The Pencil Has Changed: Integration of Professional Level CAD Software into the Undergraduate ME Curriculum

Kim J. Manner
University of Wisconsin - Madison

Abstract

The area of mechanical engineering design development and documentation was once the exclusive realm of the pencil and paper. As computer technology and its related software have improved this is no longer the case. In the last 8 years a new generation of dimensionally-driven, feature-based modeling packages have entered the marketplace. The tools of design have changed and we as educators must provide some level of instruction in their use. The challenge becomes to include such information in a format appropriate to a four year engineering program. This paper will discuss techniques for accomplishing this goal and provide suggestions for other institutions which plan to integrate such software into their curriculum. A relatively new course offering within the University of Wisconsin - Madison, Department of Mechanical Engineering will be used as a model.

Introduction

Prior to the advancements made in computer technology (both hardware and software) over the past 20 years, most engineering design documentation began and ended with the pencil. Education in design documentation was referred to as engineering graphics or mechanical drawing. Students were instructed in the fundamentals of projections, dimensioning and the accepted standards. While some time was allocated to the use of drawing instruments, this typically represented only a small portion of total instructional time. After all, the principal tools of mechanical drawing were the pencil and the straightedge and students had been using those in some fashion since their education had begun. With appearance of PC-based 2D CAD packages, many instructors felt it necessary to integrate this technology into their engineering graphics courses. At many institutions, the debate ensued as to whether instruction in software use fit the mission statement of the four year university program. At many institutions, a misplaced de-emphasis on engineering graphics also placed serious constraints on the amount of material which could be included in these courses.

As the software has evolved, its effect upon the professional community has increased to the point where today the areas of design, analysis, and manufacture are all significantly impacted. Professional level CAD packages are now becoming a standard part of the design engineer's arsenal and the educational community must examine their inclusion in the engineering curriculum.

Relationship of CAD and Geometric Modeling to Engineering Design

The development of computer-aided part modeling software can be traced to the early 1960's. These early CAD packages were two dimensional systems, designed to fulfill only the role of electronic drawing board. During this same period, efforts in the area of NC machining by companies in the aeronautical and automotive industries lead to the mathematical work in the area of computer-modeling of sculptured surfaces. Finally, computerization of engineering analysis began with the development of finite element analysis (FEA) software. This software relied upon geometric modeling techniques for both pre-processing (development of the model geometry) and post-processing (display of the results)[5].

During the early 1970's, efforts were directed toward the development of solid modeling systems. Two separate paradigms developed somewhat simultaneously. These are the Constructive Solid Geometry (CSG) technique which is based upon the use of set specific Boolean operators to combine volumetric sets defined by algebraic inequalities and Boundary Representation (B-Rep) system which defines a solid in terms of a set of finite orientable surface elements. From these research efforts followed commercial applications in the late 1970's and early 1980's. Industry began to use solid modeling systems for design development, creation of 2D graphical output, and for the creation of geometric input for CNC manufacturing software and FEA software. (those wishing further information on the principles of geometric modeling should refer to an appropriate text such as *CAD/CAM Theory and Practice* by Zeid)

Professional level CAD Packages

Beginning in the late 1980s, a new generation of CAD software has entered the professional market. These high-end packages are typically feature-based, dimensionally-driven solid modeling packages which frequently support some form of assembly modeling. A feature-based solid modeler is one in which the underlying user-accessible entities available for model construction (the features) provide additional engineering information beyond the geometric and topological. Features possess a level of engineering information regarding function and/or production. Designers work with entities such as "counterbored holes" and "milled slots" rather than the generic cylinder and block. This represents an effort to more closely tie the areas of design and manufacture. In addition, these packages are very often dimensionally-driven with respect to entity construction techniques. Construction features are based upon 2D profiles which are constrained both dimensionally and geometrically. These profiles are then used as the basis for lofting and sweeping operations to define both positive (added) and negative (removed) volume. Dimensionally-driven systems permit the use of such techniques as iterative design and part families. In addition, Shah/Mantyla in their text provide an estimate that "perhaps 80% of all design tasks are *variational* in that the goal of the design is to adapt an existing basic design to new requirements"[5].

Author's Note: The terms *parametric* and *variational* have frequently been used interchangeably to describe such systems, especially in the commercial world. I prefer to use the generic *dimensionally- driven* since it is not typically obvious to the software user which system the software is based upon and in many cases the software may use some combination of both.

