Technical Animation: A New Concept for the Engineering Design Graphics Discipline

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Abstract

Engineering and technical graphics professionals have seen major changes in the content and the way we teach our students (Clark & Scales, 2000). Today, professionals going into fields related to engineering/technical graphics require a broader knowledge of differing forms of graphics with the expectation that they understand and can use these new technologies. With the need for new and better understanding of the role graphics plays in the professional worlds of graphics education, the faculty at NC State University began updating their curriculum for students wishing to major or minor in Graphic Communications.

Starting in the fall of 2001, a course titled "Basic Technical Animation" has been piloted to meet the current needs for our majors. This course develops the fundamental understanding of how animation and simulation can be used by professionals in fields related to engineering, science, mathematics, technology, and graphics, and develops skills useful in integrating this emerging area into the graphics profession. The course develops visual skills in students and enhances their understanding of the role graphics plays in their future careers. This paper will focus on the rationale and content used in developing this course with information and examples of the type of knowledge and skills gained by students from taking a course in technical animation. Student work and example exercises will be discussed as well as the focus on developing students' understanding of working with three-dimensional areas and transformations related to animation.

Introduction

Animation has a long history as a way to tell a story. Since its invention, people have used animation as a way to entertain, to convey an idea as well as to communicate a process. In 1824, Roget presented the first documented animation titled "The persistence of vision with regard to moving objects." Though animation is most commonly associated with movies and cartooning, many early professionals in related fields of engineering and technical graphics, like Roget, saw it as a way to improve communication, increase visual capabilities, and demonstrate a process. Today, thanks to the personal computer and the low cost of animation software, anyone can make an animation and many industries are relying on animation as a way to improve and better explain their product or process (Mak, 1996).

During the fall of 2001, the Graphic Communications Program within the College of Education and the Department of Mathematics, Science, and Technology Education at NC State University offered a new course titled "Basic Technical Animation". Given the current trends in industry and the need to update the curriculum with more current and futuristic course offerings, the Graphic Communications Program developed this course for students wishing to major or minor in the graphics program and to give students an understanding of how animation can improve their ability to communicate technically.

Brief History of Animation

Although many people associate the computer with animation, especially three-dimensional (3D) imaging, most of the history associated with technical animation begins in the early 1800's with Roget and his moving objects and Plateau and Ritter's invention of the phenakitstoscope. These early initiatives led to Edison's research

in motion pictures in 1887-89. Though Edison's research started the use of motion pictures and animation as a form of communication and entertainment, it was not until Lumiere invented cinematography and the first animated film titled "Humorous Phases of Funny Faces" in 1906 did the public actually see a use for animation. In 1915, Hurd developed a new way to create animations called cell animation. This led to a productive way to quickly make animations that is still used today and most animation software still uses this process for frame development. In 1927, Warner Brothers released the first animation that combined sound and images together called "The Jazz Singer." Up until this point, animation was a series of pictures or images (i.e. photographs) logically and uniformly placed together either linearly or on a round disk like a record. In 1928, Disney made the first success drawing of an animation called cartooning featuring Steamboat Willie, or better known today as the character Mickey Mouse. The first computerized animation was developed by Bell Laboratories in 1964. By the 1980's, we started to see a variety of animation software programs come on the market (http://www.bergen.org, 2004). It was not until the mid-1990's that software became cost effective enough that anyone with a personal computer could create an animation, and we started to see professionals in science and technical areas use it as a way of communication (Clark & Wiebe, 2000).

