An Instructional Method for the AutoCAD Modeling Environment

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ABSTRACT

This article presents a command organizer for AutoCAD to aid new users in operating within the 3D modeling environment. While teaching solid modeling as the basis for engineering design, as well as a using the modeling database as a focal point for the generation of other types of technical and engineering graphics, it was found that new users frequently encountered the same problems and asked the same questions when presented with the 3D environment. The organizer presented in this article is designed to help engineering students become acquainted with the AutoCAD modeling environment and the commands that control the environment; it has met with limited success in both visually organizing the command structure and decreasing new user questions. Although it is specifically designed for the AutoCAD environment, it must be noted that the underlying environmental controls and the operation of the environment is consistent and applicable to many other software packages and graphical applications.

INTRODUCTION

The use of three-dimensional environments in engineering education has drastically changed the way engineering graphics concepts can be presented and taught. Three-dimensional modeling enables engineers and designers to work in a realm that on paper can so easily evade them. As educators continue to increase the implementation and use of computer modeling tools, they continually request more and more features in their desktop CAD software. In doing so, the interface and other aspects of the software become more complicated for new users.

As engineering educators, we ourselves have no doubt gradually migrated to the modeling package of our choice. Often this migration occurs in small, incremental steps over several years of our professional career. Unfortunately, for students, the introduction to 3D tools is foreshortened. Students must become accustomed to the software tools much more quickly for success in the limited amount of time they have in the computer laboratory. Many times students struggle to not only learn a new software, but also to adapt to the three-dimensional environment and the graphics concepts being taught.

As modeling continues to become a larger part of engineering education, often it is difficult to separate theory instruction from tool instruction. Much classroom time is spent teaching tool specific techniques rather than more global, conceptual matters. Techniques and procedures in model manipulation are a daily occurrence because tool instruction is important in the day-to-day nature of the tasks and projects the student must execute. But the optimum is to be more than teachers of a software tool. To empower students, engineering educators must help students overcome the learning curve of new software and the modeling environment so they may conscientiously attend to learning concepts.

In software such as AutoCAD, new users are often intimidated by the wealth of commands, not to mention the three-dimensional working environment. Many of these 3D modeling packages have evolved significantly from version to version, with very few features being removed. The evolutionary nature of the software presents the student with several complex paths to get from A to B; some being more efficient than others. This nonlinear characteristic makes the CAD software an inhibiting and unstructured environment for new or casual users.

In addition, educators continue to involve students with the modeling paradigm earlier in their education. Several sources state that early introduction to modeling increases visualization skills. Likewise, many have departed from traditional board-based descriptive geometry to modeling environments to teach visualization (Bertoline 1991, Devon, et. al. 1994, Sexton 1992).

The focus of this paper is not to debate these issues, but rather to acknowledge that early introduction to computer modeling and the 3D environment compounds the number of cognitive skills being concurrently developed, particularly if computer skills are waning. Engineering educators must analyze the possible attributes that make the 3D environment difficult for students to use, as well as the various teaching aids that can assist the student in understanding and becoming efficient in the operational 3D modeling environment. By endeavoring to decrease the software learning curve through the use of mnemonic devices, organizers, multimedia and visual descriptive aids, students can more easily focus on the process instead of the tool or environment. Enabling students to move beyond the software should be a goal; allowing them to focus on visualization and spatially-focused analytical skills. In reality, anything engineering educators can do to help the user cognitively arrange and understand the 3D environment and software commands lowers the learning curve and empowers the student.

ANALYZING THE PROBLEM

To begin creating efficient and effective tools or aids for instruction the problems associated with learning a 3D tool must be analyzed. A review of literature points out that there are many factors that can contribute to the difficulty new users have with a 3D environment. Let's face it, students who can now interact and build almost anything within the virtual universe contained within the desktop computer are not used to being able to draw or operate within a virtual 3D environment. Previous drawing experiences of most students are almost certainly limited to drawing in two-dimensions. Experiential conditioning to be "flatlanders" has prepared most students to think in a two-dimensional manner, always striving to find a way to draw in three-dimensions when they only have two with which to work. Three-dimensional environments contradict the traditional drawing and sketching paradigm that students have been presented and for which they have been conditioned. This alone presents students with a learning curve that is quite pronounced when it comes to 3D environments. Not only must they deal with the environment but they must also learn to control it. Yet there are also other factors that contribute to the difficulties of today's 3D modeling environments.

