Chair's Award Winner

CAD Software Industry Trends and Directions

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Abstract

There is an interesting and unique relationship between industry and college level academic engineering and technology programs. This relationship is constantly evolving and redefining itself, reflecting both the accelerating level of technological change in industry, as well as the flexible and somewhat fickle focus of the industrial environment. In order to produce graduates who are well prepared for industry and who can be immediately productive in an industrial/technical setting, college and university engineering and technology programs must be knowledgeable regarding the trends affecting industry and incorporate into their curricula the necessary and relevant material to meet those goals. The engineering design graphics field is especially subject to rapid technological change. This is due to fundamental changes in how industry views the design process, and the pace at which computer hardware and software improvements are introduced and incorporated into standard procedures.

This paper reviews current trends in the high-end computer aided design software industry, with discussion regarding the direction and focus that CAD industry leaders are taking with their products, and the industry needs that are driving those developments. The impact of these changes and trends on academic programs is addressed. This discussion includes recommendations as to what portion of these developments should be incorporated into the curriculum, and what college and university engineering graphics programs should do to prepare their students for these developments in industry.

Introduction

Trying to analyze the ever changing and dynamic trends and directional movement of the CAD software industry can be roughly compared to trying to analyze the stock market: one must deal with a seemingly infinite number of outside forces affecting an incredible number of constantly moving reference points at an ever accelerating rate of speed. The complexity of the task can be overwhelming, and the results will more often than not make the analyzer appear as either misinformed, foolish, or totally incompetent.

In spite of this, there appears to be some practical value in attempting to make such an analysis. As one reviews the path that the CAD industry has taken over the past several years, or even decades, several 'threads' or trends emerge that can be projected out into the near future. If accurate, these projections can be of great benefit to us as educators, simply due to the impact of this technology on today's industrial products, and, therefore, society as a whole. Industry consultants have stated, "Eighty percent of the manufacturing gross national product passes through CAD, CAM, and CAE systems at some point. Every vehicle, aircraft, sophisticated electronics system, most industrial and manufacturing equipment, and most consumer products depend upon these tools." (Marks and Riley, 1995). Realistically, we cannot expect academia to be able to provide all the latest 'bells and whistles' of CAD industry developments to all our students as soon as they emerge. However, we can be expected to be forward-thinking enough to focus our curricula in the direction we feel these developments will take within design departments, manufacturing companies, and entire industries, so that our students will be adequately prepared to be productive and successful as they move into their careers.

Trends in the World of CAD - Past to Present

At its beginning, CAD technology was primarily focused on automating the 2D drafting process and related functions, with varying degrees of success. There were several factors that affected the technology's effectiveness in these early days, including the availability and usability of computer hardware, efficiency and usefulness of the CAD programs, and the willingness of drafting personnel to embrace the technology, which was usually inconsistent and frustrating to use. As time progressed, improvements in the technology and its applications gradually allowed for a grudging acceptance of CAD in the workplace, followed by general usage, and finally, an enthusiastic welcoming of CAD as a needed productivity tool. This is especially true as progress has been made into new applications and focus areas, such as manufacturing, design, test, analysis, etc., and as the technology has evolved from 2D only into three-dimensional capability.

In hindsight, the trends and developments of this 'pioneering' phase usually centered around two areas: more features and faster operation. More features refer to adding 'horizontal' software functionality, or the ability to perform additional separate operations, with each succeeding release of the software. Occasionally these additions were of little practical value, and not smoothly integrated within the software's general application. This is a shortcoming that CAD providers have learned to overcome as quality of software operation became important to the user community. Increasing speed of operation was marked by improvements in hardware and computing capability, and by smarter and more efficient software programming techniques and architecture.

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Incidentally, these two trends continue to be an important part of the industry's progression today. This will continue into the future as both a result of advancing technology, and as a driving force causing the technology to advance.

As CAD users' sophistication and expectations increased, so did the pressure on the CAD industry to improve in several areas. Chief among these were the quality of released product, the addition of both user-desired features and greater capability of existing features, better ability to change or edit already existing CAD data, and the application of the technology across functional (i.e. job-related) boundaries. One industry leader has labeled these important issues as "ease-of-use", "ease-of-modification", and "ease-of-collaboration" (Carelli et al., 1997). It is apparent that CAD vendors must continue to be conscious of these areas as they develop new releases of software if they desire to remain successful.

