Using CADKEY to Solve Intersections of Thin-Walled Surface Models

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Abstract

Fundamental constructions in descriptive geometry deal with determining the intersection of various elementary solids, such as planes, cylinders, and cones. Systems involving planes, cylinders, and cones are generally produced from sheet metal or other thin materials. When panels of these thin materials are fastened together, complex objects result. Determining the lines of intersection between the basic shapes that create the final product by using manual methods has always been a complex procedure. The process is greatly improved when using a computer-aided drafting (or design) (CAD) program such as CADKEY; however, the orthographic results can be misleading. To avoid any problems associated with orthographic views of surface models, software developers should consider integrating within the modeler a means by which the surface model can be displayed as a solid model, thus eliminating hidden lines that nearly coincide with object lines.

Introduction

Determining lines of intersection of solids has always been a complex problem in descriptive geometry. Common solutions warranted use of cutting planes and transfer of points through various views in order to generate the correct intersection. Furthermore, when dealing with curved surfaces, the solution required one to plot several points and then establish the intersection by connecting the points with an irregular curve. The skill of the drafter was extremely important in the overall solution.

With three-dimensional CAD programs, lines of intersection can be determined very simply if the solid modeling software uses Boolean operations to enhance solid construction (Bertoline, 1997). Boolean operations include UNION, DIFFERENCE, and INTERSECTION functions. For example, in Figure 1, the pyramid and the triangular prism (Hawk, 1962) are generated separately and then using a UNION operation, are combined into a single solid.

Holes in solids can be generated using a DIFFERENCE operation. Figure 2 shows a triangular prism with a hole through it. The hole was produced by creating a cylinder long enough to pass completely through the prism and then using the DIFFERENCE operation.

Once the solids are formed, the lines of intersection are also formed and stored in the database. Most CAD programs permit the user to display the solid in many different ways including rendered, hidden lines removed, or hidden lines visible. Figure 3 shows a solid that has been rendered. The triangular prism intersects the pyramid as shown in Figure 3. It should be noted that after the intersection operation, the pyramid and prism characteristics extend only to the lines of intersection. This is shown in Figure 4 where hidden lines depict the intersection.

Solids Composed of Lateral Surfaces

Although CAD programs in general, and CADKEY in particular, can be used to easily determine the lines of intersection between two geometric solids, what about the lines of intersection between objects composed of surfaces only? These geometric solids are hollow and offer a somewhat different approach in their solution. The primary difference between thin-walled surface models and objects that are solid throughout is the surface model will show two parallel lines for the intersection due to the thickness of the surface that makes up its geometry. This is very important since many real world applications deal with objects constructed out of sheet metal.

The significant issue in dealing with thin-walled surface models is the actual construction of the model. Fortunately, most CAD modeling programs offer a shelling routine, which will automatically hollow a solid model to produce a thin-walled surface model. CADKEY has this capability built into its solid modeler and it is very easy to "shell out" the solid and be left with the surface model. Figure 5 shows the result of the pyramid and prism intersection in a surface model format. The left side of the figure shows the thickness of the material that composes the lateral surfaces. The right side of the figure simply shows the surface model without the hidden lines and it looks exactly like the solid model in Figure 1.

Orthographic Views of the Thin-Walled Surface Model

CADKEY, through its layout mode, offers the user a way to create a design drawing showing any number of orthographic views desired. It must be noted that when showing the orthographic views of the thin-walled surface model, thickness of the material is depicted and may offer some confusion. See Figure 6. When a layout of a solid is presented, single hidden lines allow ease of interpretation; when a layout of a thin-walled surface model is presented, often double hidden lines add a great deal of confusion. Figure 7 shows the orthographic views of a solid. Note the clarity of the intersection; however, if the intent of the design is to use folded sheet metal or other material to construct the solid, then the drawing (Figure 7) does not represent the true object. Figure 7 shows hidden lines only in the front view, which is correct. There is little chance that anyone trained in orthographic reading would misinterpret the intersection.