Technical animation has its roots in simulation, which is defined as "the ability to simulate a real-world environment virtually, to either collect data or demonstrate a process." Engineers and scientists used large mainframe computers as far back as the 1960's to create virtual environments, it was not until the 1980's that simulation became "mainstream" for many engineering and science professionals, thanks to the low cost of software being developed for the personal computer. Today, engineers use animation and simulation on a daily basis, from testing materials and environments in Finite Element Analysis (FEA) to Computational Fluid Dynamics (CFD) as well as present ideas to a diverse audience. For scientists, the ability to create and recreate environments to see interactions among molecules and other forms of collected data is important to further advance fields of research. Simulation, with the help of animation,

has helped to visualize large amounts of information in a relative small amount of time or space, as well as convey ideas for research to different audiences. Today, the beginning engineer and scientist need to have a diverse knowledge in many areas of computer application, including simulation and animation. By developing their visual skills beyond the static modeling commonly taught in university and college settings, these young professionals can become more productive at the start of their careers and communicate to a variety of audiences beyond their peers (2000).

Areas of Study in Animation

Animation can take place in many forms of media, but computer animation seems to be the type most professionals in engineering and science prefer. Given the ability not only to show the viewer what is happening, but at the same time, collect data that is useful. Computer animation and the concepts associated with this form of animation were the main components for this new course. The three areas of study that are directly associated with computer animation and this course are modeling, rendering, and animation processing.

Modeling

Modeling is the basis for all forms of computer animation. The elements of modeling that students need to address in their study of technical animation include the ability to understand and use both two-dimensional (2D) and three-dimensional (3D) views in creating their animations. Students must learn how each view type is used in virtual environments for the creation of an animation. The ability to use and see in both dimensions aids students in aligning their scenes and objects together as well as linking together objects that need to react to one another during the animation (i.e. collision effect). Students must decide if the final animation they want to show to their intended audience is 2D or 3D and understand the advantages and disadvantages of each. Also associated with modeling in animation is the understanding and use of geometric primitives. From the sphere to the torus, understanding primitive shapes and their mathematical structure plays an important role in the creation of animations. Students must know how to select the appropriate geometric
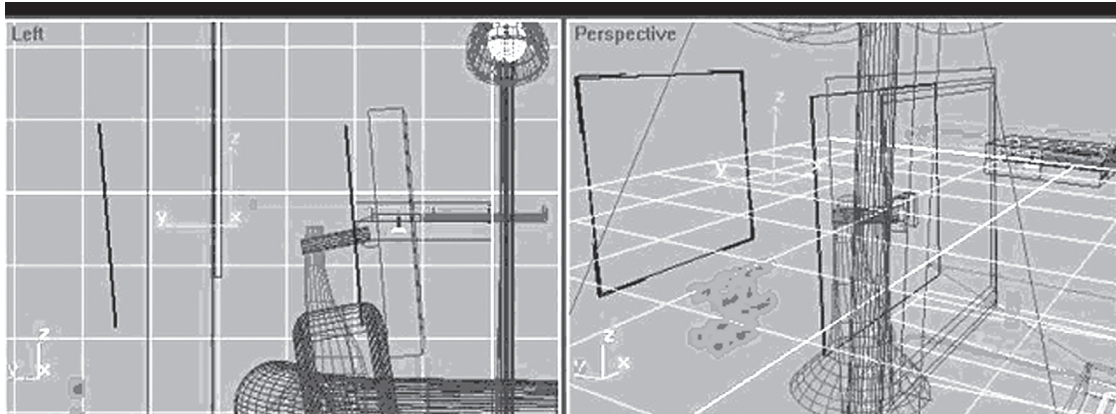
Figure 1. Working in both 2D and 3D to develop an animation.

shape they need in order to modify the object and produce their desired shape or model. The ability to do geometric breakdown of objects is important. If this is not understood, students will waste time extruding 2D objects into 3D forms and cannot calculate volume and area correctly to simulate the animation's dynamic movements in a 3D space (See figure 1) (Clark & Wiebe, 2000). Once a student learns how geometric shapes or primitives are used, then the ability to work in a mathematical coordinate system becomes important. Unlike traditional computer-aided design (CAD), students developing precise movements in animation need to work with three coordinate systems at one time. The X, Y, and Z placement is created for the scene or background of the animation as well as for the objects located within the scene. The third type of coordinate system is used when all objects and scenes are working together in a world system of movement or the entire environment created for the animation. At the same time, students must use Boolean operations, like those found in most 3D solid-based CAD modeling programs for shaping their objects to their desired forms. A final area in modeling is the ability to understand and create transformations. Transformation can be defined as the ability to separate static modeling from the dynamics of animation. This process includes the ability to move, rotate, and scale the object or scene to produce the desired effect of the animation.

