Impact of Product Data Management (PDM) trends on Engineering Graphics Instruction

Eric N. Wiebe
North Carolina State University

Abstract

The use of 3-D Computer-aided Design (CAD) systems in engineering design and manufacturing has popularized the concept of the virtual product database. Product Data Management (PDM) and similar computer-based information management tools have increasingly been implemented to help manage this product database. Just as 3-D modeling is becoming an important component of the engineering graphics curriculum, PDM concepts should also be addressed. This paper outlines how 3-D modeling and related graphics activities in the classroom need to be reconceptualized. Specific concepts and exercises for use in graphics courses to help introduce students to PDM are outlined.

Introduction

Engineering graphics, being a curriculum closely tied to technology, has been considerably influenced by the rapid changes in computer graphics software. Though the principles based in geometry have not changed, the vehicle used for teaching these principles and the context in which they are placed. In order to assure that future engineers and technologists possess the abilities to apply these principles in the workplace and their future studies, it is important that the curriculum in engineering graphics represents both the tools and practices which are being used in industry and research. This paper outlines the current revolution in manufacturing and design information management and how the engineering graphics curriculum might respond to it.

Engineering graphics technology is currently undergoing changes much more profound than the movement to 2-dimensional (2-D) CAD in the 1980's. Though there has been some utilization of 3-dimensional (3-D) modeling software since the early 1990's [1, 2], the technology was still being used primarily as a vehicle for the static documentation of individual parts. For example, review of the original syllabus of North Carolina State's solid modeling course (circa 1989) shows that one third the semester was spent working with 2D projections derived from 3-D models [3]. Only in later iterations of the course was more emphasis put on other uses for the geometric model. The software being employed in these types of courses were largely constructive-solid geometry (CSG) or boundary representation (B-rep) modelers capable of creating static models from geometric primitives and/or profile sweeps.

The rise of parametric/variational (constraint)-based modelers such as Pro/ENGINEER™, SolidWorks™, I-DEAS™, and Mechanical Desktop™ has caused a shift in thinking towards the potential of the geometric model as a dynamic database [4, 5]. In these modelers, the desire to modify the model was assumed from the start, and the model is constructed from the start with key geometric features controlled via parameters. Still, many of the published and demonstrated examples of parametric/variational modeling demonstrate dynamic modification of the database limited to single parts and/or assemblies isolated from the remaining components of the end product or other processes which make use of this database.

Similarly, in the last few years, professionals have strongly embraced the notion of 3D modeling as the generator of a 3-D database for use throughout the design and manufacturing process [6]. PDM has become both a metaphor and an operational technology for managing this geometric database [7]. Current modeling texts, primarily 'industry handbooks', spend considerable time discussing PDM and related technologies[8, 9]. Similarly, those who are looking at the larger context of this technology in the organization see PDM technology as a strategic partner in the overall goal of creating more agile and responsive engineering and manufacturing environments [10-12].

New curriculums in engineering graphics need to find ways of exposing students to the integrated and dynamic nature of the modern geometric database. Curriculum revisers must understand the role of graphics in communicating key engineering information in the context of a broad array of industries and throughout a design and manufacturing enterprise [13]. Research and development in the product realization process has been identified as a key national priority for US manufacturing if it is going to stay competitive in the world market [14]. Engineering graphics has the potential of providing key elements in research and in the education of students in this area. To do this, however, it has to be willing to rethink how geometric principles are conceptualized and applied.

Geometry at the center of a product database

First, the geometric model created needs to be thought of, not as an isolated entity, but as the center of a dynamic, enterprise-wide product database. The model not only has to 'look' like the final product concept, but internally structured in a way that supports analysis, manufacture, and future redesign of the model. A favorite expression in literature discussing constraint-based modeling is *design intent*. At its core, the way in which you constrain your model needs to capture the 'solutions' proposed by the designer/engineer to meet product goals. As a simple example, if a hole is meant to be centered along a 400mm bar, then the hole should be constrained to the center of the bar, not 200mm from one side of the bar. The reason for this is not that the later violates the current geometric configuration, but that this feature will not 'behave' properly when the bar length is later modified.

