

## **Multimedia Tutorials to Improve Visualization Skills in Engineering**

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### **Abstract**

Engineering students require a high level of visualization skills not only in the design process but also in the solution of engineering problems. Many students have problems in the representation of a three dimensional space in a two dimensional plane or visualizing a two dimensional drawing as a three dimensional solid object. This problem has been addressed in almost every engineering graphics book but still the analysis of the problem is limited to the two dimensional format of the book. Due to this fact, two multimedia tutorials were introduced in a first year engineering design and graphics course to help the students to enhance their visualization skills. These tutorials provide the students the opportunity to solve graphics problems interactively using solid modeling and computer animations allowing the students to visualize in a very effective way the relationship between the solid object and its projection in the two dimensional plane. Even though these tutorials are still in the process of evaluation, the response from the students has been very positive. Other multimedia tutorials are planned to be developed and used in basic mechanics courses not only to reinforce the visualization concepts but also to assist the students to grasp the concepts.

### **Keywords**

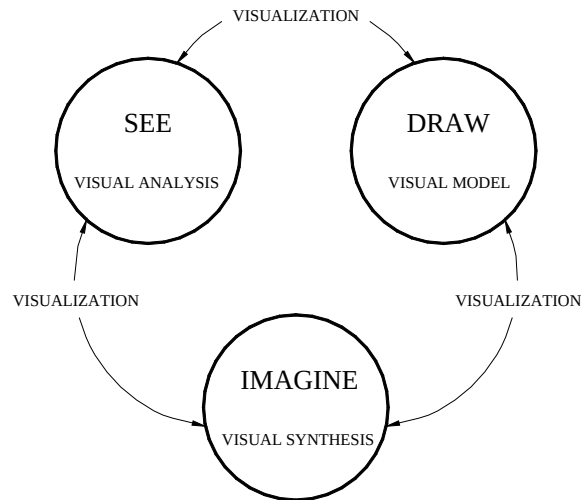
Multimedia, tutorials, visualization, design

### **1. Introduction**

The study of engineering requires some level of visualization skills. Engineers have always used graphics to represent quantities and solve problems. A typical example is the use of vectors to represent forces, velocities, and accelerations among other quantities. The use of the free body diagram is another example of graphic representation for the interaction between bodies in contact or subjected to a system of forces. In the design process, the visual reasoning plays a fundamental roll. As shown in Fig. 1, the design ideation requires visual analysis and synthesis. One of the major challenges in the first year for engineering student is to develop the necessary visualization skills.

The use of visual aids in the learning process has been recognized by many educators and researchers as can be seen in Juarez-Espinosa et al. (2000), Lowrie (2002), Les and Les (2003) among others. The use of labs for many engineering courses is a form to expose the students to actual real problems and they can use the visual component of the lab to better understand the phenomenon under consideration. The well-known expression "graphics speak louder than words" is applicable to the engineering students. However, the use of labs for all the engineering courses is not only expensive but sometimes almost impossible to accomplish.

The use of computers and multimedia systems has become very popular recently. Multimedia system is considered a computer-based communication system as defined by Burleson, et.al (2001) that includes the use of text, audio, video, graphics and computer animations. The use of multimedia software is becoming very important in the learning process. Instructional software can be found for different levels of knowledge and a wide range of subjects. Therefore, the integration of classroom lectures and multimedia tutorials provides not only the theoretical foundations but also the visual component for the engineering problems that help the student to grasp the concepts and enhance their visualization skills.



**Figure 1: Visual thinking as a fundamental piece in the design ideation**

## 2. Multimedia Tutorials

Multimedia tutorials have shown to be a very effective learning tool (Poli et al. 2003). Multimedia tutorials can have all the necessary tools for an effective learning experience. Text, audio, visual effects, videos, pictures and graphics animation can be easily integrated in a single program making the tutorial not only user friendly but also a pleasant experience. Computer-related tutorials can be used as a supplemental learning tool for the traditional classroom teaching or they can be used as a single teaching tool for on-line courses or even for in-house courses. In both cases its effectiveness has been proved as concluded by Merino and Abel, (2003).

