AC 2008-2094: THE ART OF DESIGN MODELING – TEACHING FRESHMEN GRAPHICS COURSE

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The Art of Design Modeling – Teaching Freshmen Graphics Course

In the last decade, several engineering schools have introduced feature-based, parametric solid modeling as a part of the Engineering Graphics course in the freshmen year. This new technology made the traditional methods of teaching engineering graphics obsolete. However, a review of the graphics and CAD books reveals that modeling is characterized as a very systematic process with definitive outcome. In our pedagogy for teaching solid modeling, students explore and design mundane as well as novel objects as a part of open-ended projects. While the use of open-ended projects is not novel, our emphasis is on being creative and systematic. While technology and value are not discussed in detail, the need for style is emphasized in the course. The students build upon the existing designs by morphing them to create new ones. During this process, creativity and exploration play a crucial role in the outcome. The students are highly motivated as they model objects that interest them. In the process, they not only master the solid modeling skills but develop their own unique artistic style. The paper presents several examples of student designs, and provides a framework for teaching modeling.

I. Introduction

Visual thinking is one of the distinguishing characteristics of an engineer. At a mundane level, it is useful for documenting ideas, representing designs, and communicating them to others. At a more fundamental level, it helps in reasoning about ideas and designs. For instance, designers use visual thinking to reason about stress, strain, fluid-flow, electric, and magnetic fields. Recognizing the importance of visual thinking as a means of communication and a tool for reasoning, educators have incorporated visual thinking throughout the engineering curriculum.

Engineering graphics has been at the heart of engineering curriculum. Until recently, in most schools, it was the only "engineering" course taught in the freshmen year. Traditionally, the course has been structured around the orthographic projections. Along with the evolution of computers, the course content moved from pure manual drawing to a combination of manual drawing and computer aided drawing using 2D CAD packages, such as AutoCAD. This shift from manual drawing to 2D CAD packages was relatively minor, in academic terms, as underlying philosophy, i.e. the orthographic projections, is the same. Students learned a few new techniques such as pattern and mirror. These techniques accelerated the drawing process and have NOT changed the design process. Note that these traditional graphics courses have a strong bias towards Mechanical Engineering which often resulted in incomplete training for the graduates[1].

In the last decade, many schools have integrated the feature-based, parametric solid modeling technology into the course curriculum. To encourage the integration, several solid modeling packages, such as ProEngineer, SolidWorks, CATIA, and UniGraphics, are academically priced. Most books reacted to this technology by adding a chapter or two on this new technology. Some books primarily focused their attention on teaching the software with no consideration to the theory. A disjoint approach to the theory (orthographic projections) and the practice (solid modeling) of graphics created confusion in students.

In teaching graphics with an emphasis on solid modeling, the authors found that this technology is ideal for introducing design into the freshmen curriculum and also, shift the emphasis away from pure mechanical engineering. In the course, freshman engineering students work individually on several projects and open-ended problems. Project-based design courses at freshman level have been successful[2,3,4,5,6] at different schools. While they rightly tout the student designs, very few papers focus on the teaching methodologies for successfully imparting the modeling skills.

Hartman and Branoff[7] discuss the process of strategy development and implementation in constraint-based modeling tools. Hartman[8] emphasizes the need for new educational activities that provide a context for a model's acceptability and flexibility to adopt to design changes. Rodriguez et al.[9] emphasize the role of design intent. Condoor[10] discusses a generic methodology for teaching parametric, feature-based solid-modeling software. This methodology helps students develop and internalize good design practices.

The primary focus of this paper is teaching the art of design modeling to freshman engineering students. While the activities may be projects, open-ended problems, and modeling tasks from books, the paper provides an implementation and evaluation framework for these activities.

II. Framework

The framework helps the student to be both creative and systematic. By being creative, students can conceive unique and multiple modeling strategies. Before implementation, students can systematically evaluate these strategies and select the most appropriate one. This front-end thinking reduces modeling time and results in a robust model.