Rendering

Rendering is often considered the art of applying materials and colors to a surface or object to make it look realistic. Although these techniques are elements within the study of rendering for technical animation, the basic definition for rendering is the process of producing two-dimensional pictures from three-dimensional data, or via-versa. Students studying technical animation need to develop skills in working with objects in both wireframe and shaded models (See figure 2) (O'Rouke, 2003). The ability to work with objects as they exist in both a two-dimensional orthographic form and a three-dimensional model is important for the placement and development of an animation. Lighting is one element within rendering that students commonly do not study in a fundamentals of engineering graphics class. The use of lighting can directly affect the way the background is used or how objects appear in a scene. Students must know the different types of lighting and how each interacts within the animated environment. The study of lighting includes areas like intensity, color, ambient, direction, and ray-tracing. Although lighting enhances the animation, the use of texture mapping is just as important. The ability to apply the right texture to an object will enhance both the image and animation being created. Texture mapping not only includes the use of applying texture to surfaces, but knowledge about how the texture will look once different surface characteristics are selected. These characteristics include the use of color or hue, saturation, luminance, diffuseness, and specularity. Students learn to apply different types of texture maps to control the parameters of reflectivity and refractivity once texture, color, lights, and shading are all in place. The final element of rendering that students need to study in a basic technical animation class is the use of cameras. Typically, students
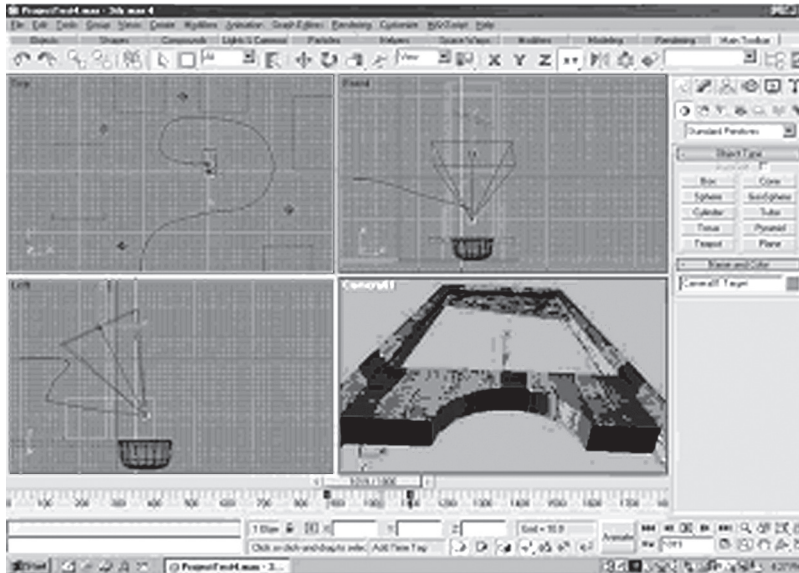
Figure 2. Example of working with wire-frame and shaded models in animation.

studying engineering graphics only look at objects from a certain view point or angle. This is because of tradition, standards, and conventional practices associated with certain professional practices. On the other hand, cameras allow students to explore all the possible ways an object(s) within a scene can be viewed. The ability to place and use different camera techniques is a major focus in the study and understanding of technical animation and why it can be a powerful tool for visualization, when compared to traditional CAD or modeling.

