Future Applications of Geometry and Graphics

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ABSTRACT

Definitions of geometry and graphics are developed based on a panel discussion held at the 8th International Conference on Engineering Computer Graphics and Descriptive Geometry (ICECGDG) held in Austin, Texas (Baker, et al., 1998). These definitions are used as a starting point for discussion of the future applications of geometry and graphics in engineering graphics education. Past, present, and future applications in graphical analysis, descriptive geometry, and engineering documentation are used as examples.

Introduction

This paper started as part of a panel discussion on the taxonomy of geometry and graphics at the *8th International Conference on Engineering Computer Graphics and Descriptive Geometry* (ICECGDG) held in Austin, TX (Baker, et al., 1998). Whereas the panel was primarily concerned with a larger, theoretical discussion of geometry and graphics and how this dialogue could help guide the structure of future ICECGDG conferences, the goal here is to try and bring these issues to bear specifically on the future of engineering and technical graphics instruction. The paper will open with a summary of how the panel attempted to define geometry and graphics and then discuss how these definitions apply to specific instructional issues in engineering and technical graphics.

Definitions of Geometry and Graphics

Most of the panel members agreed that geometry is a branch of mathematics concerning itself with the properties, relationships, and measurements of spatial entities. The practice of geometry originally focused on measuring and only later made use of relations and operations. In this way, geometry evolved into a deductive system founded upon agreed axioms and concepts. Geometry is, at its essence, a way of thinking as much as any tangible artifact. Any taxonomy of geometry must note that it is not a single monolithic field of study, but is divided into numerous branches. Branches of geometry include Euclidean, non-Euclidean, projective, descriptive, hyperbolic, topological, fractal, analytic, differential, and so on. Each area will have its own axioms and theorems as its basis and have varying degrees of overlap with each other or with other branches of mathematics. In a similar vein, different professions will apply different branches of geometry in different ways. Even though geometry has at its roots the study of spatial entities, it does not mean that these entities must be represented graphically. Purely geometric concepts can be modeled without objects such as points, lines, and planes.

A definition of graphics becomes harder to bring into common ground. One panel member, L. Cocchiarella, traced the term back to an etymological root meaning 'to engrave'. This follows right in line with other panel members' contention that graphics are inherently two-dimensional representations. To ground graphics in the physical world even more, a number of the panelists state that graphics is a tool rather than a deductive system or way of thinking. Still, as a physical representation, it makes use of many technologies in its production. Computers, pencils, pens, knives, lasers, and photosensitive chemicals are all put to use in the creation of graphics that are often classified based on its visual properties. They can be line drawings or shaded images, etchings or photographs, color or monochromatic. Graphics can be further classified based on what subject matter they are representing. It is here that it may be worthwhile beginning a discussion of how geometry and graphics relate to one another.

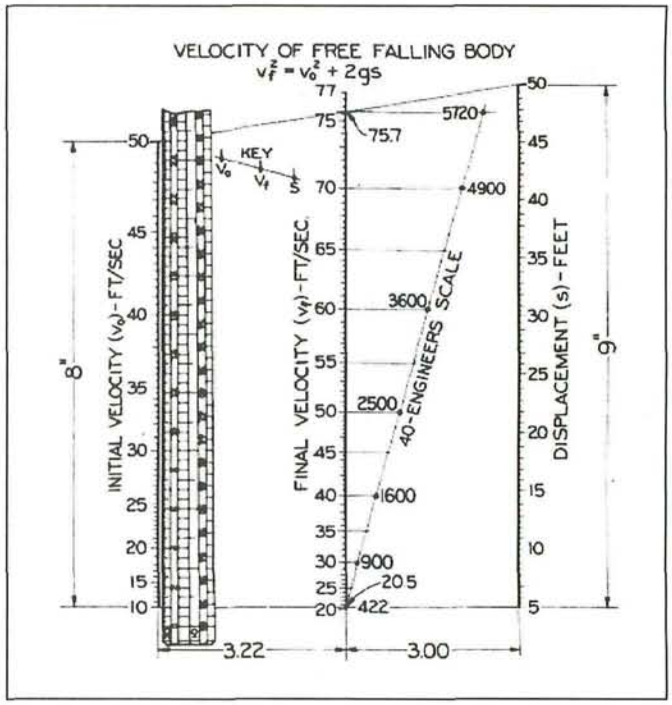

Figure 1 *- A nomograph for calculating a physics problem. (From Giesecke et al. (1991), p880).*

