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Using Interactive Multimedia Computer Tutorials for Engineering Graphics Education

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Abstract. Since the Fall semester of 1996, the freshman engineering graphics class at UC Berkeley, with an annual enrollment of 300, has been using an interactive multimedia computer compact disk (CD) entitled *"Graphics Interactive."* It was assigned, in addition to a conventional text book, as required review material for the class. The CD assisted in visualizing the principles of orthogonal projection and sectioning in engineering drawing, geometric dimensioning and tolerancing, the geometric relationships involved in descriptive geometry, and other engineering graphics topics. The CD presented classical engineering graphics topics using a combination of animation, audio description, and interactive excercises. Results of surveys indicate that the new presentation media was extremely well received and helped with the understanding of the course material.

Key Words: Engineering Graphics education, multimedia
MSC 1994: 51N05

1. Introduction

Engineering education is now realizing the potential of multimedia as a learning and teaching tool. The use of computer multimedia offers several tools that are useful in engineering graphics education. Many of the topics encountered in a graphics course deal with 3D objects or concepts, which are often difficult ot visualize for students. Orthographic projection, object sectioning, and descriptive geometry are typical of topics that are sometimes especially difficult. In these cases 3D representations and animations of these representations may be beneficial to students trying to relate 2D drawings to the 3D objects they represent.

A computer can be used to provide a multisensory experience, where a key part of this experience is that it is controlled and managed by the participant's actions or decisions. Engineering educators that have experimented with various multimedia instructional aids include Rais-Rohani, Young 1966 [5], Lipmann, Lieu 1994 [4], and Agogino, Hsi 1994 [1]. The different media types reinforce each other in presenting topics that are sometimes

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difficult to understand, visualize, and/or illustrate. For understanding orthogonal projection or how a 2D representation correlates to a 3D object, 3D animation of objects, pictures, and audio descriptions, and other media have a significant advantage over the inanimate graphics of traditional text books, as explained by Wilson 1996 [6]. An additional benefit of multimedia presentation is that more than one type of media can be used to simultaneously present information. Using both motion and sound through multimedia may alleviate the difficulties with traditional printed media.

The most important benefit provided by multimedia is probably that of interaction. Many studies indicating that interacting with information can be a positive effect on learning since people remember/internalize more information if they interact with it (e.g. hear, see, and do). Multimedia provides an excellent means of generating interaction through interfaces that require the user to make choices and perform actions.

At the University of California at Berkeley (U.C. Berkeley), a multimedia tutorial has been developed by Krueger, Lieu 1996 [2] that focuses on engineering graphics. The tutorial, entitled *Graphics Interactive*, was intended to be a learning aid that supplements the textbook and lectures in a freshmen engineering graphics course. Much of the effort in developing the tutorial was focused on using the tools provided by multimedia to aid 3-dimensional (3D) visualization through animation, focus the user on graphics rather than text through audio narration, and promote learning by association through interactive user interfaces. The tutorials were authored using Asymmetrix ToolBook™. The animations were created using Autodesk 3-D Studio™. The audio development was done with standard Microsoft Windows™ development tools. The entire tutorial development effort took place mainly during the summers over a span of approximately three years. With the Fall semester of 1996, the freshmen engineering graphics class, with an annual enrollment of 300, was assigned to use *Graphics Interactive*, in addition to a conventional textbook. At the end of each semester, a survey, specific to the *Graphics Interactive* CD, was taken. The survey presented questions about the organization of the CD, its clarity, and its ease of use.

2. Tutorial Organization

The tutorials were available to students in the form of compact disks (CD's) that the students could purchase, like a textbook from the bookstore. The CD's could be used on students' own personal computers or on the personal computers provided by the University in the graphics laboratory. The topics covered by the CD were those found in a typical college entry level engineering graphics courses. The table of contents is shown in Table 1.

Introduction and History	*Orthogonal Projection*	*Geometric Dimensioning*
Sketching	*Pictorials*	*Tolerancing*
Engineering Drawing	*Sections*	*Descriptive Geometry*

Table 1: *Graphics Interactive* CD Table of Contents

Hypertex and information linking permeate *Graphics Interactive*. Hypertext is used extensively to branch a specific topic into sub-topics. Hypertext always appears in green, so users know if they want more information about a term in green, it can be selected. The typical layout of a tutorial presentation page is shown in Fig. 1 from the *Orthogonal Projection* chapter, which illustrates the use of "hot-regions" in an interactive interface. Hot-regions are areas of the screen that users can click to evoke an action from the tutorial related to what is shown in that portion of the screen. Here all 6 projection planes are shown in a developed view at the right. At the left is shown an isometric view of the part. By clicking on a view(e.g., the back view) in the picture on the right, the user causes the object in the view at the left to rotate until its orientation mimics the orientation depicted by the 2D view clicked. The user thus makes an association between a 2D orthogonal projection and the corresponding 3D orientation of the part.