Behavior true to the design intent is critical because many other individuals besides the creator are likely to have to query and manipulate the model in the future, and they need to have certain expectations about model behavior to be upheld if they are going to productively use the model. Unfortunately, traditional methods of teaching and evaluating documentation methods do not support instilling this concept in students. If a student produced a multiview of the bar, he/she would not be marked off for pulling a dimension from the edge of the bar because the location of the hole was clearly defined and the bar 'looked' correct.

Another issue which parallels constraint strategies is feature definition strategies. For any final geometric form, there are a multitude of possible Boolean operation sequences which can be used to create the model. On the other hand, there are probably only a handful of strategies which create a model based on features which, as closely as possible, represent the geometry of critical design and manufacturing elements. These strategies not only control how the model can be modified in future iterations, but also help define an internal database structure. If later analysis needs to isolate a key design feature or if manufacturing would like to attach CNC data to an individual fabrication feature, then the model needs to properly group geometric elements to support these activities. Again, looking at a traditional multiview of the model is unlikely to show the feature structure of the part.

Finally, an organizational infrastructure designed to support cooperative use of model data will have a computing/network system that allows (relatively) seamless sharing of data across computers. A combination of the modeling software, PDM software, and the computer/network operating system provides tools for the management of the product database. Among other things, these tools allow for: the definition of differing levels of 'privileges' for accessing data, the creation of hierarchy of users and groups, and the 'ownership' of files and folders. All of these concepts are very familiar to computing system administrators, but rarely do students have a clear grasp of these tools.

Increasingly, however, professionals of all backgrounds are expected to 'publish' and manage information for other users throughout an enterprise.

Geometry in network structures

Equally important to seeing models of production parts in the context of the different individuals using them, is seeing the parts in the context of assemblies constituting complete products. Quite often the impetus for a company acquiring a PDM system is not the inability to manage the dynamic changes happening within an individual part, but the inability to manage the dynamic relationship of tens, hundreds, or even thousands of parts which constitute a product. With increased outsourcing of part design and manufacture and shrinking time-to-market windows, companies are employing sophisticated technologies for managing the interrelated network of information between parts.

Most modeling systems use a product hierarchy of features, parts, sub-assemblies, and final assemblies. The user needs to understand that the relationship between these hierarchical elements and the people responsible for creation, testing, modification, and management form a complex network. An understanding of how changes in features on one part may impact other parts and assemblies is critical for successful management of the design process.

Geometry as a dynamic entity

Much of what has been outlined above can be summarized as a need for the understanding of the dynamics of model geometry in an engineering design and manufacturing environment utilizing modeling and PDM tools. Equally important to appreciating and predicting the dynamic changes in a model is the ability to track and document those changes.

In an operational environment, most products undergo numerous design revisions, all of which need to be carefully documented. PDM systems typically offer sophisticated tools to track and replay changes over the history of a design; not just geometry changes, but also analysis results, written and verbal comments, and costing information, among other things. In a similar vein, the ability to track product evolution also allows for the simulation of the changes a part goes through during the manufacturing process. The stages of geometric change as the parts are fabricated can be tracked and organized just as are design changes. Unfortunately, many of the assignments given to students do not allow them to experience the dynamics of design iteration or manufacturing process. Incorporating these types of experiences into a course demands a higher level of priority for the dynamics of the design and manufacturing process than is currently seen in many classes.

Changes in the Classroom

To summarize many of the comments made previously, a few examples are given as to activities which can happen in the classroom that help capture the spirit of PDM.