Many of the panelists brought up the inherent synergy of geometry and graphics. Whereas graphics are based on the laws of geometry, graphics also plays a key role in communicating geometric concepts, ideas, and representations. Graphics are useful to students and researchers alike for understanding geometrical relations in space intuitively. As a number of researchers associated with the Engineering Design Graphics Division have noted, a better understanding of the psychological basis of the perception of graphics and its application in education and professional communication is key to its effective use.

This panel certainly did not pretend to come up with the definitive statements on geometry and graphics. Instead they reaffirmed the belief in the interrelationship of these two fields of study and the importance of investigatigating and discussing these issues so that our professions will continue to be vital and expand.

Past and Current Geometry and Graphics use by Engineers and Technologists

Prior to the widespread use of computers and electronic calculators, graphical methods were widely used as an appropriately accurate method of solving mathematically based engineering problems. Graphical charts, such as nomographs, were constructed to rapidly calculate commonly used equations (*Figure 1*). The widespread availability of calculators and computers with robust graphical and numeric output has all but done away with the need to manually construct and use graphical analysis tools such as these. Descriptive geometry has also been impacted by these technological trends (*Figure 2*). At what point does it make sense to manually construct solutions with instruments for problems that can be mathematically calculated on computers? For that matter, when does it make sense to use the same techniques used in manual drafting with a 3-D CAD system to solve these problems (Croft Jr., 1998)? None of these changes in technology, however, has relieved teachers of the responsibility of instructing on the proper use of analytic tools (whether they be manual or computer-based) nor on the

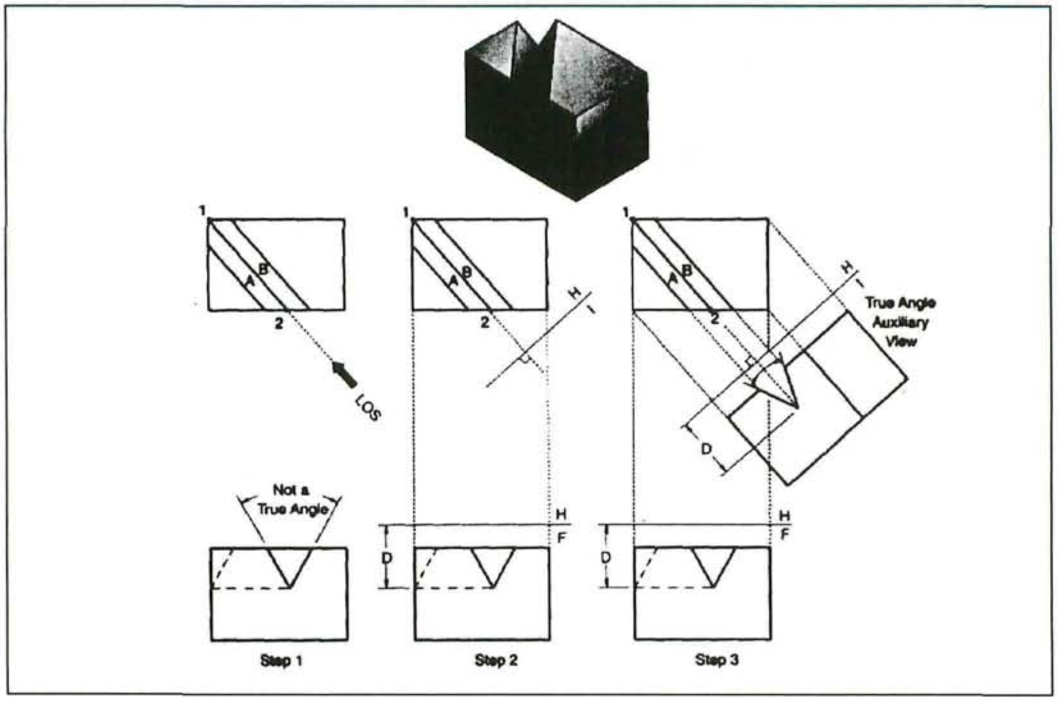

Figure 2 *- A descriptive geometry approach to determining the true measure of a dihedral angle. (From Bertoline et al. (1997), p546).*

appropriate interpretation of the answers at the appropriate level of accuracy (Ferguson, 1993).