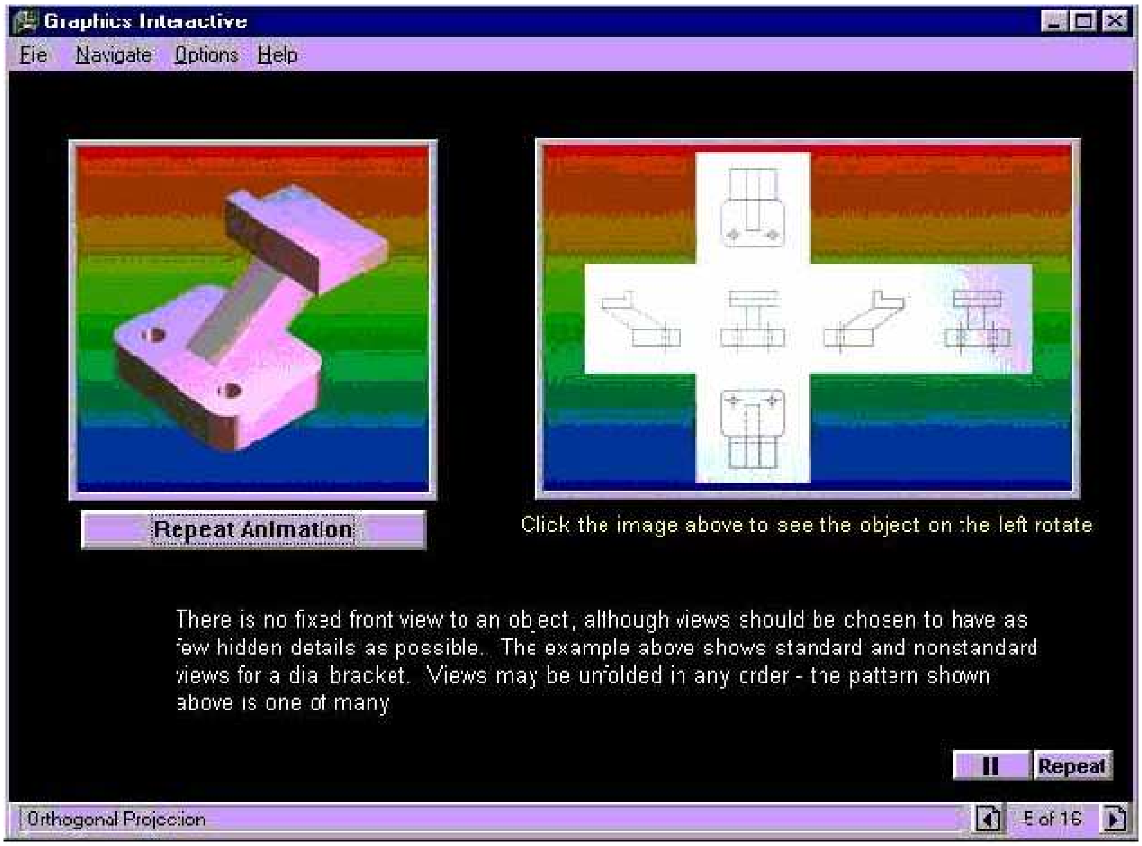

Figure 1: Example of a typical presentation page. Selecting a view on the right causes the 3D image on the left to rotate to show the corresponding side of the part

A typical problem solution page is shown in Fig. 2. The forward and backward step buttons are shown in the lower right-hand portion of the page. Clicking on these allows the user to *step* the solution forward or backward at his/her leisure, with no pressure to understand a step quickly before continuing. Each step shows a graphical portion of the step at the left and a textual description of the step above the step buttons. On all pages, the use can initiate a response from the computer by selecting buttons or regions with the pointing evice. The contents of the central region change from page to page., but the menubar is always present, as are the page forward/backward arrows on the lower right-hand corner of the page. Most pages also contain a "repeat" and a "pause" button, located in the lower right-hand corner of the page, that allow an audio narration to be replayed or paused when selected. Additionally, whenever an animation appears on the page, a "repeat animation" button is present so users can replay the animation. Control of the user environment is implemented through the menubar, including the option of full audio narration and its volume.