Current Status of CAD in the Curriculum

The development and acceptance of 2D graphical (wireframe) CAD systems coincided with changes in the ME curriculum. Many programs began to de-emphasize and remove engineering graphics courses from their curriculum. Whether the feeling was that such information was no longer required, was being adequately disseminated at lower levels (read high school), or would soon be supplanted by technology, is not entirely evident. If the assumption was the last, that prediction did not come true. It is my opinion that too many engineering educators regard modeling software in the same fashion that they regard word processing. That the institution has no responsibility to provide instruction and that the student, if provided with access to the software will learn it themselves. In the case of basic support technology such as word processing systems I think this is a reasonable assumption but I do not believe that the analogy carries over to modern CAD systems. The power and flexibility of these systems is immense. We have all attended product demonstrations which depict such packages as revolutionizing engineering design, analysis and manufacture, all with dramatic ease and simplicity. We must however, remember that these are just demonstrations. Despite the ease with which the demonstrator manipulates the software, the situation changes when we are facing the screen on our own. With the power and flexibility of these high end systems comes the cost of complexity and (typically) a relatively steep learning curve. The construction and editing concepts of professional level dimensionally-driven modeling systems are not intuitive to the average student. When faced with a menu of unfamiliar terms and operations the student typically becomes quite frustrated. The dimensionally-driven systems such as Pro/ENGINEER, EDS/Unigraphics, SDRC I-DEAS represent a great departure in function and technique from what now must be considered "traditional" CAD systems. So much so that the carry over of principles and techniques from the traditional 2D systems to the dimensionally-driven feature-based systems is very limited. Students without a cursory background in the functionality of these systems resort to the rather human approach of 'what worked before', usually with less than satisfactory results. It should be obvious that times have changed with regard to CAD software instruction. When graphics meant traditional hand-created 2D mechanical drawing, instruction in the tools was minimal. A student, through years of experience, knew how to use the pencil. Now however, for mechanical design, the pencil has changed.

Why use professional level CAD software in curriculum?

There exists several reasons why we as engineering instructors should dedicate ourselves to integration of professional level CAD software into the Mechanical Engineering curriculum:

1) As it gains further acceptance, this software has driven many changes in the approach industry is taking to design. Because of their flexibility in design variation and their tie to both manufacturing and analysis, use of this category of software strongly supports a move toward concurrent design principles. Whereas early solid modeling systems required full dimensional specification for model construction and hence could only be truly used as a design documentation tool, the dimensionally-driven systems allow the user to model in terms of "design intent".

2) This software represents the tools which the student will be using in their professional career. By providing an introduction to its use and the theory behind it functionality, the student will be better prepared to enter the work force as a design engineer.

3) This area will only be evolving. No one can expect the area of computer-aided engineering to remain static and tomorrow's engineers will be constantly under pressure to learn and master new software developments. Familiarity and comfort with this technology will only enhance those efforts.

Methods for Integration

How do we as engineering educator proceed with the integration of such software into our curriculum. One can foresee several approaches, each with its own advantages and pitfalls.

1) Integrate the software into the already existing graphics course. While this may appear to be the obvious solution, it may be the most ineffective. These courses are usually overburdened with too much vital material and too little contact time to begin with. The primary responsibility of these course should be to bring incoming engineering students to a comfortable level of understanding of engineering graphics standards and the development of visualization skills. To attempt to include the necessary geometric modeling concepts along with the hands-on software instruction would tax the already strained resources and simply necessitate the removal of more core material from the course. The engineering world is already suffering from the effects of a de-emphasis in instruction in critical areas of engineering graphics. Additionally, at many schools the introductory courses are being given to engineering students from all disciplines. Since the vast majority of the professional level systems are developed primarily for mechanical engineering design applications, spending time in their instruction for the typical civil and electrical engineering student would not be expedient. It would be anticipated that through this approach, because of the limited time which may be allocated to theory of operation, high amounts of student/instructor contact would be required to resolve questions and confusion regarding software use.

The material currently provided in freshman level graphics courses is critical to their development as engineers and also to their eventual use of these professional level CAD packages and as such should not be compromised. I have been present at commercial training sessions in this high-end packages where some of the students have been industrial personnel with poor or limited graphics backgrounds and poor visualization skills. These students proved to have a very difficult time is mastering the software, in my opinion because of these deficiencies.