As CAD systems technology has improved and accelerated, and as acceptance has grown and also accelerated, CAD gradually has moved from being a fringe element in the design process to a much more mainstream function in product design. Continued developments in hardware capability and affordability, as well as software advances in such areas as solid modeling technology, parametric modeling, and database management have placed CAD systems today as an integral strategic tool in all aspects of the design industry.

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Trends in the World of CAD - Present to Future

In order to predict where CAD is going over the next few years, one first needs to look at what pressures or forces the users of CAD products are bringing to bear on software providers. It is logical to assume that these influences will be what causes continued change and growth in the industry. A major CAD developer has identified several of the factors that industry is concerned with, including: 1) global competition, which forces companies to constantly seek reduced cycle times and costs, 2) the global nature of business, both customers and partners, and the associated need for better communication and information sharing, 3) product quality issues, 4) data management concerns, 5) rapid growth of the World Wide Web and Internet/Intranet technology, and 6) the ability to work with larger and more complex data in CAD (AutoDesk, 1997). There are other areas of concern, but these are several that are frequently mentioned. From discussions with several of the major CAD providers, from information gleaned from trade publications, from conversations with CAD users and educators, and from personal observation, it is the opinion of the author that the important trends and direction that the CAD industry is taking can be categorized into four distinct areas: 1) interface, 2) functionality, 3) capability, and 4) management and communication.

Interface

At one point in the not-too-distant past, most CAD systems were very unique with regards to the 'look' and 'feel' of their user interface. In fact, software companies placed very little emphasis on how users interacted with their product, or on how easy their product was to use. Eventually, as ease-of-use became a critical component of customer benchmarks and purchase decisions, the user interface became an important product differentiator, with such descriptors as 'intuitive' and 'user-friendly' seeing increasing use among CAD sales and marketing personnel.

Presently, the industry is making another major step in this area, but away from uniqueness and individual idiosyncrasies, toward a commonality, or generic, appearance. All of the major CAD vendors have either recently released products with significantly upgraded user interfaces, or are planning to do so in the near future. One of the largest and most successful high-end CAD providers is planning on making the modification of their user interface a "main thrust for the next several releases" of their product (R. Quinn, Parametric Technologies Corp., personal communication, February,1998). This trend will continue to be critical for CAD providers as customers demand easier to learn and easier to use products that meet quick implementation criteria.

Functionality

Functionality can be defined as what the CAD system can do, i.e. the tasks it is capable of. For a significant portion of CAD history, developers would race to add horizontal functionality (ability to do more things) at the expense of quality (ability to do things correctly) and vertical functionality (ability to do things to the extent needed by users) in each succeeding release. Customers eventually tired of this, and vendors were required to improve vertical functionality and quality, as well as continue to add new tools and features to their products.

Current trends indicate that CAD software providers are no longer adding features for features sake, but are focusing significant resources on both improving existing features (and product strengths) as well as focusing on a few key functions for future development. One of these areas is that of parametric feature-based solid modeling, and all of the major CAD entities either have this as a foundational technology in their product or are incorporating it as quickly as possible. Driven by the concept of 'modeling like the mind thinks', parametric modeling is rapidly becoming the design tool of choice in many industries. The ability to rapidly sketch, constrain, build, and modify models is a productivity tool of potentially immense proportion. Over the next several years we will continue to see major advances with this technology, especially in the areas of multiple-use models and constraint technology, which at present is somewhat rigid, inflexible and unforgiving. As Anderl and Mendgen state, "Modeling with constraints is a modeling technique which contains a high potential for efficient working in all steps of the design cycle. However, this technique still requires some research and development work. Areas of open issues are support of modeling with constraints in all phases of the product cycle, archiving and reuse of existing design solutions, exchange of constrained models and methods for covering over- and underconstrained situations. Furthermore, the development of a design methodology for modeling with constraints, considering complexity as well as flexibility of constrained designs, is a strong requirement" (Anderl and Mendgen, 1995).

A related topic of attention in this area will be the inclusion of continually more 'intelligence' in the CAD model, and the development of expert or knowledge-based CAD functionality, with the goal of significantly automating the repetitive aspects of the design cycle. Commonly grouped under the generic title of artificial intelligence, there is great potential for the application of 'smart technology' to CAD modeling. McMahon and Browne define it as, "studying how designers apply human intelligence to design, and . . . trying to make computer aids to design more knowledgeable." (McMahon, and Browne, 1993). There has been some basic success in capturing knowledge in decision-tree artificial systems for use in very specific and narrow applications, and improvements in this area will continue to happen as the demand for quicker design cycles intensifies.