Concurrent with the decreased emphasis on graphical analysis methods was the increased focus on the use of computer-based 2-D CAD systems for documentation (*Figure 3*). In this application, 2-D is used primarily as an automated drafting tool for documenting engineering designs for communicating design, manufacturing, and assembly information. Though there is still the opportunity to use 2-D CAD based multiview and pictorial techniques as an analytic tool, the primary focus in most engineering and technical graphics curriculums continues to be on the appropriate application of ANSI/ISO documentation standards.

Where do these traditional methods of using geometry and graphics in analysis and documentation fit into contemporary engineering and technical graphics? A starting point is to attempt to separate the underlying concepts and processes which help develop well rounded engineers and technologists from mechanistic practices which were purely an outgrowth of the technology available when they first developed. Graphical techniques are an excellent applied activity for reinforcing and teaching key concepts of geometry and related branches of mathematics. It is clear that traditional analytic graphical techniques help students to think 'geometrically'. As it was pointed out in the panel summary above, graphics are not needed to apply geometry to solving problems, but is a powerful means for doing so. Are there ways of applying contemporary technology to find new ways of helping students to think 'geometrically'? Numerous researchers in the Engineering Design Graphics Division have realized the important role graphical activities play in the development of spatial visualization skills (cf., Branoff, 1998; McWhorter & et al, 1990; Miller, 1996; Nowacki, 1991; Rooney, 1989; Ross & Aukstakalnis, 1993; Sorby & Baartmans, 1994). A number of studies by these and other researchers point to the important role 3-D modeling tools can play in enhancing visualization ability. Still,

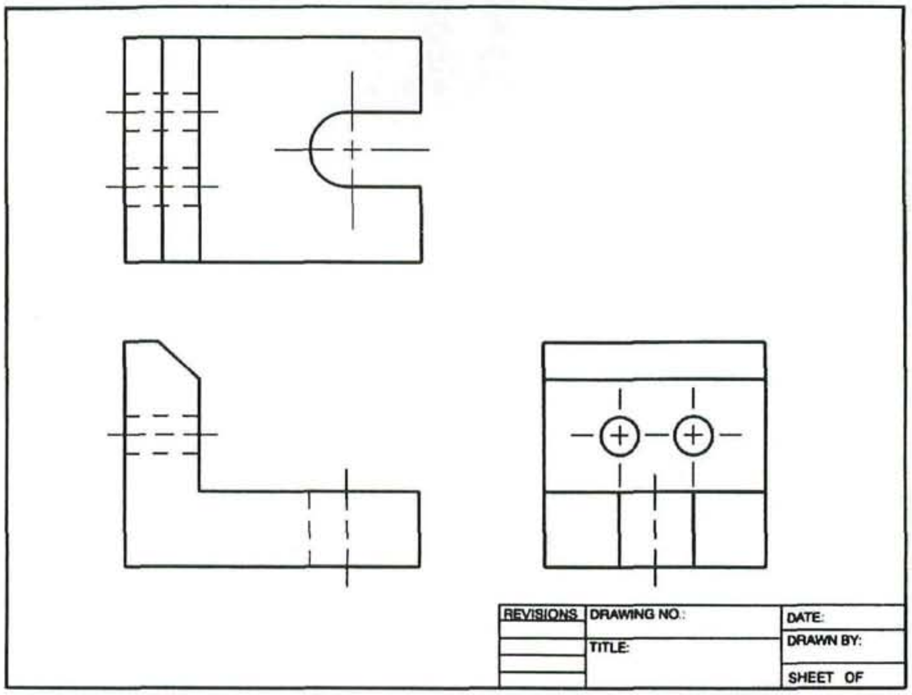

***Figure 3** - Example CAD multiview drawing for documentation (From Bertoline et al. (1997), p400).*

it is clear that we are just beginning to understand this relationship.