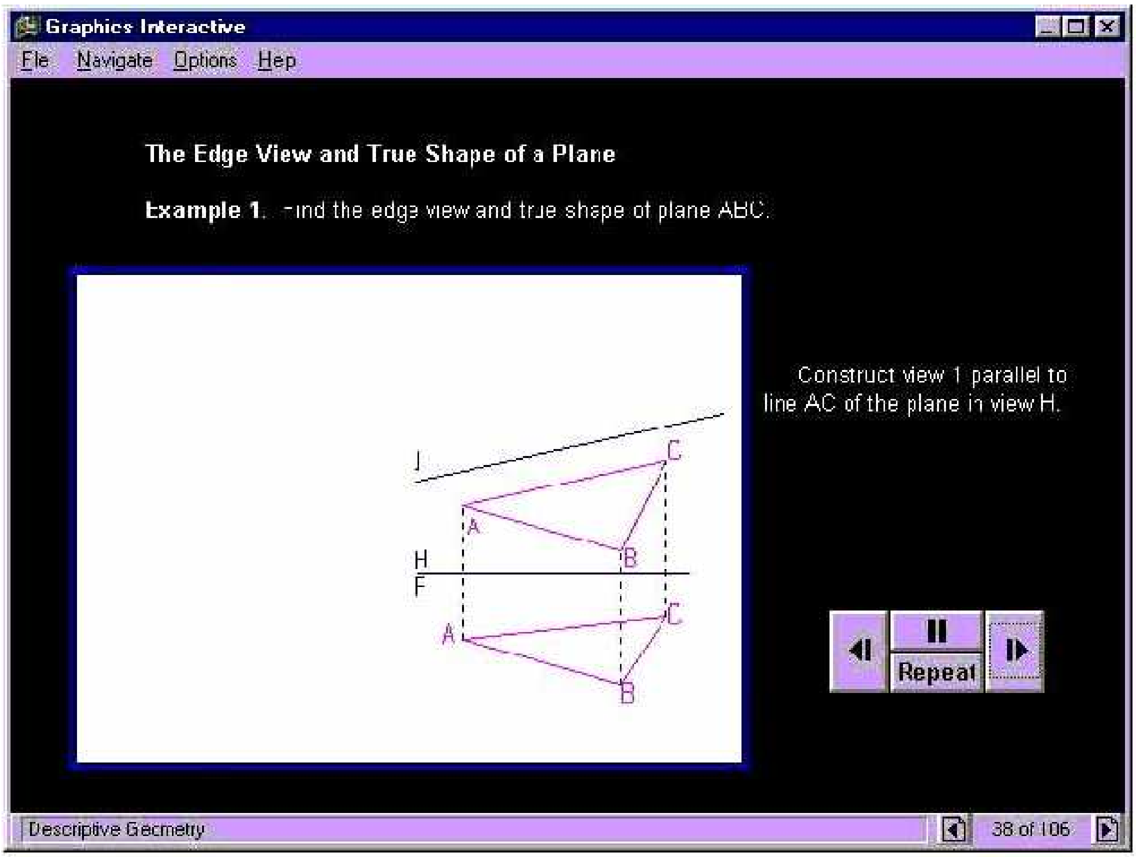

Figure 2: A typical problem solution page. The forward and backward buttons allow the user to step through the construction of the solution, with an explanation at each step

Navigation in *Graphics Interactive* is managed with the menubar and the page forward/backward arrows. The "Navigate" submenu allows users to navigate directly to any chapter or subsection listed in Table 1, or to simply move one page ahead or back in the current section. The page forward/backward arrows also allow the users to page through a section of the tutorial or to go directly to any page within the current section by entry on the keyboard.

Using a combination of 3-dimensional images, animation, and audio narration, the tutorials explained many of the basic principles of engineering graphics which would be difficult with text and 2-dimensional drawings as with conventional textbooks or lectures notes alone. A series of interactive example problems, with solutions, that parallel the course lectures and assignments were part of the CD. These examples provided step-by-step solutions to traditional graphics problems, explaining at each step the proper procedure to reach the solution.

3. Course Organization and Resources

The engineering graphics course at UC Berkeley is presented through 2 one hour lectures and one 3-hour lab per week for one semester. The lectures are conducted with the entire enrollment in a large lecture hall. Laboratory sections are divided into 6 groups of 30 students each. Attendance at the laboratory sections is highly recommended, but not required. This "open" laboratory policy permitted students to use their home computers for the required assignments, as well as the computers in the graphics laboratory. Homework is assigned weekly, and there is a semester long group design project. The course is required for all mechanical engineering, civil engineering, manufacturing engineering, and naval architecture students.