2.1. Identify Modeling Sequence

For an efficient part modeling, a designer must plan the model tree or the sequence of features. Modeling a bird house (see fig. 1) illustrates the power of an effective modeling sequence. The modeling can be effectively executed by using the steps shown in fig. 2. The design intent in this particular task is "the walls extend from the floor to the roof." This model is an effective one as it captures the design intent accurately. In other words, the model accommodates changes in the slant angle of the roof and the height without any redefinition. This modeling sequence is counter-intuitive to most students because it goes against the normal sequence of building a bird house. Students learn by this idea of sequence in creating their own bird houses (see fig. 3).
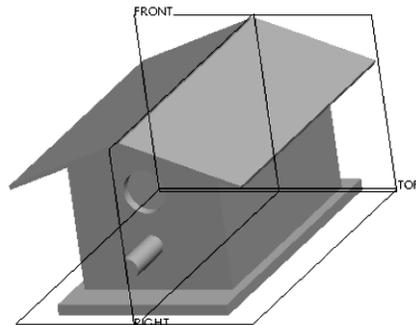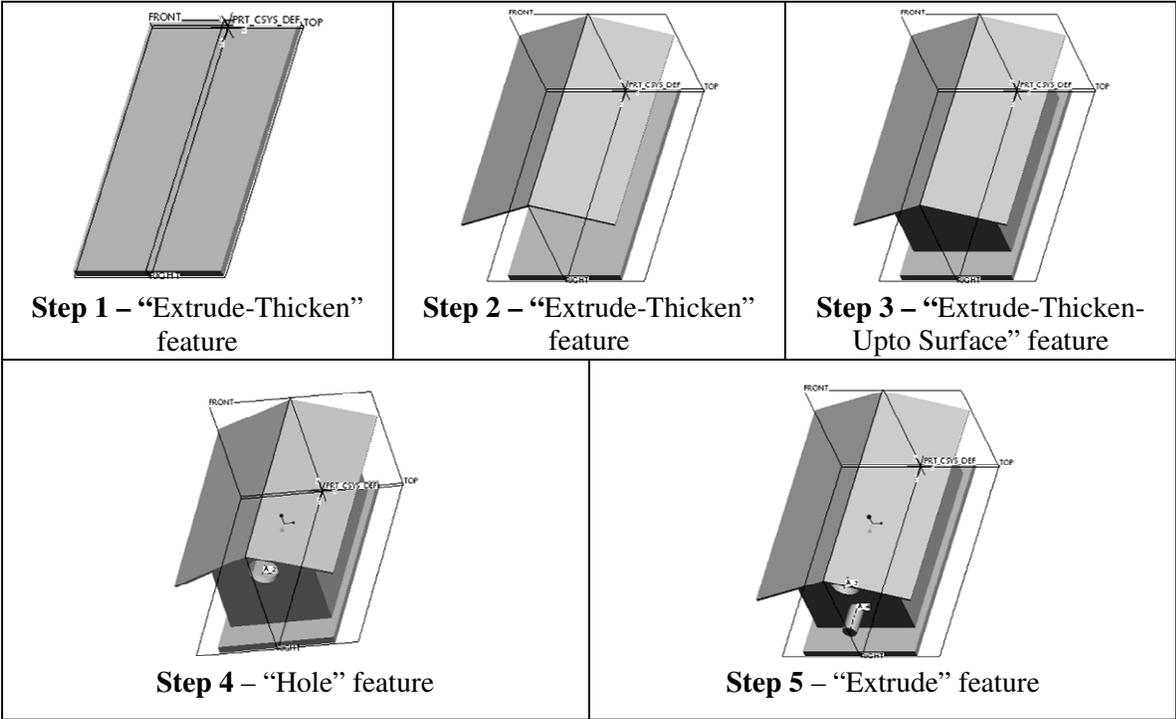

Figure 1. A bird house

Step 1 – "Extrude-Thicken" feature	**Step 2 – "**Extrude-Thicken" feature	**Step 3 –** "Extrude-Thicken-Upto Surface" feature