First, require students to document model construction strategies. One approach is a sequence of sketches outlining feature operations, to be completed before modeling begins. Another might be to, if software allows, to print out the model showing how all constraints have been placed and the feature hierarchy. Though it is often quite time consuming, the student can also submit an electronic copy of the model for inspection by the instructor. The point is, simply having the student turn in an image of the completed model sends a message that how the model was constructed was of no importance. Unlike a 2-D CAD drawing, *how* the geometry was created (as opposed to simply its spatial accuracy) in a constrained model makes a huge difference as to its usability in the future by other members in the enterprise.

Second, group activities help prepare students for working in the team environment, an important preparation many engineering students are missing [15]. Group activities require the coordination of information which, in turn, provide an entree for exploring PDM concepts. Even without sophisticated PDM tools, requiring students to demonstrate the sharing and management of files over a computer network helps introduce students to important concepts concerning shared product data in a networked environment. Ideally, students would be assigned space on a server which they can establish directory structures and access privileges. An alternative to the use of a file server is the use of a Web server, an increasingly common tool for the distribution of product information within organizations.

Thirdly, design project activities can be designed to both encourage the creation and management of multiple design iterations and the integration of information from multiple sources into a design brief. Again, the publication of the reports in an electronic form, Web-based or otherwise, exposes students to the intricacies of integrating information from disparate sources and numerous file formats. Though many software tools now make this integration easier, it still takes effort and understanding to accomplish this.

Finally, even when involved group projects and design problems are not feasible, more modeling problems can be assigned which involve assemblies rather than single parts. In fact, a realistic group activity can be created by dividing the responsibility of the construction of standard parts among class members. This allows the rapid creation of multiple shared parts for use in assembly construction. Even when portions of an assembly is supplied to students as pre-modeled parts, the experience of constraining them into assemblies and creating relations between them is a valuable experience. Poor planning in the construction of individual parts often does not show up until they are brought together in assemblies and required to be part of larger, networked interactions.

References

1. Leach, J.A. & Matthews, R.A. *Engineering Design Graphics Journal* **56**, 5-10 (1992).
2. Barr, R.E. & Juricic, D. *Engineering Design Graphics Journal* **56**, 18-26 (1992).
3. Batchelor, M. & Wiebe, E.N. in *ASEE Engineering Design Graphics Division Mid-Year Meeting* (Ames, IA, 1996).
4. Howell, S.K. *Engineering Design Graphics Journal* **59**, 27-33 (1995).
5. Ault, H. in *ASEE Engineering Design Graphics Division Mid-Year Meeting* (ed. Sorby, S.) 187-192 (Madison, WI, 1997).
6. Mills, R. in *Computer-Aided Engineering* 22-32 (1996).
7. Gain, P.R. in *Computer-Aided Engineering* 52-58 (1996).
8. Machover, C. *CAD/CAM handbook* (McGraw-Hill, NY, 1996).
9. LaCourse, D. *Solid modeling handbook* (McGraw-Hill, New York, NY, 1996).
10. Wiebe, E.N. *International Journal of Human Factors in Manufacturing* **7**, 21-35 (1997).
11. Kidd, P.T. *Agile manufacturing: Forging new frontiers* (Addison-Wesley, Reading, MA, 1994).
12. Carter, D.E. & Baker, B.S. *Concurrent engineering: The product development environment for the 1990's* (Addison-Wesley, Reading, MA, 1992).
13. Bertoline, G.R., Wiebe, E.N., Miller, C. & Mohler, J.L. *Technical graphics communications* (McGraw-Hill, New York, NY, 1997).
14. National Research Council. *The competitive edge: Research priorities for U.S. Manufacturing* (National Academy Press, Washington, D.C., 1991).
15. Fentiman, A.W. *Engineering Design Graphics Journal* **58**, 30-37 (1994).

Biographical Information

ERIC N. WIEBE, Ph.D., is an Assistant Professor in the Graphic Communications Program at NC State University. He has taught technical graphics and Computer-Aided Design at NC State University for seven years and for the past four years worked as a consultant on the use of product design and development technologies in the furniture industry.