Computer ownership was not required for the class, and students had 24 hour access to a computer lab which could run the CD. For a class of up to 170 students, there were two computer laboratories with 30 90 MHz Pentium class computers in each lab. Each machine was equipped with a 32 Mb of RAM, video accelerator, sound card, and an 8X CD player. The computers were configured to Autodesk AutoCAD™ from the hard disk drive and the tutorial CD from the CD layer. Students were required to bring their own earphones if they wanted to hear the audio output of the CD. Even though it was possible to switch between two programs on the same computer, it was noted that many students found it convenient to simultaneously use two computers that were side-by-side: one running AutoCAD and the other running the tutorial CD. The large "virtual laboratory" provided by students who had access to computers outside of the University lab provided a very valuable resource. The ability to view the tutorial outside of the laboratory, at the students' homes, was considered an important factor for the success of the CD. The result of the accessibility survey question, shown in Fig. 3, indicated that of the students who responded to the survey, 90% had access to a computer outside of class, 77% of the total test group had access to a PC. The high percentage of students with home computers, as at UC Berkeley, would almost certainly have a positive effect on the success of the tutorial CD.

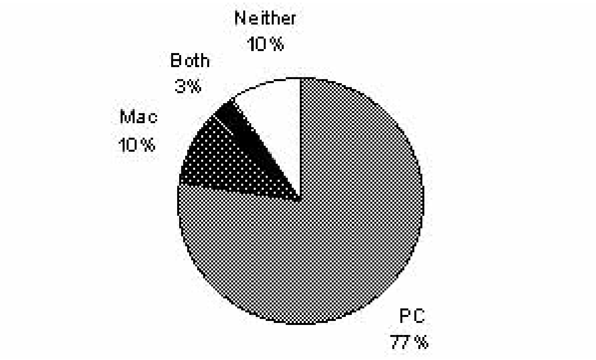

Figure 3: Computer accessibility outside of the laboratory

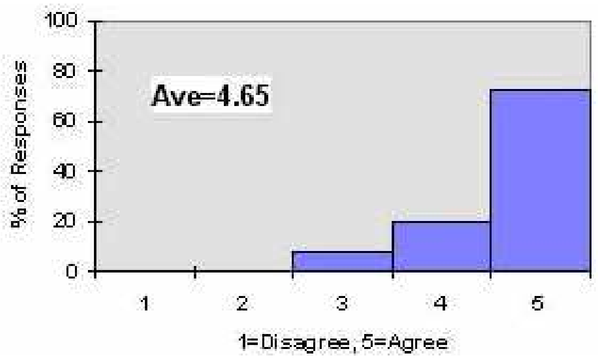

Figure 4: Understood functions of buttons and how to navigate the *first* time used

The student computer ownership survey also showed that the computers outside the lab, 82% were Pentium class machines, 95% had CD players, 86% had sound cards, 95% had internet access, and 79% had all four of the previous options.

4. Survey Questions and Responses

The responses to the survey questions provided insight to the usefulness of the CD in the class, and how students used the new media. The first question on the survey asked about the ease of use of the tutorial. Fig. 4 shows that the vast majority of students understood how to use the tutorials the very first time, and assessed the organization of the CD and the layout of the screens.

The inclusion of audio descriptions on the CD received mixed reviews, as shown in Fig. 5. Some student found it helpful, while a similar number of students di not use the audio

