New Technologies for Engineering Graphics

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ABSTRACT

Historically, design representation and verification was relegated to engineering drawings and other manual methods that were used to convey information for product design, analysis, and manufacturing. Because of the rapid development and implementation of relatively low cost and extremely powerful computer technology, the methods used to design and engineer products have radically changed. In the face of increased global competition, many industries around the world have adopted a team-orientated concurrent approach using 3-D CAD databases as computer descriptions of part geometry which can be directly applied to engineering design, analysis, and manufacturing (Bertoline, et. al., 1998). Computer technology and specifically 3-D solid modeling CAD technology has significantly altered the way in which products are designed from "art to part". The focus of this paper is to provide background information on several new technologies that should be considered for use in engineering graphics courses. The proper use of these technologies and graphics fundamentals in engineering graphics courses should provide engineering students with theoretical and applied knowledge so that they can be successful in today's digital world.

Intrbduction

Rapid changes in computer technologies will continue to allow engineering educators to review the content of their curricula and make improvements to them based on the changing technology. This is also true for engineering graphics educators where new low cost technologies are allowing powerful graphics tools to be introduced into the engineering graphics curricula. The problem facing graphics educators is very complex because these new technologies are only tools that aid in the production of designs. Thus, engineering graphics educators should review the body of knowledge that their curriculum is based upon and determine if it presents the content that engineering students will need upon graduation.

This paper presents what the author envisions the body of knowledge should be for all engineering graphics curricula or programs; but its main focus will be on some of the latest innovative computer graphics technologies and how these might impact engineering graphics programs.

Modern Engineering Graphics?

Before discussing new technologies, some basic assumptions are presented regarding successful engineering graphics program in today's computer-based technological society. Any modern engineering graphics course should contain the following emphases:

1) An emphasis on visualization is of central importance for the advancement of visualization abilities and for the applied use of visualization technologies, such as scientific visualization technologies. Without advancing visualization abilities, students may never reach their potential to be successful engineers. If visualization is not important, how can engineering graphics educators claim that the engineering graphics language is the communication tool for all engineers?

2) Creative and problem solving abilities are also important so that students are allowed to use and develop these abilities in conjunction with the most modern tools available to them. They cannot be forced to use dated technologies such as manual drafting, 2D CAD technologies, 3D static modeling technologies, and traditional descriptive geometry exercises. Although the concepts involved in these technologies are very important, traditional methods of presenting them are dated, at best, and at worst in today's industries they are extinct.

3) Design based exercises are important for the students so that they can use their creative abilities to solve engineering problems. Both structured and open-ended design exercises are important for engineering students, not only because it allows them to develop design abilities, but also because it allows them the chance to use the most modern design tools, such as constraint-based solid modeling and CAD based simulation and analysis.

4) Knowledge of engineering graphics standards is also very important for engineering students. Without knowledge of these standards and conventions, they will have a very hard time adjusting to and becoming successful as practicing engineers. It is also very important for engineering students to be able to apply the use of engineering graphics standards while using the latest computer graphics tools available to them.

5) The ability to sketch ideas is also very important for any engineering student. Many times ideas must be rapidly sketched out so that the engineer will not forget the idea or so that they can convey it quickly to others. Likewise with the advent of CAD, especially constraint-based modeling, planning sketches are important for the most efficient use of this technology.

6) Exposure to and the applied use of constraint-based solid modeling technology is important. The integration of mid-range CAD technology, much of which is constraint-based solid modeling, is revolutionizing middle and smaller companies. Most companies will be forced to change from 2D CAD drafting packages to midrange constraint-based solid modeling packages in the next few years. It is estimated that over 700,000 seats of 2D CAD packages will be converted over to mid-range CAD packages in the next few years (Potter, 1998). Thus it will be imperative for engineering graphics courses and curricula to expose students to this technology.

7) Exposure to the latest engineering computer-based technologies is vital for students to be successful practicing engineers. In today's computer-based technological industries, the best traditional engineering graphics programs will not prepare students for the tools that they will be required to use. Tools such as constraint-based modelers, the World Wide Web (WWW), graphical simulation technologies, virtual reality tools, and using graphical databases for file translation between systems and for product data management (PDM) will be vital for their success.