Visualization Skills

In addition to the tremendous shift in paradigms, another problem is that many students have little visualization ability. To present students, whose visualization skills are waning, with a 3D environment can be disastrous because they often do not have spatial visualization or spatial orientation abilities. Yet, one does not have to subject a student to a 3D environment to see this weakness exhibited. In most instances, visualization ability can be revealed through the use of imaginative sketching exercises as well as specially designed tests which reveal the level of spatial proficiency within the student. Engaging a student, weak in visualization, with a 3D modeling environment only magnifies the student's visualization weakness.

The study of visualization ability and its affect on the student has a long history in many professional societies. As described by Miller (1996), visualization has long been a part of the information disseminated throughout the Engineering Design Graphics Journal. One of the most intriguing factors, at least to this author, is the role that imagination plays in visualization ability. Many of the sources discussed by Miller, including prominent historical individuals in the field such as Orth (1941), Blade (1949), and Kliphart (1957) state that imagination is primary to visualization ability. It would seem natural (and is pointed out by these sources) that the ability to imagine familiar objects such as a chair, table or other item is a precursor to being able to visualize an object based on orthographic multiviews. It would also stand to reason that imaginative ability would be a precursor to operating within a 3D environment which requires spatial visualization and orientation abilities.

Within our own decade, the impact of imagination can be seen through suggestions for curricula and media tools to aid in teaching visualization. Wiley (1990), Wiebe (1993), and Ross & Aukstakalnis (1993) suggest that the use of real models, animations, and virtual environments can aid in teaching or enhancing visualization ability.

It seems that as technology continues to increase in its ability to entertain students, imagination is used less and less by students. Students become used to being entertained rather than imaginatively entertaining themselves. Therefore, the imaginative skill is undeveloped. Does a decreased use of imagination decrease potential visualization ability? Although research is needed to validate this point, it is intriguing to consider that a loss (or decrease) of a historically noted precursor to visualization -- imagination -- could be one of the reasons a greater number of students have difficulty with visualization, and consequently, operation within a 3D environment. It will be interesting to see the impact that computer technology such as the World Wide Web, Virtual Reality Modeling Language (VRML), and the 3D human-computer software interface has on the visualization skills of the next generation of engineering students. If 3D technologies infiltrate the younger generation, visualization skills may be more refined within entering freshman -- if not as a result of imagination, then as a result of experience.

Nonlinear Tools

Another possible contributor to the problems that students have with the AutoCAD modeling environment is the way in which they have access to the commands that control the 3D world, as well as the way in which those commands are presented in the educational setting. Much of this is related to the ability to perform any number of operations within the 3D environment at any given time -- the software's nonlinear attribute. For example, at any time, an object can be rotated or moved. At any time the view of the database can be rotated or moved. The coordinate plane can also be positioned anywhere at anytime. This scenario presents the student with a unstructured or independent mode of operation. Most often students become disoriented as a result of unstructured control -- too many variables.

Note that even the most primary introductions or exercises to the 3D environment tend to be unstructured. Often creating simple primitives, an "easy" exercise, requires more than simply defining two corners of a box or defining an origin and radius for a sphere. Attributes such as the current view, coordinate plane, and the 3D position of objects all enter into this seemingly simple exercise; making the 3D environment more difficult to learn for most individuals. It is the ability to change the view, object position or orientation, and coordinate plane at any time that causes problems because students do not understand the interrelationship between these attributes.

It is no surprise that most students learn best in a structured environment. Most educators understand that structured learning environments are a vital method of receiving instruction. Time has proven that this is an effective method of instruction in many different fields. Yet when students are presented with a nonlinearly structured tool, such as a 3D modeling environment, they often become disoriented and find it difficult to learn. Humans by nature are linear creatures and often become disoriented in nonlinear environments.

