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Methodology for Connecting Intersection Lines between Polyhedra in Technical Drawing and the Use of Computer Assistance in Object Representation

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Abstract - **Drawing intersection lines between two surfaces is a crucial problem to solve in technical drawing. In machining the surfaces of mechanical casings, complex intersections are often encountered. Common surfaces can be divided into polyhedra and curved surfaces. Finding the intersections of these surfaces is a practical problem in machining mechanical surfaces and a fundamental issue in graphic-drawing techniques. In principle, it is essential to determine the projections of specific points and then connect the lines of intersection in a defined order. Connecting the intersection lines in the correct sequence poses significant challenges. The author has proposed a set of rules for connecting the intersections of two polyhedra and incorporated computer assistance to develop surface applications for production practices.**

Keywords: Intersection connection; Visibility analysis; 2D to 3D transition; VBA; SolidWork.

I. Introduction

The intersection of polyhedra is a critical issue forming the foundation for depicting object representations. In textbooks on Descriptive Geometry [1], [2], [3], methods to determine intersection points and connect the intersections of two polyhedra using diagrams are introduced. However, when students and engineers apply these methods, they must memorize the given rules, which can be challenging to visualize and execute, leading to errors. This paper introduces a logically derived set of rules for connecting intersection lines, limited to the case of intersections between two polyhedra.

The second focus is the application of computer-assisted techniques to determine the intersection of two polyhedra, identifying intersections on metal sheets, and unfolding them for practical production purposes.

II. Connecting Intersection Lines of Two Polyhedra in Descriptive Geometry Using Traditional Methods

2.1 Problem of Finding the Intersection of Two Polyhedra

The problem is to draw the intersection lines of two polyhedra. To simplify, consider a case where one of the two polyhedra is a prism. This prism will be referred to as the first polyhedron, and the other polyhedron can be arbitrary.

A generatrix (side edge) of the first polyhedron may not intersect the second polyhedron or may intersect its curved surface at two points. If a generatrix of the first polyhedron intersects the curved surface of the second polyhedron at two points, the second intersection point is denoted with a prime (e.g., if the first intersection point is A, the second point is A’), following a consistent order rule (e.g., top-bottom, left-right). A point A in space projected onto the front view will be indexed as 1, and its projection onto the top view will be indexed as 2. For instance, the front projection of point A is A_1, and the top projection is A_2.

The problem of finding the intersection between two polyhedra, one of which is a prism, as taught in descriptive geometry in universities, is solved as follows:

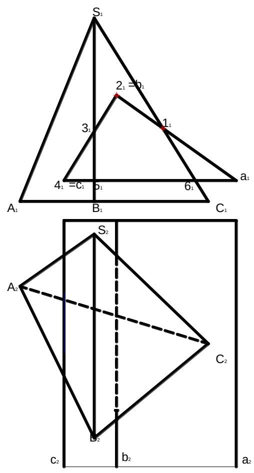

Figure 1a: intersection between a prism and a pyramid

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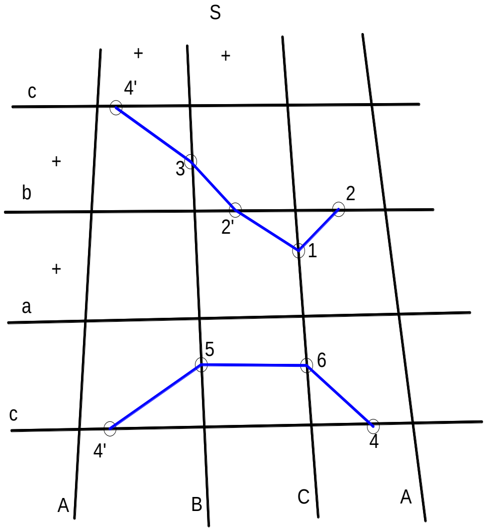