Step 4 – "Hole" feature	**Step 5** – "Extrude" feature

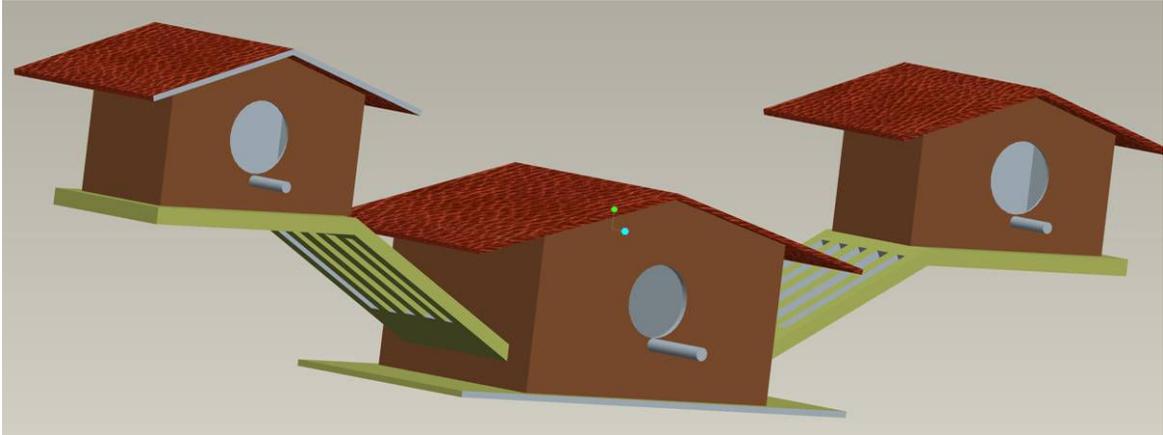**Figure 2.** Sequence of steps for modeling a bird house

Figure 3. Student bird house

2.2. Observe Inherent Patterns

Students easily recognize and model rectangular and radial patterns. With training, they can recognize and exploit obscure patterns which can greatly simplify the