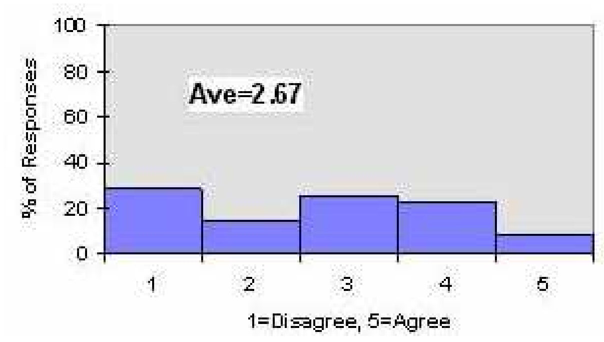

Figure 5: Audio narration useful

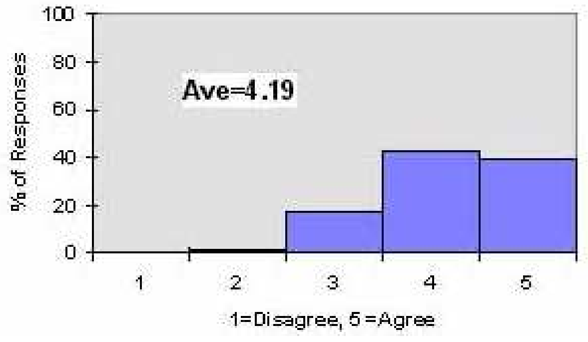

Figure 6: CD tutorial useful overall

portions at all. The audio portion followed the screen text almost exactly, and many of the written survey responses included comments such as, "Audio unnecessary, we can read." Still it seemed that the audio portion was able to perform its intended purpose, which was to permit the student to concentrate on the graphics, rather than try to read text from the screen. For the future versions of the tutorial, it may be possible to remove the screen text when the audio is active. Removal of the text altogether would not be possible, as this would not be accommodating to hearing impaired students.

The overall usefulness of the CD, shown in Fig. 6, was rated at 4.19, which represents a significant increase over conventional textbooks in past years. In past years, when asked to rate the textbook for usefulness in the class on a scale from one to five (five is most useful, one is least useful), a conventional textbook would rate an average of between 2.50 to 3.00. Fig. 7 shows the student response to the usefulness of the (conventional) textbook in a 1995 survey, which was typical for any textbook previously assigned in the course.

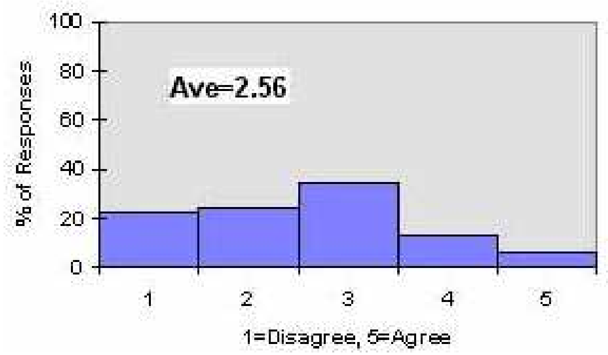

Figure 7: Typical usefulness of textbook (1995)

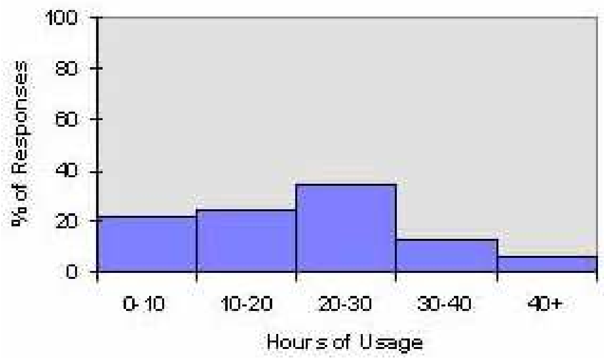

Figure 8: Hours of CD tutorial usage

On average, while studying, students claimed to use the CD 83% of the time, their own notes 10% of the time, and the conventional textbook only 3% of the time. However, since the CD tutorial was designed to follow the course as taught at UC Berkeley, it is not likely that similar responses would be expected if the tutorials were used elsewhere. The average time of usage for the CD was 20 hours during the class, although the range was quite wide, 10% of the respondents never used the CD, while 30% used it exclusively. An average of 20 hours use for the entire course appears to be shorter than would be expected for any textbook. Thus, it appears likely that the CD was a more efficient means of delivery for the course material.

Student written comments indicated that the tutorials were especially helpful for descriptive geometry. Descriptive geometry is considered the most difficult part of the course, and, as such, received a more extensive treatment on the tutorials. Many students also indicated that the use of animations on the CD made many topics clearer than was explained in the lectures.

The final question that was asked on the survey was concerning whether or not th euse of the CD format was preferred to that of a conventional textbook. Students seemed to prefer the CD to a standard textbook by a large margin. On a scale of 1 – 5 (Disagree – Agree), the average response was 4.1. It was noted, however, that many students wrote that a standard text contained much more information, but the CD was more fun to use.

5. Concluding Remarks

The description of the contents of the tutorial reveals that it gives a thorough, but standard, discussion of engineering graphics. The novelty of the CD is that the material is presented in an interactive multimedia format. Nearly all of the topics encountered in an engineering graphics course deal with 3D objects or concepts, which are often difficult to visualize. This is especially true in the cases of orthographic projection and descriptive geometry. In both cases, 3D representations and animation of these representations can benefit students trying to relate 2D drawings to the 3D objects they represent.

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