Engineering Graphics in an Integrated Environment

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Abstract - *This paper focuses on the freshman year of the Foundation Coalition program at Texas A&M University. The curriculum includes chemistry, English, engineering, math and physics taught in an integrated just in time fashion using technology and delivered in an active-collaborative environment to students working in teams of four. Through our thrusts of integration, teaming, active learning and technology we hope to produce engineers who can solve increasingly complex problems more effectively.*

Graphical analysis, not generally taught or used by engineering students, has provided the best avenue for integration of graphics into the freshman Coalition environment. Graphical analysis techniques introduce CADD (Computer Aided Design and Drafting) to the student in a manner that teaches graphical fundamentals and at the same time is relevant to topics addressed in other course work. Examples include:

- *Graphical solutions to vectors are used to introduce the concept of coordinate systems and scale. Students use CADD to solve vector problems, which are expanded to include statically determinant truss problems. Using a graphical method reinforces the concepts introduced in the problem solving technique and adds insight into the precision of engineering calculations and drawings.*
- *Traditional topics in descriptive geometry have been replaced with an introduction to 3D model development. The goals of this change are to improve student visualization skills and to provide the student with tools that reinforce other subject in the coalition. Area and mass properties generated by a CADD package are used in the chemistry, engineering, math, and physics classes. CADD packages provide unique tools for accomplishing these tasks and give new life graphics topics.*

Another area where graphics provides a valuable interface is in developing communication skills. Integrated technical reports, produced by student engineering design teams, include technical content (graded by science, mathematics, and engineering faculty) and are submitted to English.

Introduction

This paper focuses on technical graphics integration in the Foundation Coalition, FC, freshman year program [1] at Texas A&M University. Initial graphics integrations occurred in technical reports produced by engineering design teams for integrated projects. More recent integration events have been in implementation of graphical analysis techniques supporting other freshmen FC disciplines. These graphics classes introduce students to Computer Aided Design and Drafting, CADD, in a manner that teaches graphics fundamentals [2], is relevant to topics in the other freshman disciplines, and highlights the graphically analysis capability of modern CADD packages.

The freshman year of the Foundation Coalition program at Texas A&M University consists of 4 credit hours of chemistry, 4 credit hours of English, 5 credit hours of engineering, 8 credit hours of mathematics, and 6 credit hours of physics. These courses include a semester of chemistry (including lab), a two semester English class (including freshman rhetoric and part of technical writing), a two semester engineering course (including engineering graphics, and an introduction to engineering problem solving and computing), two semesters of calculus (although not all materials comes from the first two semesters of a traditional calculus class), and two semesters of physics (including mechanics and E&M). The courses are delivered to students as 12 semester hours in the fall semester plus 15 semester hours in the spring semester. Courses are taught in an integrated just in time fashion using technology and delivered in an active-collaborative environment to students working in teams of four.

A unique feature of the courses taught at A&M is the close coordination of subject matter maintained by the freshman faculty teaching team. Topics covered in each discipline are discussed in weekly meetings and efforts are made to teach and reinforce concepts across subject lines. Through our thrusts of integration, teaming, active learning and technology we hope to produce engineers who can solve increasingly complex problems ore effectively.

Graphics Integration

The engineering component of the curriculum has the following as central goals:

- to provide the student with the necessary skills to perform effective problem solving;
- to introduce the students to some of the basic engineering tools;
- to help the student develop a logical thought process;
- to enable the students to have better spatial analysis skills;
- to help the students develop appropriate sketching skills; and
- to teach the students how to read and/or interpret technical presentations.

Students typically learning CADD start with simple orthographic figures or line drawings and focus on producing increasingly complex drawings derived from sketched material produced in prior classes. The compression of curricula in most engineering programs and the advent of advanced analytical techniques have led to the elimination of graphical analysis techniques from freshman courses. In the freshmen FC program at Texas A&M graphical analysis concepts have actually provided the best avenue for graphics integration in the common FC freshman curricula. The following sections document several class exercises which teach graphics techniques as analytical tools in the integrated FC environment.

Vector analysis

Coalition students are introduced to vectors early in the first semester. In addition to vectors students study and experiment with the equilibrium of co-planar vector systems, and learn to identify resultants and equilibrients. In math [3], physics [4] and engineering [5] vector mechanics problems are solved analytically using the traditional method of summing components and applying equilibrium conditions. Physics also devotes a laboratory to experimentally determining equilibrium conditions using force tables.