modeling task. For example, each side of the dice can be modeled by selectively turning some pips off in a 3×3 pips pattern (see fig. 4a). Similarly, the obscure pattern in a Chinese checkers board can help in the modeling process (see fig. 4b). A few student designs that use patterns are shown in fig. 5.
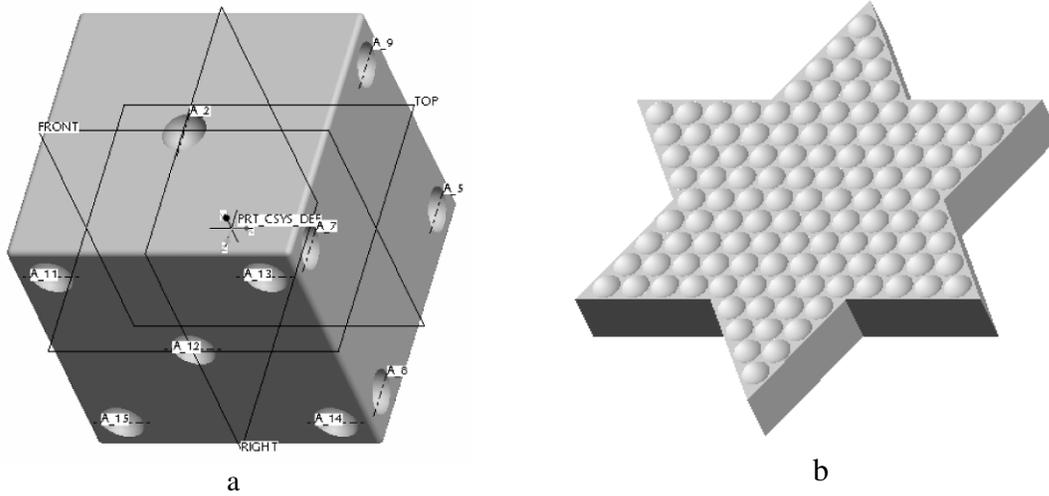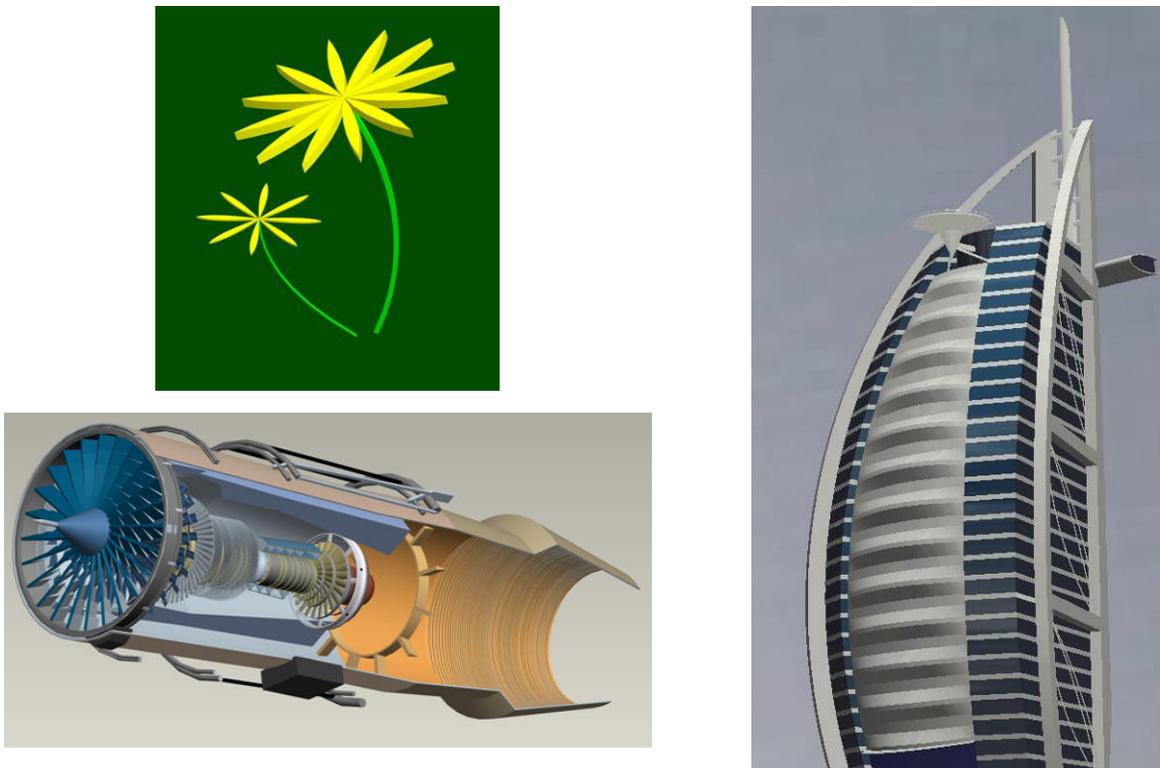