2) Provide students with access to the software and allow them to learn it on their own. Possible assistance would be provided either through the software's on line help and tutorials (if available) or handouts prepared by the instructional and support staff. While this requires less expense in terms of instructional time it typically produces mixed results. Some students will make progress in the understanding of the software through this approach, but many students struggle in their efforts, especially since this software is often non-intuitive in both its approach and uses menu terminology which many students will find cryptic. Students who become frustrated with the software will be less likely to use the software in other courses. There is also the likelihood that the student only learn a small fraction of the functionality of the system through this approach. Regardless of outcome, this represents a heavy time commitment on the part of the student.

3) Provide a specific modeling course which is dedicated to both instruction on the principles upon which the software are based and "hands-on" laboratory experience with today's professional level software. At the UW-Madison, we have implemented such a course (ME232, Geometric Modeling for Engineering Applications), required of all Mechanical Engineering students and typically taken during the junior year. The course discusses the areas of graphical (wireframe), surface and solid modeling, along with the relationship of computer-based modeling to design, analysis and manufacturing. Concepts of data transfer, data extraction from models and photorealistic rendering are also included. This material is presented in a common lecture. Parallel to this material is a "hands-on" laboratory where the student is able to see and experience the principles discussed using professional level software. Software currently used are Pro/ENGINEER (Parametric Technologies), Unigraphics (EDS), and the PADL-based CSG modeler (AME) from AutoDesk. To be implemented in the current semester are the ACIS-based packages, SolidDesigner from Hewlett-Packard and MicroStation Modeler from Bentley. It should be noted that this is in addition to an engineering graphics course (ME231) which provides instruction in the principles of multi-view drawings, projections, sections, dimensioning and technical sketching along with an introduction to 2D CAD. Completion of ME231 is a prerequisite for enrollment in ME232.

At the UW-Madison, we have found this method to be quite successful. Informal feedback from the students and from potential employers visiting campus have been very positive. Because the theoretical background in modeling techniques provided by the course, students are able to acquire a working familiarity with the software packages in a relatively small amount of time. For example, the level of expertise of the typical student after 5 weeks of lab instruction on Pro/ENGINEER (a total of 20 hours of lab time) is similar to what may be expected after attending a 5 day/40 hour commercial instruction session. The class also attempts to emphasize that there exists no single "optimal" software and rather exposes the student to as many different packages as feasible.

Conclusions and Recommendations

It appears obvious that in order to prepare the design engineering of the 21st century we as engineering instructors must provide the student with educational experiences commensurate with what will be expected in the workplace. In order to accomplish this the status quo of instruction must be examined. The pencil has changed and we can no longer expect students to assimilate the complexities of these new tools through some form of educational osmosis. Instruction in the use of this software has a place in the modern curriculum. To do so places demands upon both the Faculty and Administrations responsible.

One critical area is that of facilities. This software requires a fairly powerful computer platform for use. Much of the software was originally designed for use on UNIX workstations although many of the packages are now available for Pentium-based PC's using either an NT or Windows 95 operating system. It would be necessary for the administration to guarantee undergraduate students access to this level of hardware. The software itself is also expensive. Even with educational discounts, annual software budgets may become excessively large. It may become increasingly important for educational institutions to work with the software companies to ensure the availability of professional level software at costs the institutions can afford. We must continue to emphasize that we are providing the users, consumers, and decision makers of tomorrow.

Finally, the faculty must develop a level of proficiency with the software. Because of the demands placed upon today's faculty and the speed at which the technology changes, this becomes increasingly difficult. Departmental and College administrations must realize the importance of this technology and provide support to the faculty of these courses. Financial support for training and appropriate release time will be necessary. After all, the tools with which mechanical engineering design is performed are changing and it is up to us to change with them.

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Kim J. Manner

Kim J. Manner is a Lecturer in the Mechanical Engineering Department at the University of Wisconsin - Madison. He received his BS and MS in Engineering Mechanics from the University of Wisconsin. His areas of engineering interest include Geometric Modeling, CAD/CAM, Engineering Graphics, and Automotive Design. He has been a member of the ASEE, Engineering Design Graphics Division since 1992. He has been active with the student chapter of the Society of Automotive Engineers since 1992. Mr. Manner has performed numerous outreach programs for both minority and gifted high schools students. He is currently involved in the integration of various electronic communication media into the engineering curriculum and the development of new course material in the area of Geometric Modeling.