From experiences in early childhood, the brain is conformed to acquiring information in an organized and progressive fashion. Yet the brain, in many individuals, can be more responsive to nonlinear and nonsequential environments. Looking at the various learning styles of a range of individuals reveals that while some thrive on structured learning or information reception, others have significant difficulty decoding and encoding the information in this atmosphere.

It is no surprise then that when presented with a nonlinear tool, such as AutoCAD, that most students need an organized schema of analyzing and controlling the 3D world. When presented with even a simple task, such as creating a series of primitives, the are many variables that enter into the creation of those primitives beyond simply defining a box, cone or sphere. Location of the coordinate plane, viewing position, and the points chosen for defining the primitives all must be dealt with in this simple exercise. With so many variables, students need a structure for learning how to control a 3D environment.

A Static View of a Dynamic World

In the literature surrounding 3D environments, much research has been performed to determine the effectiveness of dynamic environments and dynamic graphics. A student's perception of concepts, interrelationships, and spatial relationships is affected by the use of animations and virtual environments. Much of human depth perception and stereoscopic vision is based upon a dynamic, rather than a static view of the world.

With 3D tools, often the student does not understand the relationship between the attributes of the actual modeling environment and what is seen on the display screen. Questions often arise concerning why something on the display has gone awry when the view has been changed or when the model has been moved. The static display could be one of the contributors to this misconception.

Fundamentally, students are used to dealing with dynamic environments and they are used to being able to move about their environment to better understand it. To better understand a tangible object, the student can move himself or turn the object to better view it, but given a 3D environment, most students become confused about how to do either of these operations when presented with a static display of the environment.

Indeed, some of the newer modeling environments such as 3D Studio Max as well as tools such as VRML focus on the need for a dynamic environment. The developers of these tools are aware that the perception of the 3D environment is much more accurate and efficient when the environment is dynamic. For example, real-time display of rotation operations along any given axis, as well as constant redrawing of the coordinate plane make the modeling environment of 3D Studio Max more understandable by those who are weak in visualization skills. A dynamic display environment is advantageous in a 3D modeling environment. Without it, the student must understand the attributes of the 3D environment as well as the interrelationship between the view and objects and their six degrees of freedom.

THE AUTOCAD ORGANIZER

While teaching an introductory CAD course at Purdue University, it was noted that a simple organizer for AutoCAD commands reduced much of the confusion concerning the introduction to the three-dimensional environment. An organizer is a cognitive organization scheme that allows the learner to mentally comprehend, arrange, and synthesize information. Organizers create a global picture that can be seen among and between the individual pieces of information in the arrangement, while also providing a means for deductive reasoning and analysis. Organizers are best used when there is relationship among and between the information pieces, as is the case with the AutoCAD solid modeling environment.

Over a period of two semesters, a trend began appearing within Technical Graphics 200 Introduction to CAD, the first modeling course, as well as the first CAD course for most of the students. During the early months of the course and throughout all sections, many students seemed to have difficulty operating in the three-dimensional environment. Most of the difficulties seemed to arise out of an apparent misconception of the three-dimensional environment and the commands that control it. Many students would change the view point and believe that the model had somehow changed location or orientation. Subsequent movement of the model further complicated the situation because the student assumed other variables had somehow changed. The ability to not only move the viewer and the object(s), but also the coordinate system, seemed to present the user with too many opportunities for error.

Through observation and student questions, it seemed that the students did not understand the global concepts of the three-dimensional environment. Primarily, students were not making the mental connection between the commands and how they affected and controlled the three-dimensional environment. Later in the semester the students did make the cognitive connections -- between the commands and the environment -- without intervention, but it seemed that it should occur much earlier in the course to be optimally effective. Through these in-class observations it was noted that to become productive in the 3D AutoCAD environment the student must (a) understand the attributes of the 3D environment, and (b) develop a mental hierarchy of the commands used to control the environment. The organizer for AutoCAD is based on these two assumptions. The organizer must be preceded by an explanation of the attributes of the environment; what makes up the environment. All the AutoCAD commands can then be divided by the attribute they affect.