The multimedia tutorials differ from the textbooks in regard to the way the concepts are presented. The textbooks contain inanimate text and figures while the computer-related tutorials are dynamic pages containing audio, video and graphics animations. Besides that, an effective tutorial allows the user to jump from one section into another in a very efficient way using hyperlinks while in the regular textbook it takes more time to find the desired topic. Additionally, in a multimedia tutorial the user can obtain immediate feedback of his or her performance and even recommend the topics to review if necessary.

The strengths and weaknesses of a multimedia tutorial can be summarized as follows:

Strength of a multimedia tutorial:

1. Students can study and review the topics at their own pace.
2. It can be use for on-line or distance learning.
3. They can contain graphics animation (many students are visual learners).
4. They contain hyperlinks allowing the students to move between topics and problems.
5. Provide immediate feedback to the student.
6. Student can access the material from any computer.

Caveats:

1. Some students learn more under pressure.
2. Replace the human instructor could affect some students.
3. Problems in the system prevent to access the material.

Multimedia tutorials have been used effectively at different levels and topics from Pre-K to advance university level. More and more topics are being explained using visual and sound effects since these are important tools in the understanding and learning process. An effective multimedia tutorial should:

1. be easy to use;
2. contain clear definitions and instructions;
3. have appropriate set of examples and problems;
4. have immediate and accurate feedback;
5. have appropriate images and animations related to the problems;
6. be enjoyable to use.

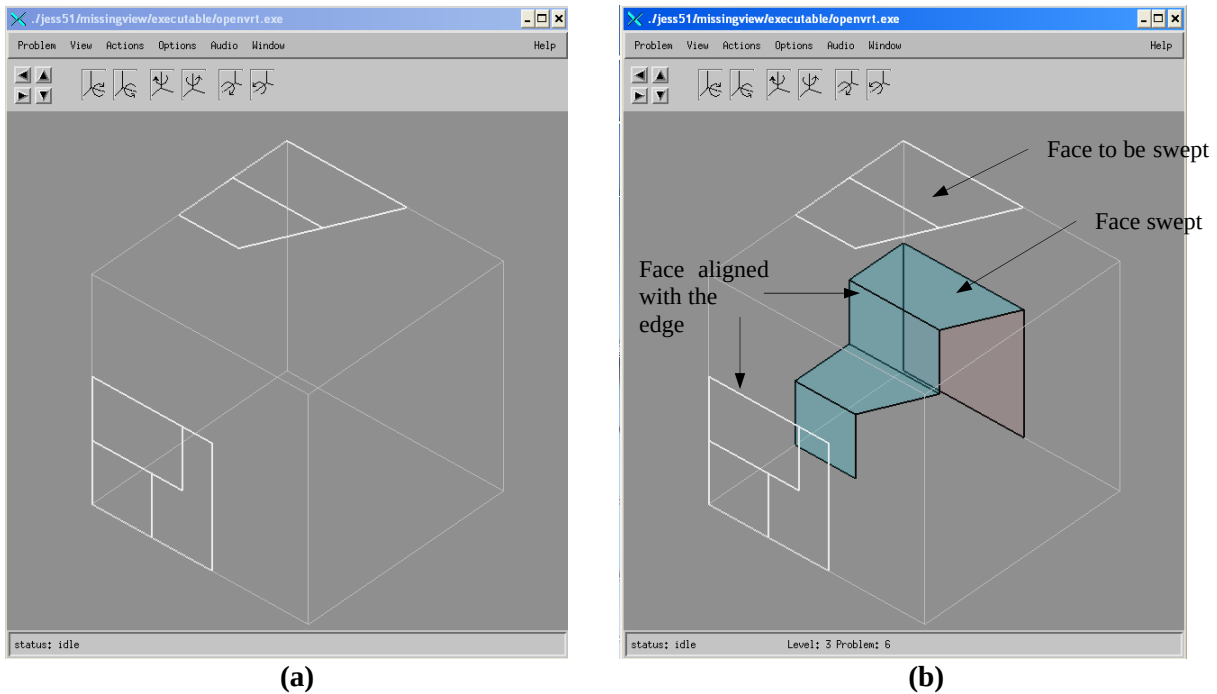
### **3. The VRT and OPT tutorials**

The Visual Reasoning Tutor (VRT) (see Zhao and Kim, (1994) and Hubbard et al., (1996)) and the Orthographic Projection Tutor were introduced in the freshman course: Engineering Design and Graphics. Both multimedia tutorials, developed by Yong Se Kim at Sungkyunkwan University, Korea, are designed to help the students in the visual reasoning process and to enhance their visualization skills. The students are instructed in the use of both programs and then they move from the simplest problem to more complex problems at their own pace.