Figure 1b: The connection method

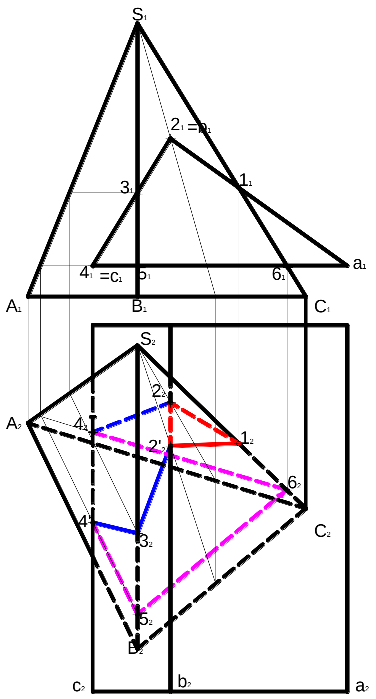

Figure 1c: The results of the problem

Example: Finding the intersection between a prism and a pyramid SABC (Figure 1a)

1. The method used involves finding the intersections of the faces of one polyhedron with the faces of the other.
2. The connection method involves unfolding the faces of both polyhedra and using an unfolding diagram (Figure 1b).
3. Solution is illustrated in Figure 1c.

However, this method requires precise memorization and execution of the rules, making it challenging, especially for general polyhedron problems.

2.2 Basis of the Method for Finding the Intersection of Two Polyhedra

Finding the intersection of two polyhedra is simplified by dividing one polyhedron into separate planes. Each plane intersects the convex polyhedron along a convex polygon. The intersections of the edges of the planes with the convex polyhedron are identified at the nodes, and these points are connected to form a convex polygon.

In the given example, the prism projection is divided into three flat pieces. The first piece, a//b, has its front view as the segment a_1b_1 and its top view as $a_2//b_2$. Since the plane (a//b) is a projection plane, its front view is the segment a_1b_1. Using the method of finding intersections, line b, with front view b1 and top view b_2, intersects the pyramid SABC at two points, 2 and 2', whose front views are $2_1 = 2'_1 = b_1$. Their top views are 2_2 and $2'_2$. The flat piece a//b has only one part within the pyramid's projection boundary, so the intersection has a front view of the segment 1_1, b_1. Additionally, SC intersects the plane a//b at a single point, with a front view of 1_1 and a top view of 1_2. Thus, the flat piece a//b intersects the pyramid at vertices 1, 2, and 2'. In the front view, the projection of the flat piece is the segment 1_1, 2_1. In the top view, there are three vertices: 1_2, 2_2, and $2'_2$. There is only one way to connect them to form a triangle. (Figure 2)

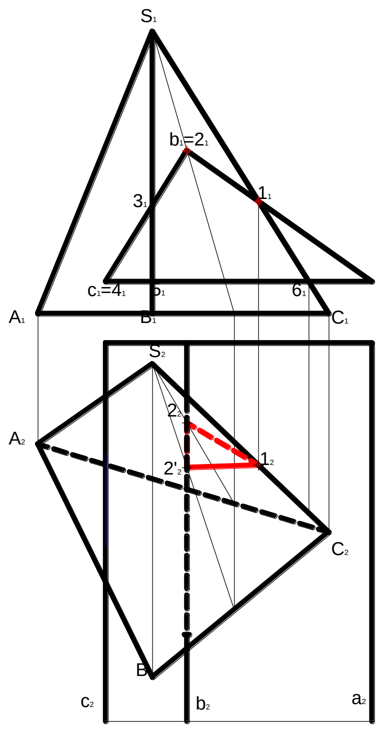

Figure 2: The solution in one face

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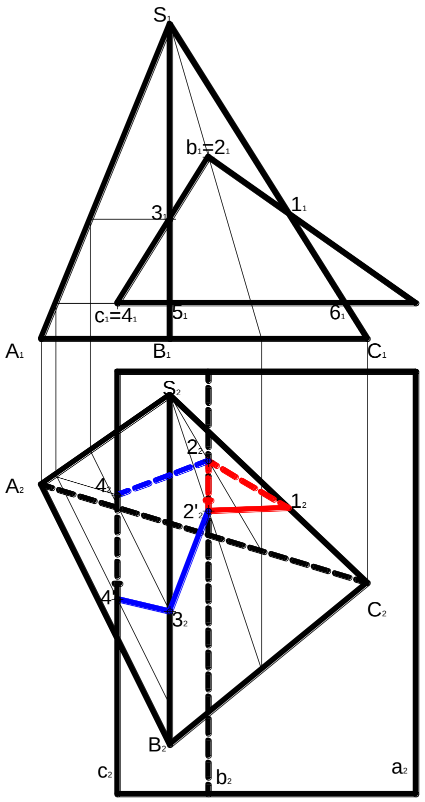