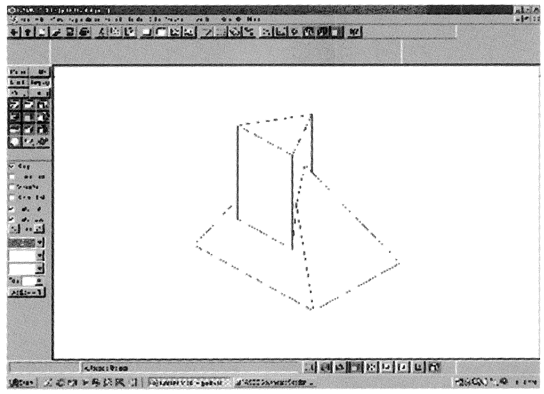

Figure 1 *Solid Model of a Pyramid and Triangular Prism formed by Boolean UNION*

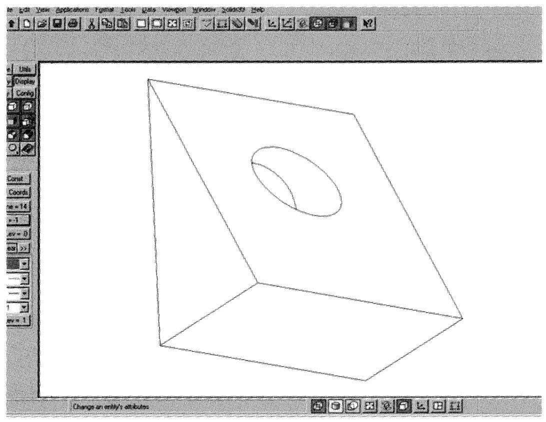

Figure 2 *Triangular Prism with a Hole Formed by Boolean Difference*

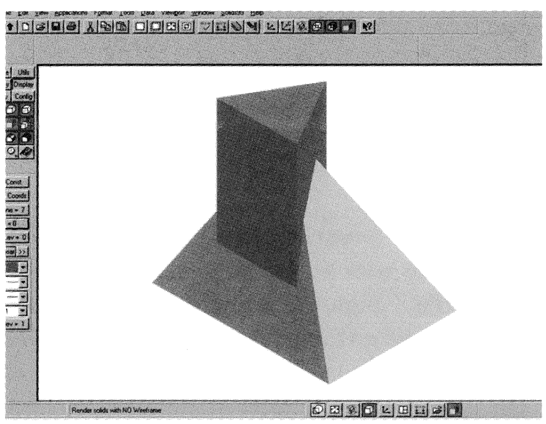

Figure 3 *Rendered Solid*

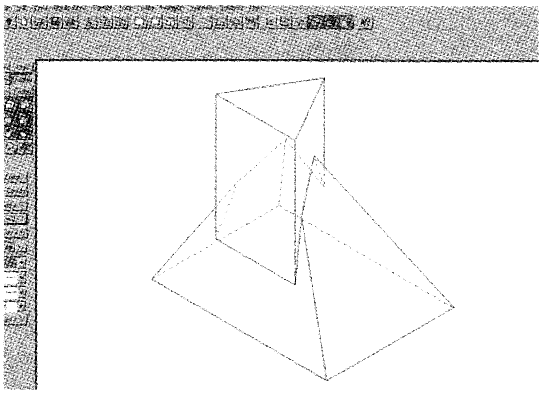

Figure 4 Intersection of Pyramid and Prism showing Hidden Lines

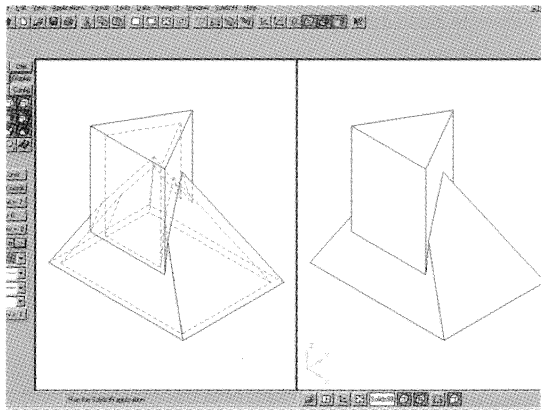

Figure 5 Intersection of Lateral Surface Generated Solids

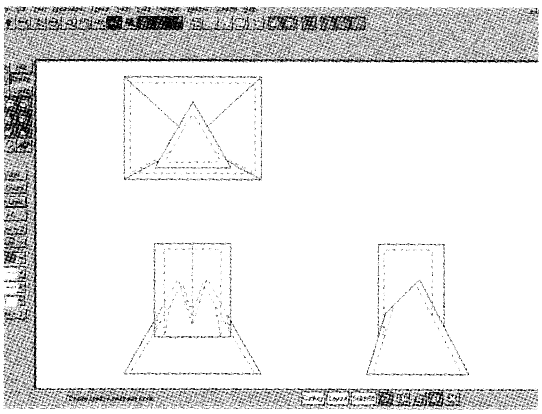

Figure 6 Orthographic Layout of Thin-Walled Surface Model

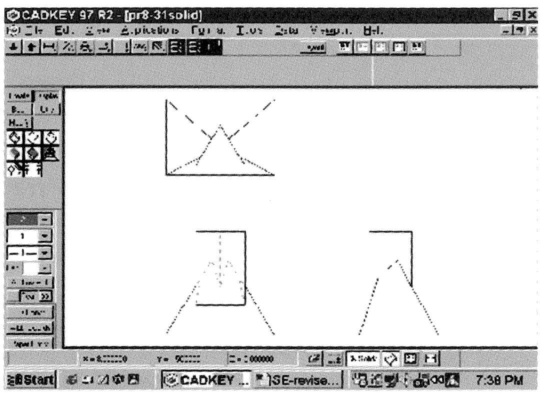

Figure 7 Orthographic Layout of Solid

This drawing, although orthographically correct, is geometrically incorrect if the drawing is meant to depict the orthographic views of a surface model. The engineering properties associated with the solid and the surface model are different.

Most CAD programs, including CADKEY enable the user to examine the engineering properties. Figure 8 shows a portion of the mass properties table for the solid as displayed in Figure 7, while Figure 9 shows a portion of the mass properties table for the corresponding surface model as shown in Figure 6. For example, the table for the solid shows a volume of 5.138 cubic inches and a surface area of 22.26 square inches. In contrast, the table of the surface model shows a volume of 2.390 cubic inches and a surface area of 39.74 square inches. These are very different properties.

Conclusions