New Technologies for Engineering Graphics

There have been several technological changes that have occurred over the last few years that have allowed engineering graphics educators the opportunity to integrate new technologies into their curricula. The first is the availability of low cost highly powerful computer hardware. Without the availability of this technology engineering graphics educators would not have been able to afford desktop computer systems that allow for the use of CAD based technologies such as solid modelers and simulation and analysis software packages. The availability of inexpensive computer technology, coupled with the development of user friendly operating systems such as Windows NT, has allowed the integration of various computer-based engineering packages without the overhead of learning the user interface. In 1999 it can be safely assumed that a majority of new freshman students have had exposure to a Windows or Macintosh operating system. The drastic cost reduction in software prices for mid-range to high-end computer software packages has allowed these

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programs to be incorporated into most engineering graphics curricula. Because of the increased competition, the cost of constraint-based solid modeling packages, finite element analysis packages and other engineering analysis packages, and graphical simulation tools have drastically been reduced (Potter, 1998). Finally, the growth and utilization of the WWW has both indirectly and directly allowed for the integration of computer graphics technology into engineering graphics curricula. Indirectly, the WWW has made most students computer literate. Introductory courses in computer literacy do not need to be required, but can now be treated as remedial courses. Directly, web technology allows engineering databases to be used and shared between users and organizations that are remote to each other.

Because of the limitless range of topics associated with the availability of new technologies, this paper will focus on how these technologies influence the day-to-day working of a typical engineer. The review of these technologies will focus on engineering-based computer graphics technologies and their importance to higher education in engineering graphics. Specifically, this paper will focus on how engineering graphics curricula can integrate the use of visualization tools, the WWW, and database technology tools. Although of central importance, constraint-based modeling is a topic within itself and will not be directly discussed in this paper.

Visualization Tools for Engineers

Visualization tools are important tools for the engineer to possess. With the advent of concurrent engineering principles prevalent in industry today, these tools can help non-technological team members visualize products or designs that they might never see through the use of traditional engineering drawings. These visualization tools can also be utilized by engineering graphics instructors in their courses to try and help students to understand a design or a product that is presented to them. These tools could help students to develop visualization abilities, thus helping them to become more capable engineers.

The visualization tools that will be reviewed in this paper are virtual reality and graphical simulation technologies and realistic image displays such as photo rendering techniques. Both of these are important technologies that are currently being used in several engineering settings, and they will become integrated in almost every engineering setting in the future because of their ability to help in the visualization of products, designs, and environments.

Virtual Reality (VR) Tools

Virtual reality tools allow an individual to experience an environment without actually having to be exposed to it. Many times exposing an individual to a specific environment is difficult because it is either too expensive to create the environment or it is simply too dangerous. In engineering settings, the above factors may be true or the environment actually does not exist. Thus engineers can use this technology to develop a setting or product and conduct design reviews of it without ever having to actually build it.

Training settings are prime examples of where VR tools are being widely utilized. Trainees can experience the working environment they will work in through the use of a VR environment where they will receive virtual "hands on" training. The correct procedures and proper techniques can be replicated until the learner has mastered the task at hand. Mistakes in doing a task can be reviewed with the learner so that they have a greater understanding of the complex nature of the task at hand. This experience can be gained in a less hazardous environment (Hodges, 1998).

The biggest drawback to early VR systems was their million dollar cost, the poor image quality that was produced, and the awkward tethering and uncomfortable head mounted displays (Hodges, 1998). But as with many other technologies, the costs of VR technology has been drastically reduced. This is coupled with more realistic image displays and the availability of inexpensive desktop systems that will function in a Windows environment. The cost reduction coupled with more realistic displays has led businesses and industries to become more willing to invest in and implement the use of this technology.

VR systems are classified as immersive or non-immersive. Immersive VR systems totally enclose the individual in the virtual world typically through the use of head mounted displays, audio, and tactile experiences. These systems are the most realistic experiences but are also the most expensive.

Non-immersive VR systems typically utilize a desktop PC with some type of input device, such as a mouse, to control navigation through the virtual environment. Although these systems are not as realistic as immersive VR systems, they are gaining widespread acceptance and are rapidly being adopted (Hodges, 1998).

Desktop non-immersive VR systems allow visualizations to occur through the use of flythrough environments, thus allowing simulations to occur. These systems allow for the assembly or disassembly of systems or products. Many corporations use non-immersive VR for sophisticated simulations which allow products to be manufactured and serviced easier. These simulations can be used for design verification and for the elimination of training requirements before a design is actually finalized (Hodges, 1998).