In the VRT, students have to construct a solid model from the two orthographic projection views given. Since two orthographic views do not completely describe a solid object, more than one solution is possible in some of the problems. The students should construct the feasible 3D solid object from the given views by using sweeping operations, which are the reverse procedure of orthographic projection. These missing view problems help the student to complete the visual thinking process depicted in Fig. 1: see the given views, imagine the object and draw the solid model. Students are encouraged to determine if more than one solution is possible and find other viable solutions. The idea of this is to exercise the visual thinking. This software provides assistant during the solution of the problem allowing the students to check at any point their progress and determine if the sweeping operation performed (inverse projection) has produced a feasible solid face.

Figure 2 shows one of the problems available in the VRT tutorial. Figure 2(a) shows the statement of the problem. Two orthographic views are given and the solid model has to be generated from those views. To construct the solid model, the “Actions” command is selected from the pull-down menu bar. This button lists the “sweeping operations” available. To sweep a face the “Sweep Face” option is selected and then using the mouse the edges forming the face are selected. Once a close contour forming a face has been selected, the sweeping operation can be performed just by dragging the face with the mouse. Once the face is aligned with an edge in the corresponding projection plane the operation is completed as represented in Figure 2(b) that shows a partially completed solid model. The same operation is repeated for all the faces that can be swept. Edges and vertices can also be swept to totally complete some faces. The face to be completed in the Figure 2(b) consists of 2 steps: first the face is swept and then an edge is swept to completely have the inclined face in place. When oblique faces are present, the “Sweep Vertex” command is required to complete the oblique face. There are faces that can not be created by sweeping operations. Those faces are created using the “Construction” command after all the faces created by sweeping operations are generated. By clicking the “Window” command, the “Teacher” window can be activated and the user can have immediate feedback for each sweeping operation. If the sweeping operation generates a feasible face this face will appear green in the teachers window; if the sweeping

operation generates a partially correct face this face will appear yellow in the teacher window; if the sweeping operation generates a wrong face this face will appear red in the teacher window.