CAD programs, such as CADKEY, are very powerful tools that can display complex intersections between solids without the cumbersome cutting planes and projection techniques of the past. The Boolean operations associated with most CAD modelers enhance one's ability to develop complex solid objects and enable us to have confidence that our geometry is correct. On the other hand, since many real world designs depend on objects developed from flat material such as sheet metal, CAD solid modeling software should be able to incorporate

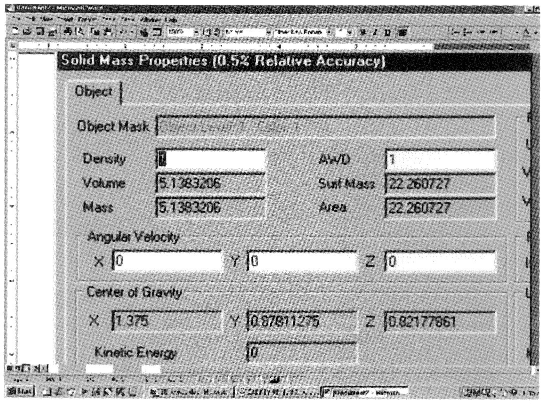

Figure 8 *Engineering Properties of Full Solid*

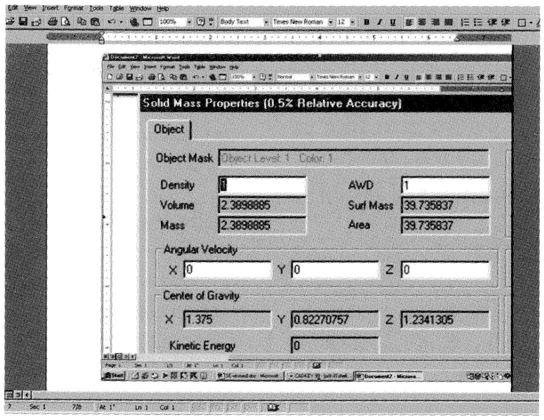

Figure 9 *Engineering Properties of a Thin-Walled Solid*

the standard representation of the solid objects made of these materials. The thickness of the material, although important to the flat pattern developers, is unimportant when constructing design drawings. The proper view representation can be achieved if a solid representation of the object is modeled; however, a solid does not represent the real world object and its engineering properties. Finally, it is recommended that software developers consider integrating within the modeler a means by which the thin-walled surface model can be displayed as a solid model, thus eliminating hidden lines that nearly coincide with object lines. This can be done to avoid any confusion associated with orthographic views of surface models.

References

Bertoline, G. (1997). *Technical Graphics Communication, Second Edition.* McGraw-Hill: Chicago.

Hawk, M. (1962). *Theory and Problems of Descriptive Geometry, Schaum's Outline Series.* McGraw-Hill: New York.