Engineering graphics educators should investigate the use of VR technologies in their curricula. Because of its rapid acceptance in industry to do both training and design verification, and because it is a graphics based product, this technology is by nature an engineering graphics technology. This coupled with the price of this technology being within the reach of educational budgets allows VR technology to be integrated into the engineering graphics curriculum.

The WWW as a Tool for Engineers

The utilization of the WWW has drastically changed the way people gain information and conduct business. From reading a newspaper to buying stocks, the WWW has and will continue to influence the lives of people around the world. Likewise the engineering profession has been vastly changed by this technology. Sharing design information and corresponding via email has vastly reduced the time in which a product or system is developed from the initial design to the final product. Specifically, the development and rapid acceptance of the WWW has made the Internet an accessible and practical tool for not only interactive business activities but also for CAD/CAM and distributed manufacturing activities as well (Adamczyk & Malek, 1998). In effect the WWW has become the de facto standard for providing information on the Internet (Silva & Katz, 1995). Because technology has been largely accepted as a standard tool in industry and because engineering graphical databases are being shared over the WWW, engineering graphics educators should consider implementation of this technology within their curricula.

One of the greatest improvements that the Web has provided for engineers is its ability to effectively and inexpensively distribute project data for almost every engineering task including the distribution of very large and complex solid model files. Rapidly changing technology in 3D data streaming, coupled with improvements in multi-user and network-based visual communication, have allowed engineers to exchange data around the world. This has allowed access to and sharing and reuse of engineering data. Because of the ease in publishing engineering data on the Web, engineers can use this technology to share data, even complex 3D solid modeling data, in which data delays are almost zero (Beazley, 1998).

Beazley (1998) states, "Although we have seen advances in collaboration before, none have matched the impact of the Web with its ease of use, universal access to data, platform independence, and standardized protocols and formats." The impact of this is the ability to collaborate with clients or colleagues thousands of miles away as conveniently as if they were working beside you. This allows for reduced versions and copies of engineering documents. This technology also allows for central storage of engineering documents with accessibility from around the world 24 hours a day (Adamczyk & Malek, 1998).

Another example of the impact of the Web is the capability of accessing 2D and 3D database libraries. It is estimated that as much as 70% of major product designs consist of standard components such as fasteners, valves, motors, etc. The use of standard parts is essential for the manufacture of a product. Engineers spend countless hours locating, referencing, and modeling these parts into their designs. As much as 25% of an engineer's time is spent on gaining this information on standard parts, thus adding time and expense to the developed product. These standard parts can now be purchased from digital part providers and can be used in many of the popular CAD systems such as AutoCAD and Pro/ENGINEER. Although there is a charge for the parts, the wasted time finding and redrawing standard parts is eliminated (Chon, 1998)

The Web is fundamentally changing how engineers accomplish modeling, simulations, and complete design verifications with greater ease and in a quicker fashion. Likewise, more demands will be placed on engineers as Web practices are embraced and implemented (Beazley, 1998).

Limitations of Web Accessible CAD Databases

Although the advantages to utilizing CAD databases across the Internet are virtually limitless and with unknown potential, there are also negative aspects that must be considered. Until all of these issues are addressed, many corporations may be unwilling to use this technology regardless of its potential. Techniques for data protection against intentional sabotage and unintentional database corruption must be developed and constantly refined. Data security is even a concern within a company Intranet that allows only internal accessibility, because access to design files is almost always restricted to the engineers who are working on a project (Hauck & Knol, 1998).

Security issues for Web-based CAD systems can be broken into three classifications: client security, transmission security, and server security. Client security involves all of the issues of protecting the CAD databases on the user's machine from attacks that are unrelated to the Web-based CAD system. Transmission security is involved with the security of Web-based CAD data from interception and decryption from data being sent or received from a server. Both client and transmission security are common to almost all Internet databases. Standard solutions such as firewalls are used to protect databases from these security threats and from invasion from outside sources. Encryption measures are typically used to protect data that is being transported across the Web (Hauck & Knol, 1998).

Server security deals with the user's trust of the Web-based CAD tools. Typically with server security, steps are taken to minimize the amount of information that can be obtained from the CAD database. Server security poses a special problem for CAD databases and many times vary between different applications. Restrictions are typically placed on the read and write files of a database, but CAD files are unique in that CAD databases need this information to be functional to various users across the Web. The crux of the problem is to allow design verifications to occur without the loss of intellectual property such as trade secrets to vendors who may not always be trusted (Hauck & Knol, 1998).

