, P. 6, AutoDesk Inc., 1996.

5 *AutoCAD and its Applications, Release 13 , Basics and Advanced*, by Terence M. Shumaker and David A. Madsen, Goodheart-Willcox, 1996.

6 *Schematic Capture with MicroSim PSpice*, by Marc E. Herniter, Prentice Hall, 1996.

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