Animation

Animation can be defined different ways depending upon the intent of what the creator wants to happen, however, for most basic forms of animation, professionals define animation as "the process of using movement to convey an idea or story" (Hodgins & O'Brien, 2002). Movement can be viewed different ways, but animators call these movements "transformations;" in other words, moving objects around in a scene, or rotating around an axis as well as scaling objects, are all forms of transformations. When any of these transformations are applied to an object, then animation is taking place. Students studying animation must learn different forms of animation as well as simulation. Once a student is familiar with the basics of creating an object and scene then the development of the animation can happen. Keyframing and pathway animations are the two common forms for creating these transformations. Keyframing is where students move the object(s) within the scene based on a number of frames designated for that particular movement. Pathway animation is when students create a path for an object(s) to follow and the software creates the needed number of frames. One process is not better than the other, and each has its own particular form and rationale for its use (See figure 3). The motion paths that students learn to create are important to the clarity of what is being animated, and in technical animation, they are the final task to be done after rendering the animation. It also will be the deciding factor determining if the animation explains the topic well. Animating objects and scenes are not the only areas to be animated. Lights, cameras and surface properties can be animated as well.

As illustrated in the above three areas for animation, many new areas must be discussed in a technical animation class when compared to a traditional engineering graphics class. Although enough time in the classroom is always an issue for most educators, the study of animation does not include the more traditional areas of engineering/technical graphics like standards, dimensioning, and certain projections; therefore, time can be used for topics needed for animation practice. The final product is essentially the same, a student's ability to better communicate an idea or topic (2002).
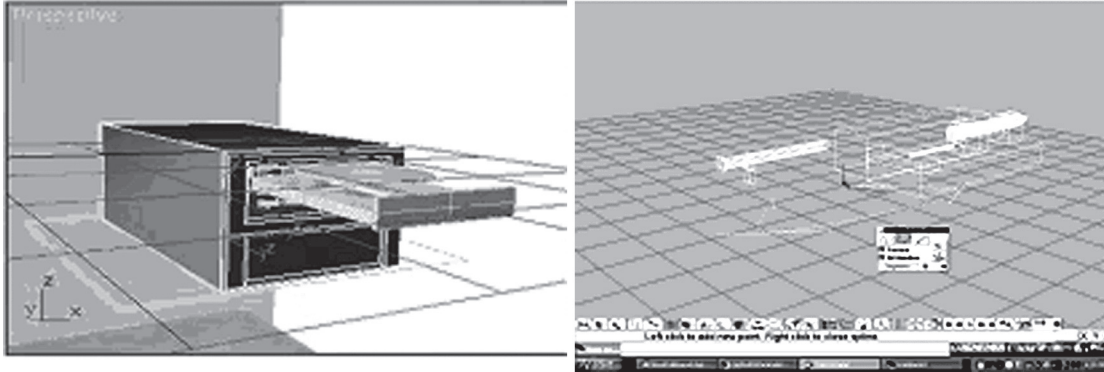
Figure 3. Early stages of developing a keyframe and pathway animation.

Basic Technical Animation: The Course

In the fall of 2001, the Graphic Communications Program at NC State University decided to offer a basic technical animation class to students in the program and other majors in fields related to engineering, communication, business, science, and technology; but, before such a class could be developed, the instructors for the course wanted to see what other institutions are doing in the area of animation. It was found that only a few colleges and universities were offering this type of class to students. After discussions with these institutions, the instructor for this course came up with the following course description and objectives (Clark & Matthews, 2000).

Course Description

With the speed new technologies are being developed, an over saturation of information has exploded society's knowledge base. With the pace that technology is being developed, it has become evident that the information age is here to stay. In the future, people will need to be effective communicators verbally and graphically. Effective communicators should be skillful at conveying concepts and ideas that are hard to understand in a way that the information is conveyed clearly and without confusion. This course will teach students how to become effective communicators using 3D animation. In this course, students will not learn to animate for entertainment purposes, but to communicate information and enhance their communication skills in a technical environment. This course is designed to teach the basics of technical animation as it applies to the workplace. Students will experience a variety of software,

incluing: PowerPoint®, Flash®, TrueSpace®, and 3D Studio Max®.