In FC classes students are introduced CADD drawing using vector concepts in lieu of traditional orthographic or geometric construction techniques. Students are taught to draw vectors and component of vectors during their initial CADD sitting. Only a few drawing commands are taught that allow construction of line and text entities. The simplicity of vector mechanics allow coalition students to focus on the fundamental CADD concepts of entity and point location and placement, relative and absolute coordinate input, coordinate orientation, and drawing scale. Figure 1 shows a typical vector polygon assignment. Vectors are naturally expressed in Cartesian and polar forms which leads directly into the introduction of CADD coordinate systems. Using vectors as an introductory topic reinforces current topics is other coalition courses and presents the CADD package to the students as a drawing and analysis tool. Interrogation commands return basic geometric properties of vectors including magnitude, direction and component values. Vector magnitudes are quite variable immediately highlighting the need to scale drawings, the normal layering or level concept common to many CADD packages is expanded to include complex entities like resultants, equlibribants, and component layers. Complex line types are used to represent vectors and introduce students to the modularity inherent in CADD packages.

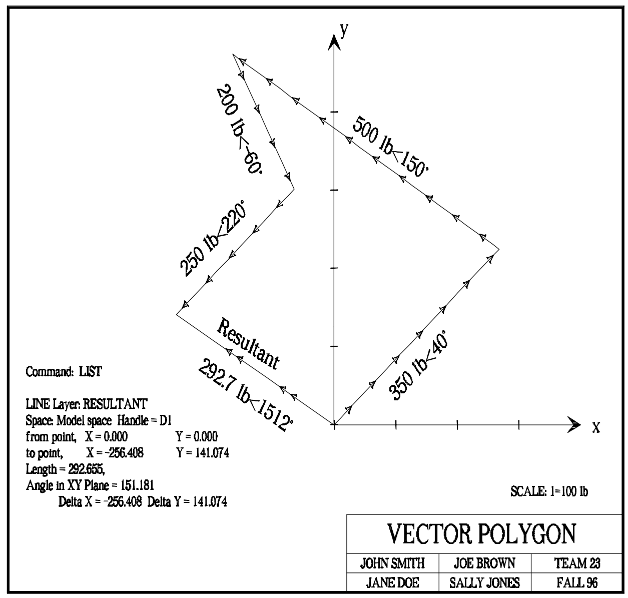

Figure 1 Typical vector polygon problem

Because vectors are simple entities and were introduced in other classes the primary focus in the first drawing session is on the mechanics of object positioning, orientation and scale. More time spent on scaling methodology and explaining the desirability of printing vector polygon results at an acceptable scale for visual verification and checking. The large variation in magnitude of the vectors from problem to problem and the possibility of changing of base units, force, velocity, etc. generalizes the concept of model space dimensions and scale.

Graphical analysis of a determinant truss

This second CADD topic reinforces initial placement and scaling concepts and introduces students to the production of a drawing set documenting steps in a comprehensive integrated analysis process, here the determination of member forces and displacements of a statically determinate truss. Integration of graphics into an engineering mechanics problem-solving task is achieved in this process. Students are expected to generate several different drawings documenting the solution process. Included are a scale drawing of the truss, vector polygons drawn to determine member forces at joints, and a drawing of the truss displaced shape. Drawing accuracy and resolution is highlighted in the development of drawing of the displaced truss shape. Concepts in dimensional scaling and dimensional units are integrated in the problem solving sequence. Each student team performs the following task list.

1. Draw a scale drawing of truss with all applied loads
2. Use the drawing of the truss to generate a free-body-diagram of the system and apply equilibrium equations to the truss to find reactions.
3. Systematically draw vector polygons of truss joints to determine member forces.
4. Enter truss forces, material data, and member geometric data in a shreadsheet and compute the axial deformation of members using basic mechanics of materials relations presented in prior problem solving classes.
5. Produce a CADD drawing of the displaced shape of the truss using deformed member lengths computed in step 4.

An integrated assignment set is shown in Figures 2 through 4 and Table 1.