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Capability

Capability refers to the CAD system's ability to handle large amounts of data. Formerly, this ability referred to a CAD system's ability to function when working on a complex part with a high entity count. Presently, the capability or capacity descriptor is used more to describe complex product assemblies, i.e. a large number of parts combined into a complex assembly. This shift in concept has evolved as CAD products have enabled users to apply true design methodology to their processes. As one CAD supplier says, "Companies design products, not parts. The performance of any one part in the product is dependent on how it interfaces to surrounding parts and the environment in which it operates. To effectively design this part, you must be able to quickly retrieve library data for the assembly and design in the context of the assembly." (Klapproth, 1997). The two obvious advantages of being able to model large assemblies is the ability to build virtual prototypes of assembled parts, and through this, detect interferences early in the design cycle. These advantages have a huge impact on cost and time-to-market considerations.

CAD providers are using several strategies to deal with large assembly issues. One is called referencing or instancing, in which the assembly model 'instances', or points to, needed components rather than actually copying the component into the assembly database. Another methodology utilizes simplified or less-detailed versions of parts in the assembly model. For example, an outline of a subassembly or complex part may be created and used in the assembly, rather than the entire complex feature-rich part. A third method involves using just the area of interest in an assembly to eliminate unneeded entities (Potter, 1996). For example, this would be applicable for someone who needed only to work with the bumper assembly of an automobile, but not the entire assembly of the vehicle. The system would recognize the request, and only access the area of assembly that was needed. Another very effective technique uses an alternative, faceted or 'lightweight' representation rather than the complex mathematical model. This faceted version, which is associated with the true model, is much easier and faster for the system to compute and display, resulting in less time the CAD user has to wait for the system to process commands.

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Some CAD software producers and industry analysts feel that the issues surrounding large assemblies have been thoroughly addressed and rectified, but some of the solutions mentioned here leave a lot to be desired. One can assume that there will still be significant progress in this area in the years to come, especially in important 'crossover' areas such as those relating to data management and data sharing.

Management and Communication

The most exciting trends relative to CAD are the World Wide Web, data management, data exchange standards, and collaborative engineering. These can be grouped together as management and communication issues. This is perhaps the fastest growing and changing area that the CAD industry has to deal with. All four of these topics blend together with regards to impact and motivation: the need to get the same information in readable formats to everyone who needs it as quickly and securely as possible. This is true whether those individuals are part of the same company, a supplier or subcontractor to the company, or a customer of the company.

As an information sharing resource, the World Wide Web is a barely tapped resource of incredible breadth and depth that the CAD world is beginning to utilize. Many applications are currently being explored, including placing support documentation on the Web, software patches and upgrades, discussion groups for users, and, through the use of special Web formats, placing accessible, transferable CAD data in a usable format directly on Web sites. This last is seen as an area of significant future development, and is a key focal point with most, if not all, of the major CAD vendors. As one trade magazine reports, "Integrating the Internet into the system is the direction all CAD/CAM/CAE system vendors are going. In a survey of the leading vendors in the industry, it seems that the unanimous response of Web-enabled systems with access to the Internet and Internet capabilities from inside the CAD system is either in place or an imminent reaction." (Knoth, 1997). The concept of making the Web a hub, linking communication via the Internet and local Intranets is very attractive to industry as they begin to better understand and apply the possible applications of this technology. Knoth has also stated that "The understanding of Internet technology and the simplicity of the browser interface have really permeated the infrastructure of organizations—enabling total collaboration for the entire project team. The tools of the Web are navigating the way we communicate with each other, outside vendors, and team members across the continents." (Knoth, 1998). Advantages promise to be gained in the areas of part sharing, workflow management, speed of revision, cost effectiveness, accuracy, and long-distance communication.

Another area of current and expanding interest is in the area of product data management, or PDM. As companies turn more and more to CAD technology, the logistical challenge of controlling information access, data sharing, information transfer, versioning, workflow, and data archiving increases incredibly. Data management software either integrated into the CAD software or as a separate package, is becoming more prevalent in industry, with some major users spending millions of dollars for PDM software to help control their increasing CAD data. Typically, PDM uses have been limited to design and engineering applications. Current practice is beginning to include many other areas such as manufacturing, project control,

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sales and marketing, and purchasing. This logical outgrowth of the technology reflects many industries' developing understanding of the concepts of concurrent design. This requires getting all of the necessary personnel in the design cycle involved in the process as early as possible, to simplify and expedite the development of new products.