ENVIRONMENT ATTRIBUTES

Most three-dimensional CAD courses begin by introducing students to the three-dimensional environment; requiring them to create a series of the modeler's primitive objects (assuming the use of a CSG modeler) or some other base exercise. Creation of the basic primitives allows the students to "get their feet wet" in the three-dimensional, digital world. However there are underlying attributes, beyond the objects, with which they must contend. For example, the particular view that is used in the creation process directly affects what appears on the student's display. The coordinate system also affects this exercise by limiting the way the primitive is defined. These underlying factors, view and coordinate system, create a mild barrier in this exercise because the student is actually dealing with three separate attributes at one time. Many times students do not recognize that all three attributes, viewer, object(s), and coordinate system, exist, interrelate, and affect the database simultaneously. Because they do not recognize the three attributes, students become confused with the commands that control the viewer, object(s), and coordinate system. Hence, the thought that changing the view has moved the object. As a result of this logic, this simple exercise lead to the development of the AutoCAD organizer which is based on the three primary contributors to the three-dimensional environment shown in Figure 1. These primary contributors include the viewer, the object(s), and the coordinate system. Once students understand and recognize both the existence and relationship of these three elements they can more easily operate in the three-dimensional environment.

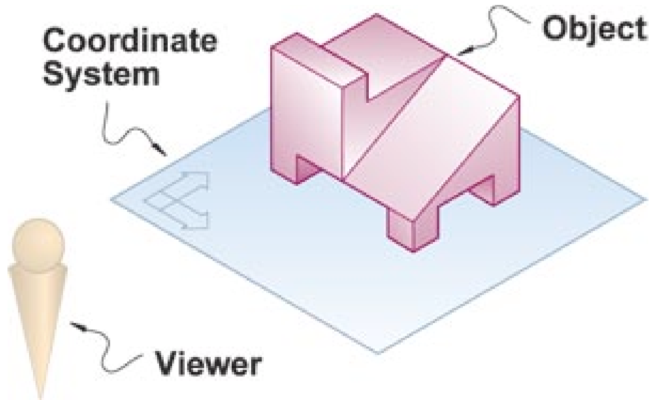

Figure 1. The three primary attributes of the 3D modeling database: viewer, object(s), and coordinate system.

To support the organizer command structure, students must be taught that there are three major elements or attributes found in the three-dimensional database. In Technical Graphics 200, the modeling environment was described in the following way.

The first attribute or element of the modeling environment is the objects. They are the main focus of the modeler; they are what is being created. The objects exist in theoretical space without ends. Each object has both a location and an orientation, and can be moved, rotated, or edited anywhere in the theoretical space.

The second element is the viewer. The viewer is the student's vantage point of the three-dimensional world. Unfortunately, the theoretical space (in which the model exists) goes on without end; therefore, students can only see through a small window on the monitor (Figure 2). However, the student's view can be changed, allowing them to see adjacent parts of the three-dimensional world. Knowing this, the viewer, like the object, has a specific location and orientation.