An Evolving Role of Geometry and Graphics

Looking at the new generation of technologies used by engineering and technical fields leads to some ideas of where we as a profession may be going. It is going to be critical to continue to address core goals of developing spatial visualization, graphically based problem-solving, and effective communication skills in future engineers and technologists. What must be done, however, is for technical and engineering graphics professionals to be leaders in applying new, 3-D modeling technologies to achieving these goals. This approach serves two critical educational goals, developing graphics literacy and giving students experience with state-of-the-art technology.

Instruction in how to 'think geometrically' has to evolve towards the use of virtual 3-D models in modeling systems. The challenge will be how to preserve key analytic processes (and develop new ones) while discarding drawing and documentation techniques which are no longer appropriate in the 3-D modeling environment. For example, *Figure 4* shows an exercise where the student has to pin the pivot arm at a 60 degree angle to the base, then pin the rod to the pivot arm and have it pass through the center of the width and thickness dimensions of the plate. Finally, the student has to calculate the angle of the bore in the plate needed for the rod to pass through. For this problem, there is no need for the student to manually construct various projections of the assembly nor is it necessary for them to physically measure lengths and angles. On the other hand, they must be able to generate a systematic strategy of how they are going to create the necessary 3-D construction geometry and then assemble the parts. This strategic activity requires spatial visualization skills, a knowledge of how to limit degrees of freedom through geometric constraints, a knowledge of how to define points, lines, and planes in three-space, and a knowledge of how the

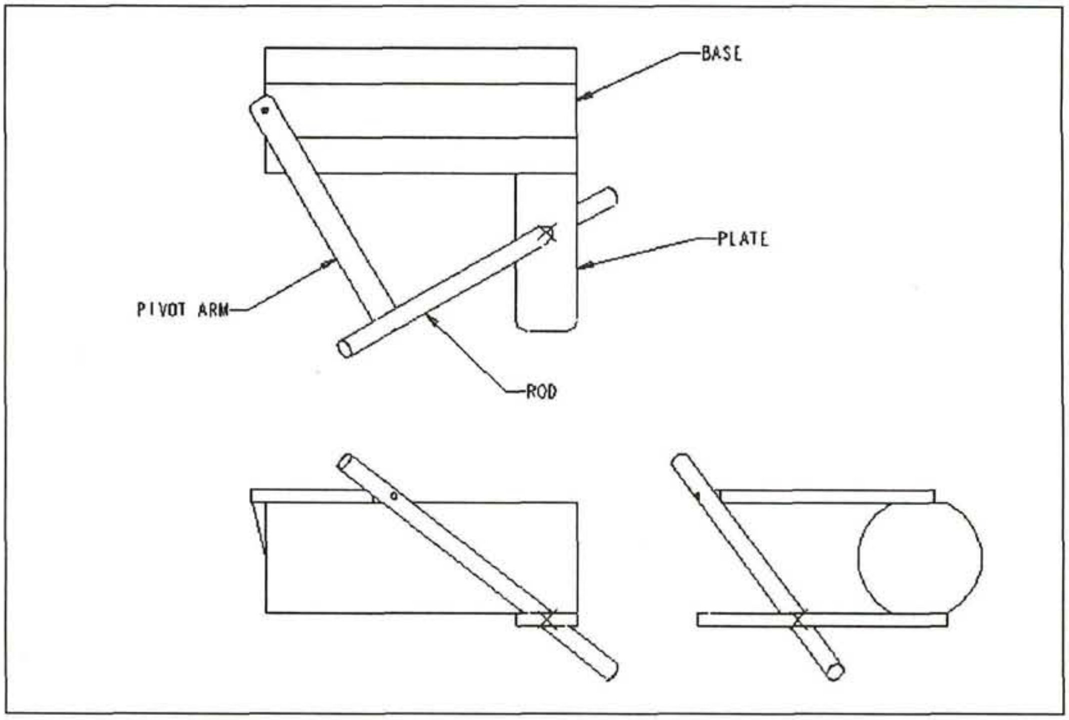

Figure 4 *- A graphical analysis problem using 3-D modeling software.*

software creates and manipulates these entities.