a

b

Figure 4. Obscure patterns

Figure 5. Student designs that use patterns

2.3. Exploit Symmetry

If the part is symmetric, only a part of the whole component needs to be constructed. Then, it can be mirrored to obtain the final part geometry. This approach reduces the dimensioning requirements, and provides greater flexibility. An architectural triangular ruler (see fig. 6) model can be simplified by recognizing and exploiting symmetry. The modeling sequence for the ruler is shown in fig. 7.
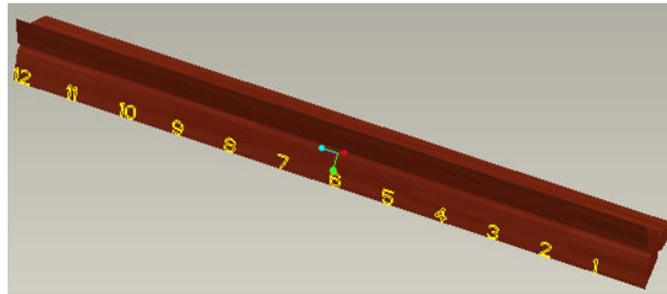

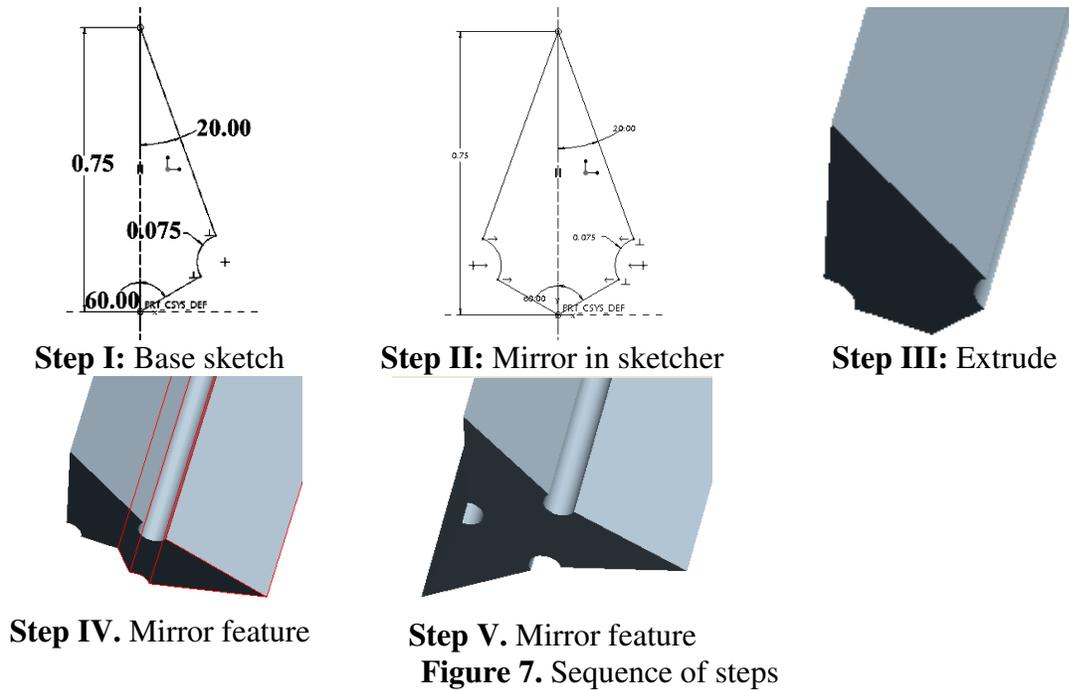**Figure 6.** Architectural triangular ruler

Step I: Base sketch

Step II: Mirror in sketcher

Step III: Extrude

Step IV. Mirror feature

Step V. Mirror feature
Figure 7. Sequence of steps

Figure 8. Student designs that use symmetry

2.4. Think outside the Physical Geometry

As modeling represents an object, the primary focus tends to be on the physical geometry of the part. Sometimes, we may have to create additional features to aid in assembly operations. A good example is the assembly of tetrahedron and octahedron structures using magnetic toys (see fig. 9). To simplify the assembly process, datum points are necessary at the location where the spheres are assembled (see fig. 10).
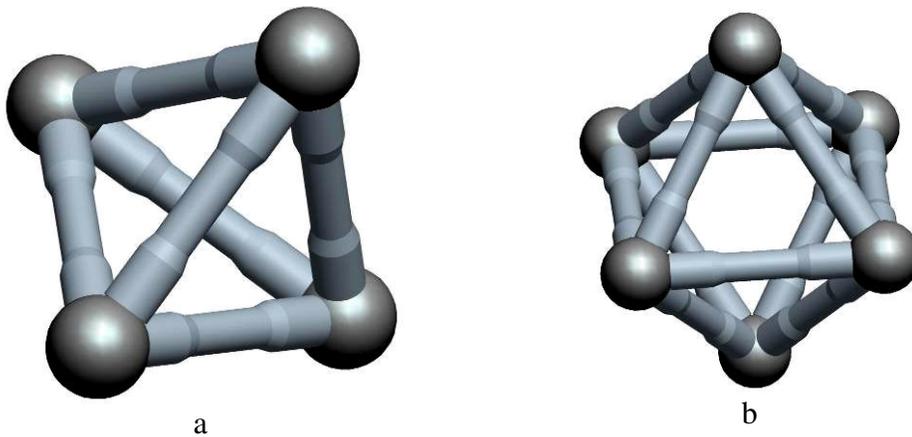