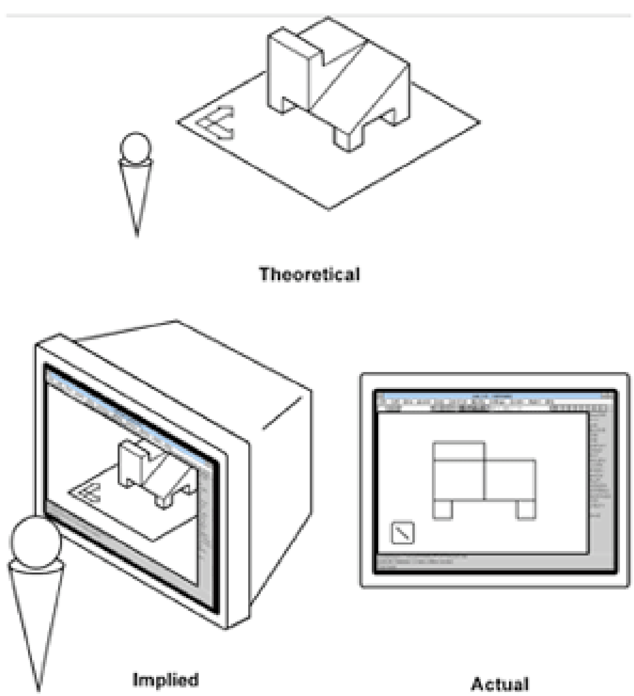

Figure 2. The theoretical, implied, and actual display of a 3D environment.

The third element, the coordinate system, is the orienting plane. During the introduction to the environment, the students were encouraged to use a grid to help visualize the location and orientation of the coordinate plane. In AutoCAD, the student must realize that the height of all primitives rises out along the Z-axis; therefore, the coordinate plane affects how primitives are created (Figure 3). The coordinate plane, or User Coordinate System, is moveable and it has a location and orientation. If the plane did not move, all primitives would have to be created in one location, then rotated and moved to the "final" position. A moveable construction plane allows primitives to be created "on-site."

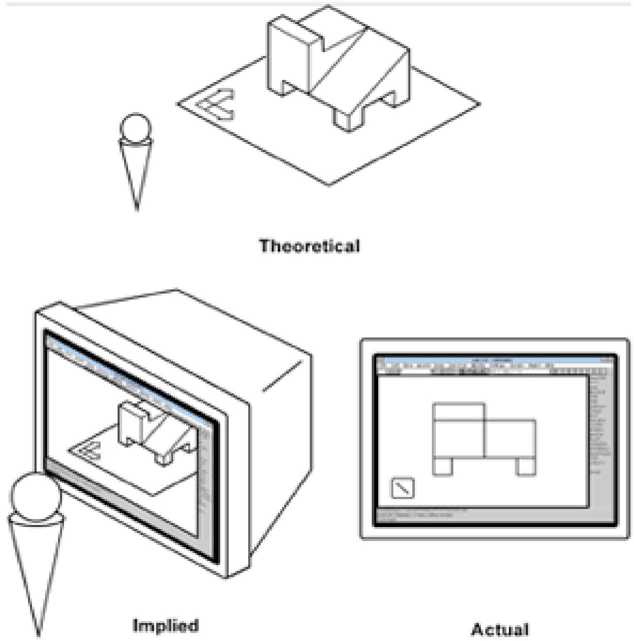

Figure 3. In AutoCAD, the height of all primitives rises parallel to the Z-axis.

Once students understand these elements, the environment can be summarized by the following:

1. The viewer, objects, and coordinate system (UCS) exist in conceptual space that is unlimited in scope and defined by an absolute, fixed coordinate system called the World Coordinate System (WCS).
2. The viewer, objects, and coordinate system (UCS) can be oriented and/or moved anywhere in the coordinate space.
3. The relationship between the viewer location and orientation and the object location and orientation determines what is seen on the computer screen.
4. The coordinate plane determines how a primitive is created in the drawing space.

CONTROLLING THE ENVIRONMENT

Once the students understood the environment attributes, the commands were then described using the organizer. In Technical Graphics 200, all the commands were divided into one of four areas: object, user, coordinate system, or utility (see Figure 4). By dividing them in this way, students could analyze what they wanted to do and find the division to which it belonged. They could then reference the division's commands and decide upon the scheme that allowed them to analyze what they were doing in real time. For example, a student wants to change the current view. Looking at the organizer and understanding that the viewer location and orientation defines the view, he finds the viewer division in the organizer and executes the appropriate command. If he wants to affect either of the other two attributes, simply referencing the organizer structure will indicate the appropriate command.