Objectives

Listed below are the objectives and topics developed for the course in Basic Technical Animation (Special Topics Course) at NC State University.

1. Ability to relate 2-D and 3-D basic design vocabulary and processes to the computer.
2. Acquisition of basic skills in image processing including cropping, transformations (translation, rotation, and scaling), color manipulation, and color enhancement.
3. Use of the principles of good design, balance, harmony, rhythm, and proportion in the development of 3-D objects and spaces.
4. An overview of basic mathematical concepts such as 2-D and 3-D coordinate systems, trigonometry, splines and voxels.
5. An exploration of the interrelationships between 2-D and 3-D, including the integration of surface properties with form manipulation.
6. Ability to visualize, conceptualize in 3-D, 3-D space, and 3-D environments, including the use of motion or stereoscopy to enhance the impression of space.
7. Basic concepts of constructing 3-D objects, spaces, and environments.
8. Principles of creative thinking to create unique shapes and forms.
9. An understanding the basic theories of resolution, including input relationships, bit-mapped and structured (object-oriented) drawings and output relationships.
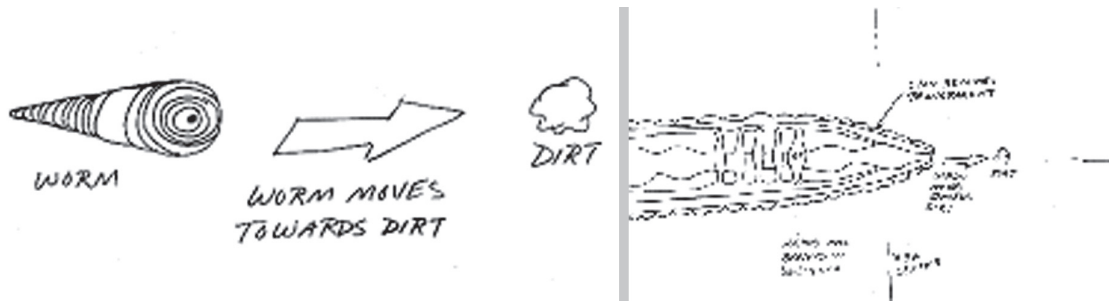10. An understanding of the nature of com-

Figure 4. Storyboard for the digestive tract of an earthworm.

puter medium in relationship to other media, sufficient to explore how the choice of the medium influences design decisions, and to judge what medium is appropriate for specific tasks.

11. Study of environmental attributes including surface study, texture, color, lighting models, photo-realism, and raytracing.

The course has two exams, including a comprehensive final exam. Each exam counts 15 percent of a student's final grade. Also, the course requires five homework assignments that count a total of 20 percent of the grade for the class. A major part of the course is an extensive final project that counts 25 percent of a student's final grade. The remaining ten percent of the course is based upon a student's participation in class and attendance. Students are required to purchase two textbooks, one for content and the other has a series of tutorials, and weekly reading assignments are given. Each student is responsible for having storage media (i.e. zip disks, CD-RW) for saving his or her work.

Topics of study and software skill development coincide during the semester. The course, with two hours lecture and two hours laboratory per week, allows for an easy transition. All topics are directly related to required reading materials. The weekly schedule of topics covered during the semester are briefly described below:

Week 1: Intro to course and history of animation

Week 2: Modeling and storyboarding

Week 3: Introduction to 2D animation and Flash software

Week 4: Basics of 3D animation and working with primitives

Week 5-6: Introduction to 3D animation and TrueSpace software

Week 7-8: Intro to 3D Studio Max

Week 9: Working with scenes

Week 10: Basics in keyframing/ modeling

Week 11: Modifiers, Boolean operations, and morphs

Week 12: Advance rendering in 3D Studio Max

Week 13: Keyframing/recording and video post

Week 14: Introduction to PowerPoint software

Week 15-16: Finalproject

Content and Activities

The course was developed to teach students how to use animation to convey an idea or process associated with technical areas; therefore, all content and activities were based upon areas in science and engineering, not the artistic or character animation that most people associate with this type of skill development. The course begins by introducing students to technical animation by explaining the history and types of animations. Students spend time at the computer "surfing" the internet to find good examples of technical animation or areas associated with the processes to be used throughout the semester. Each student is required to find at least five good examples on the Internet and share these examples with the class. Students also learn to develop basic visual literacy by learning to sketch and create both 2D and 3D representations of objects. Once this is completed, students study the basics of storyboard development. The area of storyboarding is vital for success in the course: if students do not learn this time saving process, many hours can be wasted in the laboratory by using trial and error for animation development (Clark & Scales, 2000). Storyboarding is required for every animation created for the class during the semester. The assign-
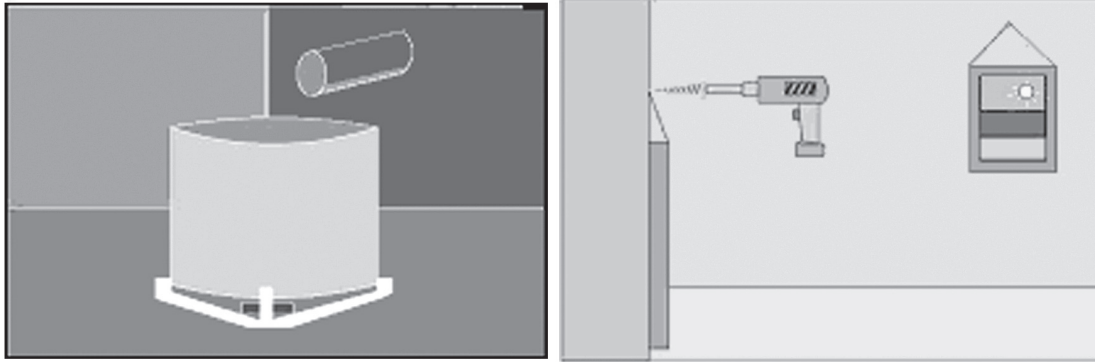
Figure 5. Examples of 2D animations (distillery operations and hanging a picture).
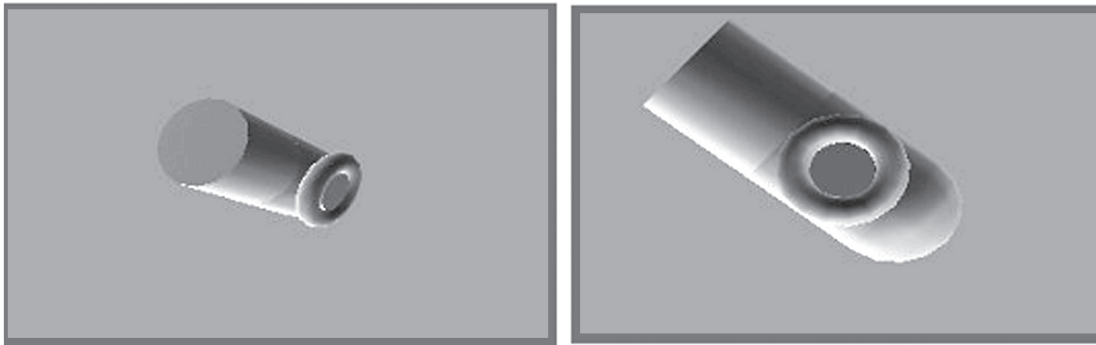

Figure 6. Examples of a perspective and a front view of a 3D cannon.

ment for students is to develop a storyboard for a technological process. This may include anything from changing a flat tire on a car to how an earth worm's digestive tract works, as long as it is science or technology-based, any topic will work. The student picks his or her topic to storyboard after approval by the instructor (See figure 4).