a   b

Figure 9. (a)Tetrahedon and (b) octahedron

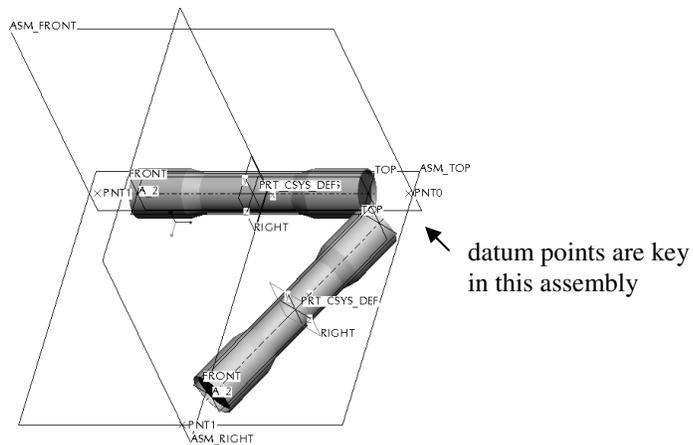datum points are key
in this assembly

Figure 10. Assembly process using datum points

2.5. Pay Attention to Details

Modeling detailed features is a time-consuming and tedious process. Besides increasing the level of patience, it helps the students master different features through practice, discover the limiting conditions for each feature, nurture observation skills, and develop pride in their realistic models. Even simple models (see fig. 11) can be made aesthetically appealing with proper choice of color scheme. A complicated model (see fig. 12) looks realistic, and helps to gain expertise of various modeling features.
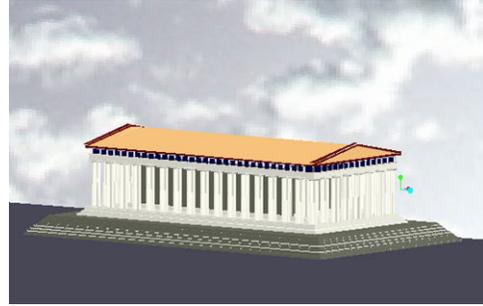

Figure 11. Simple models
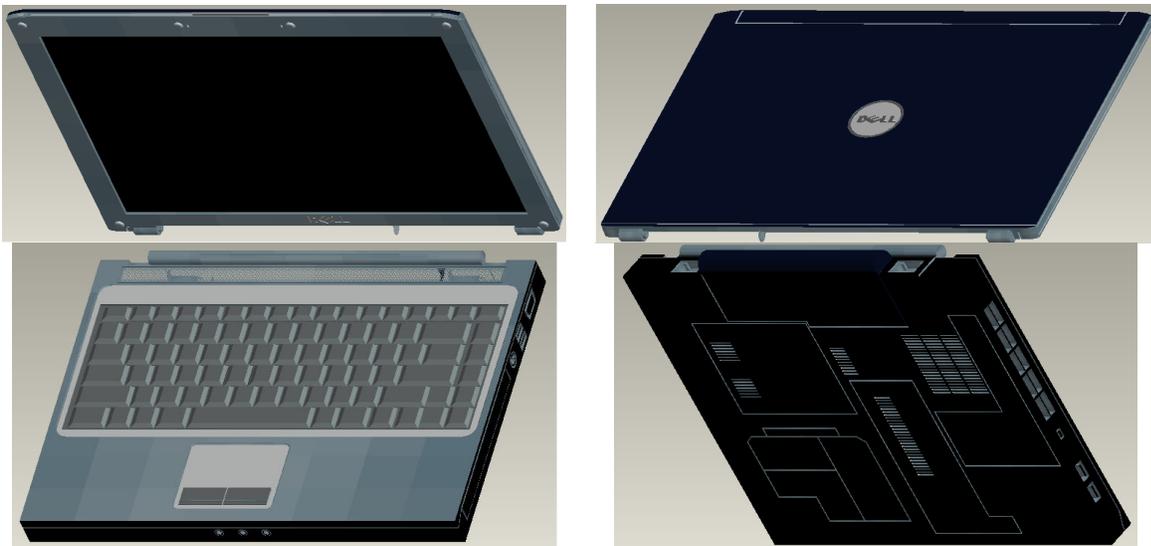
Figure 12. Complicated models

While modeling a building, students can work from an image of a blueprint or an aerial photograph. The students can quickly sketch the geometry and produce a realistic rendering (see fig. 13).

Figure 13. Model of a building using an aerial image.

III. Conclusions

The course emphasizes the need for being creative and systematic. The students are challenged to expand their thinking and visualization skills. In the course, the students build upon the existing designs by morphing them to create new ones. During this process, creativity and exploration play a crucial role in the outcome. The students are highly motivated as they model objects that interest them. In the process, they not only master the solid modeling skills but develop their own unique artistic style.

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