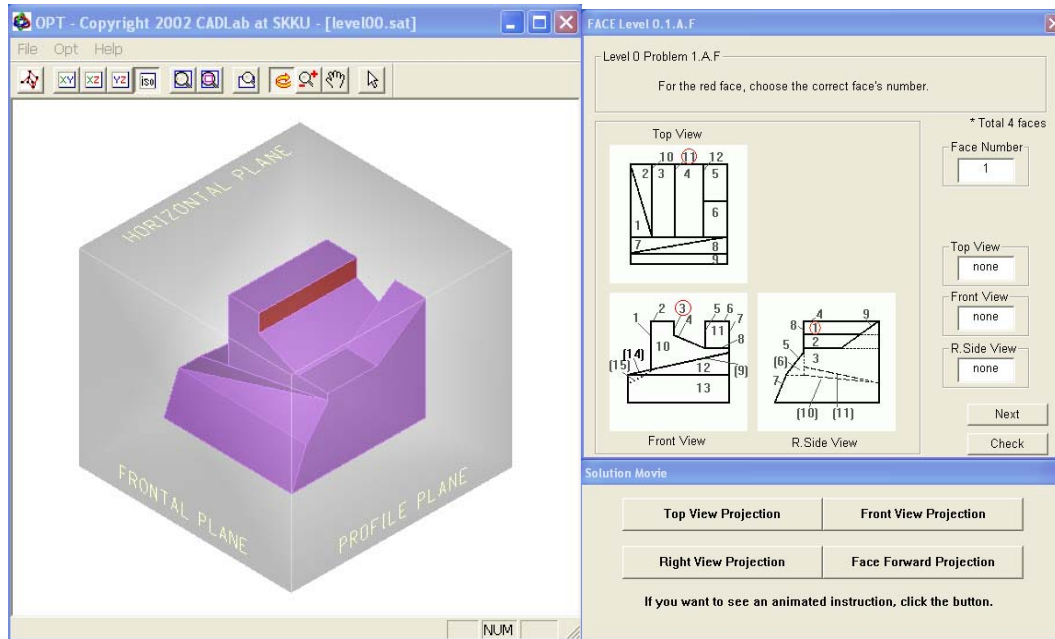


**Figure 2: Missing view problem partially solved using the VRT software**

The OPT tutorial provides a set of problems involving orthographic projections. The software is designed so the students can start solving problems at the highest level. If the students have difficulties solving the problems at this level the software leads the student to a lower level where he or she can solve simpler problems and review the concepts needed for the higher level. The tutorial was designed following a learning network where the concepts and problems are related and linked according to the definitions and concepts concerning the specific topic in orthographic projection; therefore, students are sent through the learning network to review the problems and concepts needed for the problems at higher levels. Even though the tutorial was designed to start solving problems at the highest level, the tutorial has been introduced in the freshman engineering design and graphics course not only for the student to solve the problems but also for the instructor to present the concepts for multiview drawings. Therefore, instead of starting in the highest level, students are instructed to start from the lowest level and move up once they have solved all the problems in the respective level. This practice allows the student to reinforce the concepts and being better prepare for the higher level problems. Students are instructed to move across the learning network so they can choose the level and problems they want to work in at any stage. This permits the students to advance at their pace. In any case, the tutorial keeps the ability to “evaluate” the performance of the students and send them back to a lower level if they do not solve a problem properly. The greatest feature of this tutorial is the relation between the concepts, problems and animations. Each level contains a good set of problems that are always complemented with a three dimensional animation for each particular problem.

Figure 3 shows a typical problem in the OPT. The example shown belongs to the highest level (level 0) and is identified as Problem 1-AF. It is observed that on the left side, the solid model is shown and this can be moved, rotated, panned, zoomed in and out similar to the actions that can be performed in any solid modeling software. On the right side the statement of the problem is given with the space to provide the answer. On this example four faces are highlighted, one at a time, and the user should identify the face number in the multiview drawing shown. The user can check the response immediately by clicking the

check button. This action also causes the “solution movie” window appears and from here the animation movie showing the projection of the highlighted face can be played. It can be seen that the animation has four options; therefore, the user decides which projection he or she is interested in reviewing.



**Figure 3: Orthographic projection problem using OPT software**

#### 4. Conclusions

Both tutorials have been effectively used not only to teach the engineering graphics concepts but also to help the students to enhance their visualization skills. Most of the students have learned the mechanics of both tutorials very quickly and have been able to use them to study engineering graphics at a self-paced rate without needing additional interaction with the instructor. Very few students required additional interaction with the instructor for an effective use of the instructional multimedia packages. Even though not all the students in the freshman engineering design and graphics class have the same background in engineering graphics (some students have already taken technical drawing classes in high school), the entire group adapted comfortably to the tutorials since the problems provided vary from very basic to more complex and difficult problems. Therefore, the variety and level of problems are adequate for any stage of technical graphics knowledge.

Students have shown that they enjoy the interaction with the tutorials and learn visualization skills while they are challenged to solve the problems. The immediate feedback makes the whole practice a learning experience rather than an evaluation process. The tutorials have solely been used for the students to study, practice and learn but not as a grading tool. This is an effective way of removing the grade related pressure so students have the benefits of learning while playing.

Students have effectively applied the concepts learned using the tutorials in developing three dimensional solid models using AutoCAD and SolidWorks. It has been observed that the use of planes in the three dimensional space as well as the use of two dimensional drawing in a plane and the subsequent extruding operation to generate solid models are better understood by the students as a result of the tutorials. The use of these solid modeler programs is an important tool in the design ideation process where the visualization plays a fundamental role as depicted in Fig. 1.

The teaching and learning experience of engineering graphics using the multimedia tutorials is not only more enjoyable but also more effective as compare with the traditional teaching and learning method using the board. With the multimedia tutorials students can see the relationship between the 3D solid model and the 2D orthographic projection and vice versa taking advantage of the animation showing the forward and backward projections. This definitely helps the students not only to clearly understand the concepts of engineering graphics but also to enhance their visualization skills.

## 5. Acknowledgement

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