Closely related to this concept of product data sharing and concurrent design is the idea of collaborative engineering. Although concurrent engineering brings together many segments of the design team for a faster design cycle, it is generally thought of as a single location entity. Collaborative engineering expands the concept of concurrent engineering to include many segments and sub-segments that may be very widespread geographically. Obviously, both the Web and PDM issues have a considerable impact on a successful collaborative engineering venture, as data must be simultaneously controlled and delivered to relevant parties as quickly as needed, regardless of how far distant the parties may be from each other. The use of collaborative engineering accelerates the process of data sharing, the real-time design process, and allows for higher quality products to be generated at a cheaper cost. These advantages insure that Web-based CAD, product data management, and collaborative engineering issues will remain critical topics in CAD industry development for a significant length of time into the future.

Academic Impact

The challenge for engineering and design engineering technology academic programs is to keep curricula current in the face of the onslaught of technical progress in many areas. Furthermore, the challenge is exacerbated by the fact that the tools of technology are being upgraded constantly in industry. If an academic program focuses on 'tool-based competence', i.e. producing graduates who are able to perform a single task using one specific CAE/CAD/CAM platform or software package, that program will most likely not enjoy long term success. The graduates of such a program will find themselves, in just a few years, scrambling for retraining in order to remain valuable to their employer. While no coursework in any technological field can guarantee future relevance, we can best serve our students in the CAD area by ensuring that key technologies and trends are taught and incorporated into classes. This will provide a foundation for continued growth and competency as industry develops new processes and methods.

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Specifically, we should concentrate some significant effort to ensure that the trends in the areas of management and communication, general functionality, and capability find place in our teaching. User interface issues, on the other hand, are probably fruitless to pursue from an academic standpoint. The current trend of UI commonality, along with the relative rapid learning curve that today's user interfaces allow for, require only that a major program have a relatively recent release of a major CAD product to effectively train students. To have a small variety of CAD packages is even better, but should not be considered vital for the success of the program.

Functionality improvements will continue to be important to incorporate into academic programs. 'Hot' topic areas such as parametric feature-based applications, intelligent data capabilities, and developments in artificial intelligence must be understood by students matriculating in CAD-based programs to provide them a competitive edge over the next several years. This will also provide a basis for on-going progress within these critical technology areas. Therefore, coursework should include parametric and 'smart' data applications whenever possible. If practical applications in these topics are not possible due to technological or facility constraints, it is still important that course content include exposure to the theories and current applications of these areas.

It is a given that capability issues in CAD systems will continue to be important in industry. To ensure adequate coverage in academia, we should make certain that students are working with assemblies and subassemblies whenever possible, not just individual piece parts. It is not critical that huge 'mega-assemblies' be used or developed to teach the principles of large assembly manipulation, as the capability to physically do so is very resource dependent and can be unwieldy. The concepts of assembly interaction can be adequately addressed using relatively small assemblies that teach the principles of data manipulation, part interaction, etc.

However lightly the topics of functionality and capability are approached, one trend area that academic programs cannot afford to ignore is the management and communication realm. Every program that does not include CAD World Wide Web applications in its instruction content will soon be seriously outdated. Coupled with the WWW are the related critical areas of data management, collaborative efforts, and associated niche issues such as data exchange standards and developments. Engineering design programs have long advocated the importance of team methodology and concurrent engineering, with common data access, so the step to include these new areas should be logical and reasonable. Unfortunately, they will most likely be difficult to incorporate into existing academic programs. To provide realistic training in collaborative engineering and the Web, for example, programs will need to provide for more cross-functional and cooperative learning activities, where students from various majors, and even different campuses or institutions work together to accomplish a given design task. In such a scenario, data management issues could also play an important role, thus incorporating all the key factors of management and communication that result in the logistical nightmare that industry faces on a daily basis. Obviously, such an effort requires the commitment of many at many levels in our academic institutions, but the importance of exposing our students to these areas is such that the effort must be made, even if only in small incremental additions.

Conclusion

The CAD software industry is one that is in a state of constant change. New developments and applications in many areas lead to a steady progression of new software releases, features, and capabilities that are rapidly adopted and incorporated by product manufacturers of all types. As educators, we must be conscious of these current developments and predict trends for developments that are forthcoming in the near future. Topics such as the World Wide Web, collaborative engineering, product data management, large assembly manipulation, parametric modeling, and artificial intelligence will all have an impact on CAD system technology over the next several years. It is imperative that we incorporate these topics into our CAD curricula to ensure the continued success of our academic programs.

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