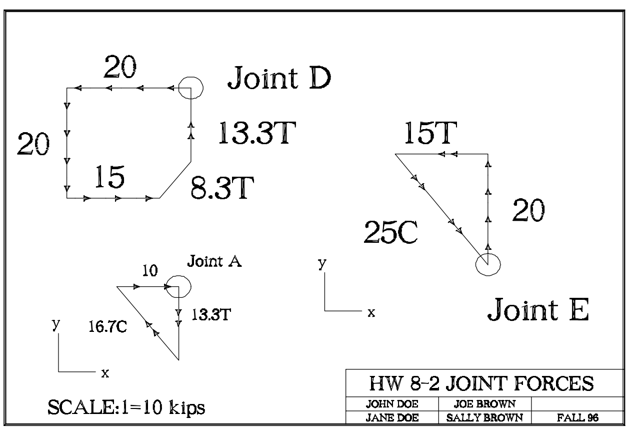

Figure 2. Vector Polygons of Joint Forces

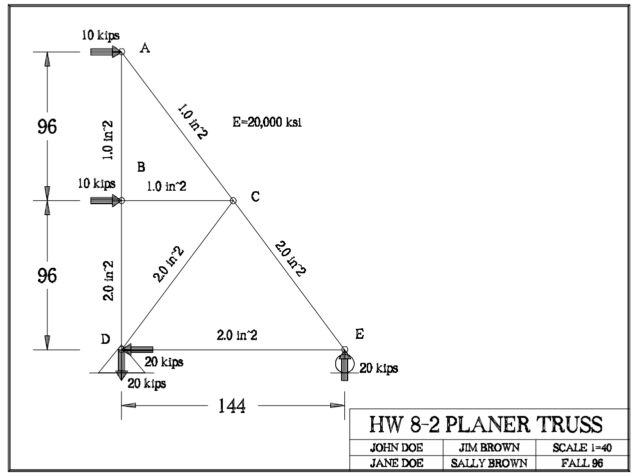

Figure 3 Free body diagram of truss

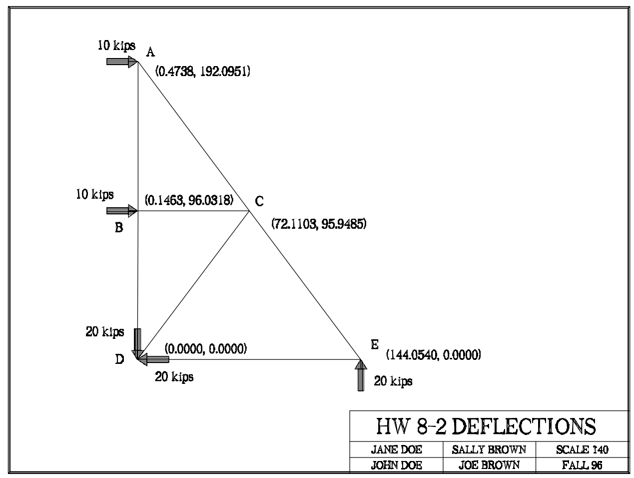

Figure 4. Displaced shape of truss

Historically Williot [6] and Williot-Mohr [7] diagrams were used to analyze trusses. More recently, virtual work, or flexibility/stiffness methods are used to determine truss joint displacements. Here students can utilize the resolution and accuracy of a CADD system to simplify the analysis process and directly create a drawing of the displaced truss shape. An initial member is replaced using its deformed length. Adjacent joints are located by swinging arcs from the ends of the initial member using radii equaling the deformed length of the two connected members. The intersection of

Table 1. Member Stresses and Deformations

Member	P kips	A in^2	E ksi	L init in	Stress ksi	Delta L in	L deform in
AB	13.3	1.0	20000	96	13.30	0.06384	96.06384
AC	-16.7	1.0	20000	120	-16.70	-0.10020	119.89980
BC	-10.0	1.0	20000	72	-10.00	-0.03600	
BD	13.3	2.0	20000	96	6.65	0.03192	96.03192
CD	8.3	2.0	20000	120	4.17	0.02499	120.02499
CE	-25.0	2.0	20000	120	-12.50	-0.07500	119.92500
DE	15.0	2.0	20000	144	7.50	0.05400	144.05400

these arcs locate the vertex of a triangle and define the displaced position of the adjacent joint. The next two joints are found by repeating this process using the two new members as base members. The displaced shape of the truss is built by repeating this process to find the displaced position of all joints. The resolution of the CADD system allows students to view the final position of all joints in the structure and interrogation commands return precise coordinates of the displaced joint locations.

Modeling in 3D

Solid modeling is taught early in the second semester to provide the students with graphical visualization and analysis tools that directly support material taught in other FC areas. During this semester FC students are introduced to integration, line, surface, and volume integrals in mathematics and to topics in physics and chemistry that require calculation of area moments of inertia and mass moments of inertia. Chemistry looks at molecular structure and mass properties that can be measured to define the structure of molecules. CADD packages provide unique tools for determining many of these geometric properties. Creation of planar and solid entities and the determination of their composite geometric properties is emphasized in the instruction sequence.

Initial 3D modeling starts with planar entities since many of the construction techniques common to 3D modeling are also used in creation of complex planar surfaces. Separating surface and solid modeling also provides a natural separation of geometric quantities for area and volume or mass. Students are given some time to assimilate area geometry and relations before looking at volume data. Surface and solid modeling reinforce the mathematical concepts of surface and volume integrals and provide an important tool for students to use in check the results of their analytical work.