The use of virtual 3-D models of engineering designs means that much of the information which was explicitly documented in traditional working drawings is now implicitly embedded in the model database. Though proper application of ANSI/ISO standards to working drawings is still an important skill; the structuring of the 3-D model database to properly represent the design intent of the engineer/technologist now requires a whole new set of skills. For example, the efficient application of GD&T notation to drawing views extracted from a 3-D model requires planning at the earliest stages of model construction (*Figure 5*) (Wiebe & Branoff, 1999). For the model in this figure, the GD&T notation - representing the size, location, and form of geometric features - is based on how these features are constrained to theoretical datums established early in the modeling process. These datums, in turn, are placed based on how the part geometry interacts between intra-part features and features on mating parts. With 3-D modeling, graphic representation of the model database continues to be a powerful tool to represent geometry. The student's understanding of the geometry he/she is representing and how that geometry addresses a design problem is central to successful model database construction. The new tools being used, however, create documentation as just one representation of the database late in the construction process. As many companies do away with traditional working drawings, documentation should be used increasingly as a tool for demonstrating to the instructor the robustness of the dynamic model database the student has created, not as a static graphic end in and of itself.

Finally, graphical techniques can continue to play a role in engineering problem solving using empirical and theoretical data (Wiebe, 1998). The difference is likely to be that these new graphical techniques are not likely to be used to find unitary 'solutions' to