Hauck & Knol (1998) contend that CAD server security must allow enough information to be given to engineers and vendors so that designs can be modified and verified without disclosing important information that they do not need. They give examples of server security systems where only the information needed to perform an operation is given with the CAD database. All other information is stripped from the database by specific algorithms before it is sent across the Web. Although this practice may work for one specific application, it may not be valid for any other (Hauck, & Knol, 1998).

Although there are realistic concerns with the use of the WWW for CAD databases, many of these concerns are currently being addressed and will probably be eliminated in the near future. Thus practicing engineers, engineering professors, and engineering students need to be able to utilize the WWW for design verification and data sharing. Most of these databases that will be shared across the WWW will be CAD solid modeling databases. Thus the working knowledge of CAD databases will also be required of engineers.

Product Data Management (PDM)

Document management issues have always been an important element in engineering. With the advent of sharing databases across the Web, coupled with the globalization of manufacturing, document management is vital for an organization to stay competitive (Osborn, 1998).

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Product Data Management (PDM) is digital technology that automatically maintains the control and distribution of databases to individuals who need the data and when they need the data (Nunez, 1998). PDM systems manage large amounts of data that are necessary for the design, manufacture, support, and maintenance of products or systems. The data that are required for product development include 2D drawings, 3D solid models, documents, spreadsheets, bill of materials, simulations, images, and other unique databases (SmartTeam, 1998).

The successful implementation of a PDM system implies several basic requirements. The management of databases is essential in order to be able to maintain, access, and modify CAD databases and other related documents. Successful PDM implementation is based on the following capabilities:

Electronic document storage – This is a means of maintaining data on a computer in a digital form. Managing the data in digital format means that data can quickly and securely be manipulated, controlled, and accessed (SmartTeam, 1998, p. 3).

Flexible file organization – This is dynamically storing documents according to projects, tasks, and design phases, or even according to suppliers or customers, regardless of whether they occur in more than one category (SmartTeam, 1998, p. 3).

Support for multiple file formats – This is the ability of the PDM system to view, plot, or print a wide variety of vector, raster, and various other file formats without opening the application that they were created in (SmartTeam, 1998, p. 3).

Document security – Documents and CAD databases are assets that need to be controlled and secured against inadvertent deletion, uncontrolled modification, as well as unauthorized access. Securing these databases in a central storage vault ensures that the data is not accessible via the operating system, but rather according to an administrator's defined set of rules (SmartTeam, 1998, p. 4).

Timely access to information – This is the ability to rapidly and easily search, access, and view design information such as a description of a file, the author, department, the revision number, and a list of links that exist with other parts or projects (SmartTeam, 1998, p. 4).

Workflow automation – This is the ability to streamline tasks or processes for greater productivity. Automatic workflow allows databases to be shared and transferred between users in various workgroups (SmartTeam, 1998, p. 4).

Customization tools – This allows the PDM system to be customized for the specific needs of a particular organization (SmartTeam, 1998, p. 5).

Integrated solutions – This allows the PDM system to be integrated with most popular CAD and office applications. The integration of the PDM system means that it works in the "background" and the package that is currently being used does not have to be exited to complete database operations (SmartTeam, 1998, p. 5).

The successful implementation of a PDM package should result in the following savings:

Reduced time to market – Less time is spent by engineers chasing misplaced databases or documents, and more time is spent on design development and verification (SmartTeam, 1998, p. 6).

Increased productivity – Implementation of life cycle management significantly reduces the time to market and helps to eliminate errors in product design during the development of costly prototypes for design verification (SmartTeam, 1998, p. 6).

Reduction in production errors – Ensuring that production ready components are manufactured from the correct version of a design document can save significant amounts of money (SmartTeam, 1998, p. 6).

Reduction in publishing costs – Digitally published documents eliminate the need for costly printed manuals and these can be quickly revised and updated (SmartTeam, 1998, p. 6).

Summary

With the rapid development and implementation of relatively low cost and extremely powerful computer technology, the methods used to design and engineer products have radically changed. In the face of increased global competition, many industries around the world have adopted a team-orientated concurrent approach using 3D CAD databases and other new technologies. Engineering educators should seriously consider these new technologies for use in engineering graphics curricula and courses. The proper use of these technologies, coupled with graphics fundamentals, should provide engineering students with theoretical and applied knowledge so that they can be successful in today's digital world.

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