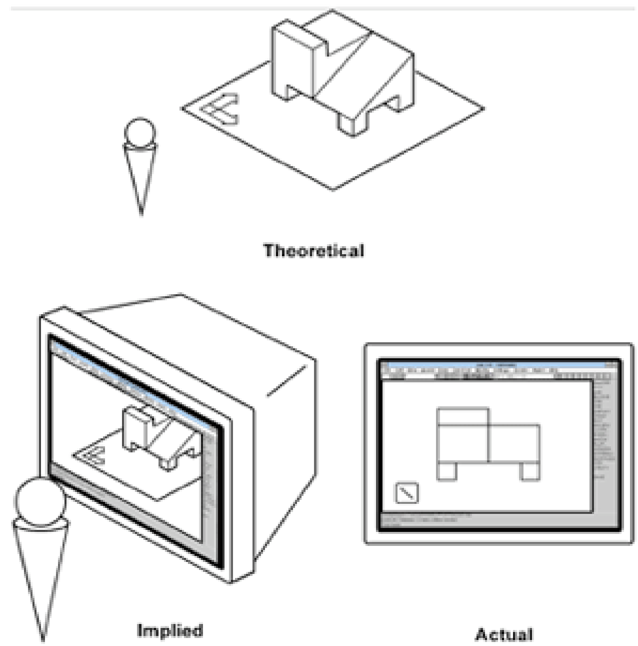

Figure 4. The AutoCAD command organizer.

In addition to hierarchy, the organizer also provided a means for students to understand that changes can only occur within one of the areas at a time. For example, many beginning students change the location of the viewpoint and mistakenly believe that the object has somehow changed location or orientation. Using the organizer and understanding that changes can occur only within a single division gives students a means of checking their logic versus the organizer and to the possibilities within the three-dimensional AutoCAD database.

WHY DOES THE ORGANIZER WORK?

One of the pervading questions that persists concerning the command organizer is why does it work? Review of the literature concerning spatial visualization leads this author to believe that the organizer works because it describes and cognitively separates the two main spatial skills that compose visualization ability. These two skills are required for efficient and effective use of the 3D environment: spatial visualization and spatial orientation.

Sexton (1992) describes the effect of using 3D CAD technology to introduce basic engineering graphics concepts. In this article he notes that there is much disagreement about the nature of visualization ability even though it is agreed that it is an important component of intellectual ability. There is also agreement in the field concerning two basic components that comprise visualization ability: spatial visualization and spatial orientation. Quoting McGee (1979), Sexton's article described spatial visualization as "the ability to mentally rotate, manipulate and twist two- and three-dimensional stimulus objects." Again, quoting McGee, spatial orientation is "the comprehension of the arrangement of elements within a visual stimulus pattern, the aptitude to remain unconfused by the changing orientations" of those patterns.

This author believes the organizer works because it aids the student in understanding how to manipulate and control the objects in the 3D environment (through the organizer structure) which satisfies the spatial visualization component of visualization ability. The understanding of the environment attributes (object, viewer, coordinate system) enables the student to "comprehend the arrangement of the elements within a visual stimulus pattern" (paraphrase McGee, 1979) by understanding what is in the environment. This satisfies the spatial orientation component.

At the time of the presentation of this paper, the biggest question for this author was, why does the organizer work? Respectively comparing the organizer method (environment attributes and command structure) to the components of visualization ability (spatial orientation and spatial visualization) may reveal the answer.

Although the significance of the organizer's impact on use of the three-dimensional environment needs further analysis, preliminary in-class results indicated that students were able to more quickly understand how the environment works. In addition, the number of questions concerning manipulation of the viewer, objects, and coordinate system decreased. Undoubtedly, the most significant reason the organizer helped the student is because it is a visual command hierarchy. Having a reference sheet designed in this way helped reduce questions concerning the AutoCAD commands.

Other instructors have also questioned how all the remaining commands could be grouped into the general "utility" division. It must be noted that the main purpose of the organizer is to provide a logical structure for understanding how to manipulate the three main elements: viewer, object(s), and coordinate system. With the wealth of commands available in AutoCAD, undoubtedly more divisions could be added to the organizer. Further development of the organizer command structure, subdividing the remaining commands in AutoCAD, could increase its significance, importance, and application.

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