After students learn the basics of technical animation, it is time to apply this information by learning a variety of software packages as well as the advanced principles related to animation. Starting the third week of the 16-week semester, students begin to use a simple 2D animation package called Flash® commonly used for Web-based graphics. During this time, students learn how animation is used as a communication tool over the Internet, and the lecture topics are based on the basics of animation development, no matter what software package used. These topics include model and model building, polygonal modeling, splines and patches, coordinate systems, viewing windows, 2D verses 3D, orthographic projection, geometric primitives, transformations, hierarchies, and Boolean operations. Once the software and topics are introduced, students perform a simple

exercise in class to learn the basics of the software and begin to develop their own 2D animation from topics related to technology. Examples of the 10 to 12 second 2D animations below demonstrate the range of animation produced (See figure 5).

Once students demonstrate a proficiency in 2D animation, the course moves to basic 3D animation. The software used to study the basics of 3D animation development is a gaming package called TrueSpace®. Using this simple animation package, students learn how to setup a scene and transform objects in a 3D environment. Lecture topics during this time period relate to more in-depth principles of animation. These areas include: lighting, shading, color, surface characteristics, texture mapping, keyframing, pathway animation, and final formats (outputs). The students' work assignment is to animate a cannon to fire a cannon ball at a prescribe distance. This reinforces the use of coordinate systems and visualization basics by utilizing different views (i.e. top, front, side) and the axis seen in each view to build the cannon. This simple three-second animation allows the student to learn how to adjust their keyframe editor and produce a final animation from different
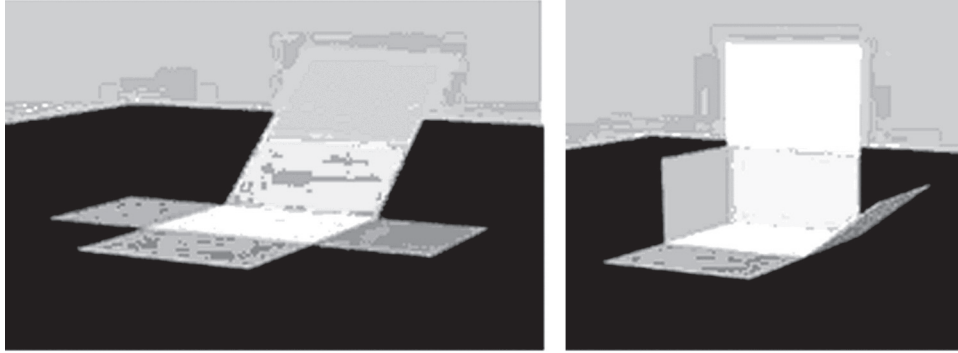
Figure 7. Example of the folding box exercise.

camera angles and formats (See figure 6).

After students develop a basic proficiency in 3D animation, they graduate to an industry-standard software that will be used for the rest of the semester. This software package, used for more than half of the semester is called 3D StudioMax®. In conjunction with more advanced topics of study, this software will also be used for the final project, which carries a major portion of the final grade. During this stage of the class, advanced topics are presented during the lecture that helps students develop their final projects. Topics include: advanced keyframing, rendering techniques, blended surfaces, motion dynamics, metaballs, particle systems, procedural animation, and video editing techniques. During this part of the course, students are asked to create a simple box with all six sides that fold together. An activity that requires the students not only to animate movement, but also teaches them how the hierarchy structure system works (i.e. pivot points) in the software and how to manipulate the surfaces to achieve the desired result (See figure 7).

Once students have completed the folding box by week ten of the semester, the remaining lab time is spent working on their final projects, which count 25 percent of their final grade. During this time, students are introduced to PowerPoint® presentation software that they will use to present their final projects to the class on the last day of classes. Topics of discussion during these final weeks include: considerations for presenting technical information, ethics, copyright, and different forms of technical presentations. Students must have approval from the instructor for their final project before they begin. This allows the instructor to anticipate students' needs and confirm that no two people are doing the same topic. Once the final

animations are completed, they are then imported into a presentation format. The requirements for this final project are that animations have two or more moving objects, within a 15 second to one minute time allotment for all animations combined per presentation, and a maximum total time for each presentation of five minutes. Students must develop slides for their presentations that explain the topic, animation procedures used, and what they would do differently next time. Figure 8 shows screen captures from several final projects created by students in the spring semester of 2002. Figure 8 is a demonstration of the mechanism of a SuperSoaker water gun and a new design on a door lever for a DC10 jet.