Students are initially introduced to creation of planar complex regions. Regions are irregular in shape and may contain voids. These regions are created from simpler geometric shapes and from freeform boundaries. Students use Boolean operations to combine simple shapes and are introduced to local coordinate systems. Figure 5 shows a typical planar mapping problem that was developed to teach students how to determine the area, perimeter and centroid of an irregular object. Math used the same problem as a MAPLE exercise [8] in numerical integration of area.

After an instruction sequence in solid modeling students were assigned the methane molecule shown in Figure 6 and asked to determine the mass properties of the molecule. This coverage was coordinated with discussions of bond lengths and angles in chemistry [9].

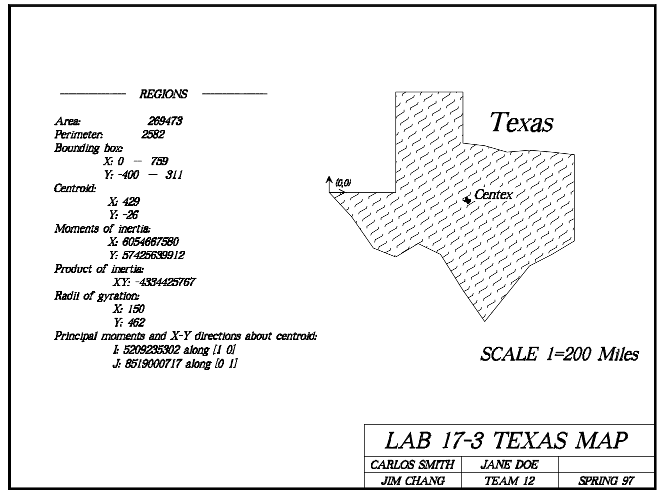

Figure 5. Map of Texas

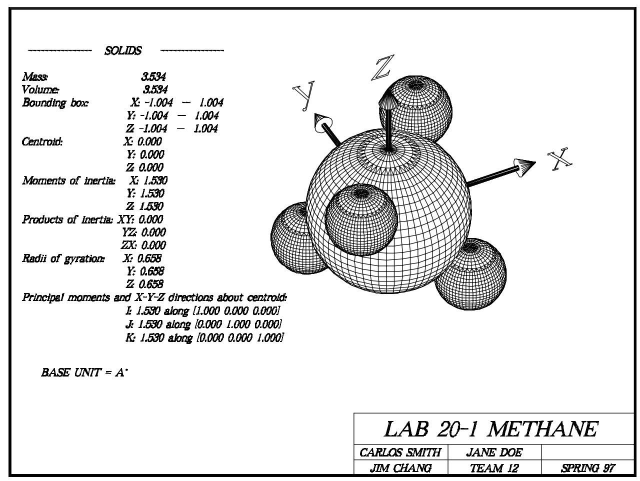

Figure 6. Methane molecule

Discussion

The integration events presented above were well received by most students. Using vectors as the initial CADD exercise flowed well with other FC subjects, was readily understood by FC students and had little impact on time spent introducing CADD. We found basic CADD concepts like coordinate input, relative position, and orientation were easier to teach when linked to an analysis topic like vector mechanics.

The truss problem was a very challenging exercise for FC students. Several periods were spent reviewing this problem after its assignment in the first semester. A primary exercise goal was exposing FC students to a comprehensive engineering problem highlighting the interdependence of FC curricula by utilizing mechanics concepts and analysis tools introduced in several courses.

This goal was achieved.

Teaching solid and surface modeling leads naturally to analysis of geometric and mass properties of complex objects. An emphasis on the analytical aspects of 3D modeling laid a solid foundation for the precision needed in more advanced analysis techniques like FEM. This emphasis did not inhibit student interest and exploration of artistic concepts like presentation graphics and rendering. Final projects submitted by FC students at the end of the second semester typically included very complex solid models of their project assemblies. While the standard orthographic detail drawings in the project documentation set still exhibited minor "freshmen" errors drawing organization, understanding of orthographic concepts and understanding of the interrelations of the assembly parts was excellent. These improvements in documentation and understanding are due in part to the students ability to construct geometrically correct solid models of their designs.

Summary

Graphics, engineering problem solving, programming, and ethics/professional issues make up the engineering component of the freshman year. This paper focused on teaching graphics material in an integrated environment. Several class exercises were presented to document this effort and a discussion of these examples followed that expanded on the success of these exercises in meeting goals of the FC freshmen year. Graphical analysis is not generally taught to engineering students, but has provided the best avenue for integration of graphics into the FC freshman environment.

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