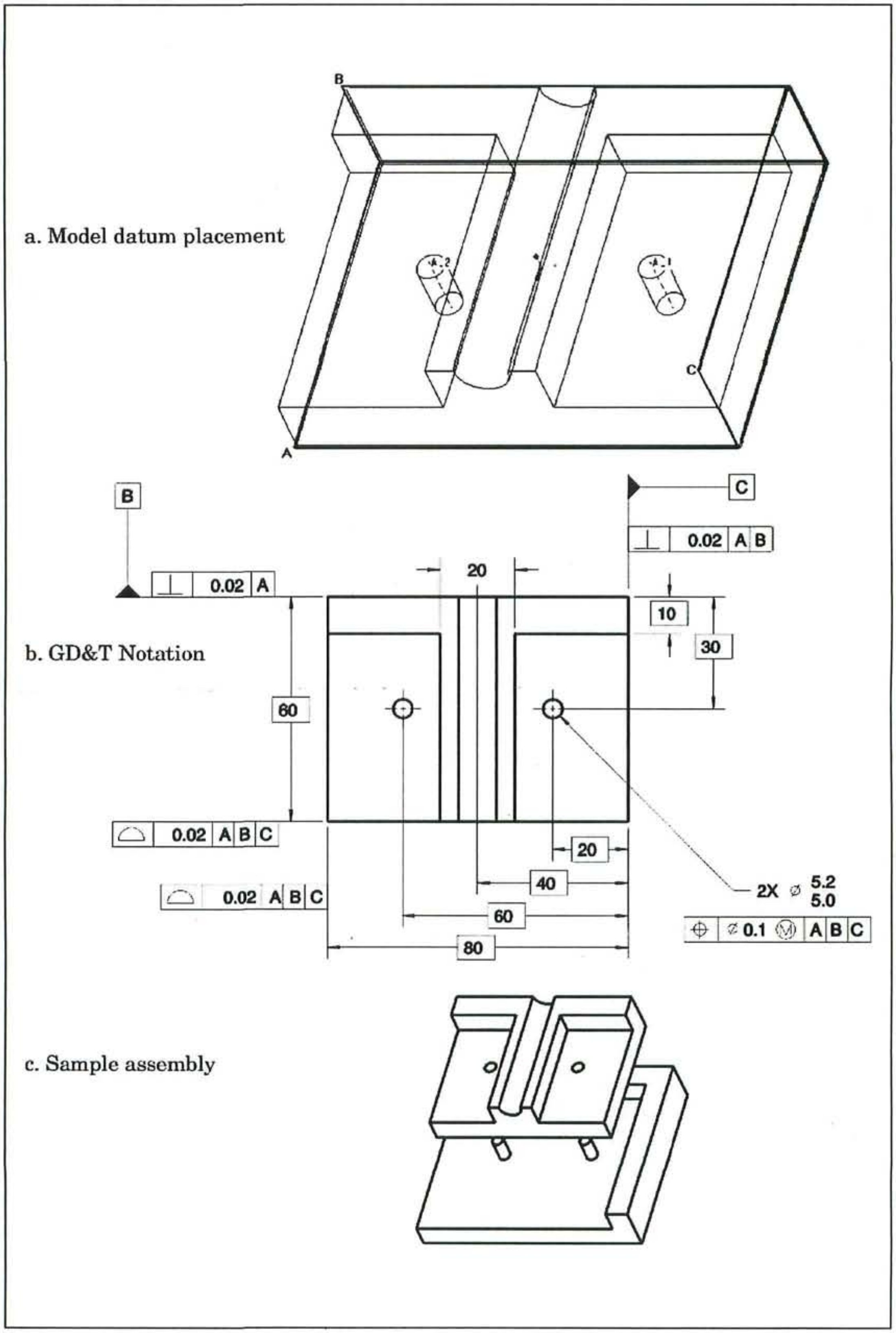

Figure 5 *- The interrelationship of model construction, GD&T documentation, and actual part assembly (from Wiebe & Branoff (1999).*

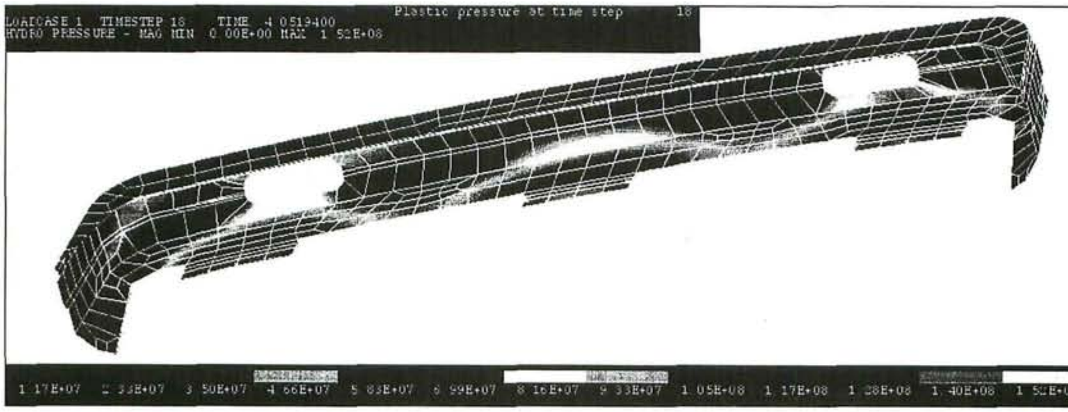

Figure 6 *- Using color to code the results of a finite element analysis of a part model.*

equations as they are to represent large data sets in a holistic fashion. Visualizations such as *Figure 6* allow individuals to synthesize the results of solving thousands of simultaneous equations, which would be near impossible without graphics. These visualizations can be used to help individuals strategize about solution paths or communicate their results to other individuals. In either case, knowledge of appropriate application of graphical techniques (most of which are not now currently being taught to our students) in addition to knowledge of geometry are critical to appropriate use of visualizations.

Conclusion

Engineering and technical graphics is going through another evolution where the profession is required to once again define the roles of geometry and graphics. As with the other evolutionary changes engineering and technical graphics over its history, the principles of geometry and the use of graphics to represent them are still central to our instructional practice. At the same time, 3-D modeling software and changing industrial practice requires us to rethink how we deliver these concepts and how we develop proficiencies necessary for a new generation of engineers and technologists.

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