Conclusions and Recommendations

Conclusions drawn from the author's previous experiences and the piloting of this course can revolve around the three rationales for teaching a course of this type. First, professionals in engineering and technical graphics need to meet the needs for our students, and the training and skill development in areas related to animation is no exception. With today's job market, our students need to have a diverse knowledge in all forms of technical graphics. From traditional engineering drawings to desktop publishing and animation, these skills make our students more marketable (Clark, Scales, & Petlick, 2004). Second, engineers and technologists need to learn to communicate to a variety of audiences; therefore, a class like this one teaches students to think "out of the box" and recognize that they must learn to communicate to non-technical people. Good presentation skills are needed for any profession, but engineering, science and technology disciplines are at a greater disadvantage in that the areas we study
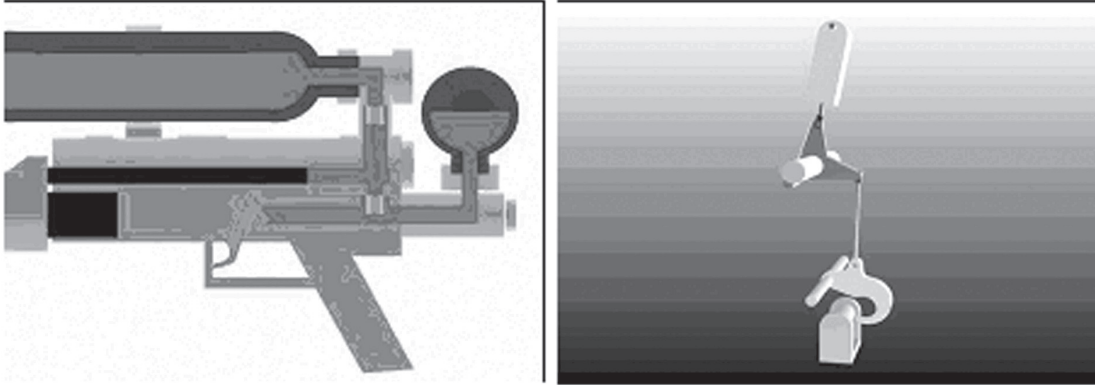
Figure 8. Screen captures of final projects.

are not always common knowledge. Therefore, there is a need to teach our students good technical presentation skills and a course like this one makes it easy. Finally, computer graphics and its use in the field of engineering, science, and technology is growing each year. Whether it is simulation or animation, our students need to develop good visual skills and know how to apply these skills in everyday situations (Khan, 2002).

Improvements that need to be made this course are as follows: First, students need access to the computer lab outside of class. Unlike some college courses, the computing requirements for software used in a course like this one is too extensive for most labs'; therefore, arrangements need to be made for students to access the software more easily. Next, rendering animations can be very time consuming and will most likely "tie up" a computer so that no one else can use it until the rendering is finished. The author of this paper suggests networking the computers and setting up each computer so it can be "pinged" by any computer in the lab that is rendering. This will save many hours of down time. Finally, have more computers than students. Although this may be difficult, it has been the experience of the instructors for this course that animation packages are not perfected and have a tendency to go down (hard drive failures) more frequently than other types of software.

In conclusion, it is the goal of professionals in engineering graphics to seek new endeavors in the pedagogy and understanding of visualization. New courses, such as this course in basic technical animation, help us reach more students and add to their overall understanding of visual science. As our society, industries, and culture become more dependent on visual information, our profession should strive to help guide students into the twenty-first century, which many say will be the "visual-age."

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