Figure 3: The solution

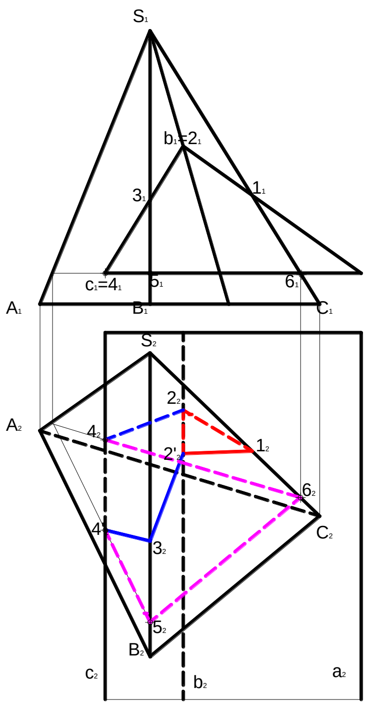


Figure 4: The final solution

The second flat piece of the prism b//c, is perpendicular to the front projection plane and has a front view represented by the segment b_1c_1, which lies inside the pyramid's projection boundary. Therefore, the intersection has a front view of segment b_1c_1. Similar to the method used to find the intersection of the flat piece a//b above, the second flat piece intersects the pyramid along the convex polygon 2, 2', 3, 4', 4. This polygon has its front view on the segment b_1c_1, and its top view is connected in a unique way. (Figure 3)

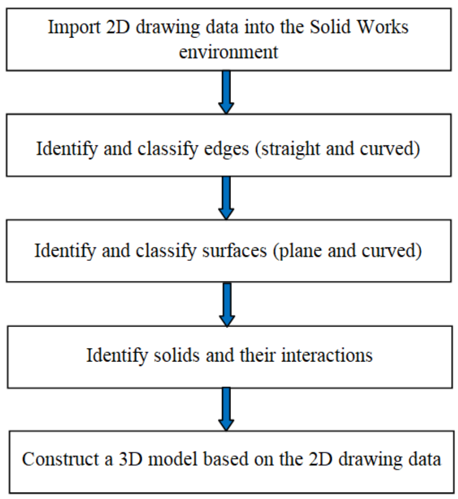
The third flat piece of the prism c//a, is also perpendicular to the front projection plane and has a front view represented by the segment c1a1. Since part of this segment lies within the pyramid's projection boundary, its intersection with the pyramid has a front view along the segment c_16_1. The intersection of this flat piece with the pyramid forms a convex polygon. Using this method, the final result of the problem is represented in Figure 4.

The second method yields the same result as the first. By dividing polyhedra into flat pieces and determining their intersections with other polyhedra, it becomes easier to identify the intersection of two polyhedral surfaces.

III. Intersection Problems with Computer Assistance

3.1 Understanding Representations Combined with 3D Design Software

The development of computers has enabled quick and intuitive solutions to descriptive geometry problems. Today, with the advent and rapid advancement of design software, researchers have developed methods to automatically convert 2D orthographic drawings into 3D models.



SolidWorks, a popular 3D mechanical design software, is widely used due to its Windows-native interface, strong assembly capabilities, ease of use, and affordability. The software can be extended using APIs (Application Programming Interfaces) and VBA (Visual Basic for Applications) or Visual C++, Visual Basic, etc. APIs provide direct access to SolidWorks functionalities like creating lines, cutting holes, or verifying surface parameters [4][5][6].

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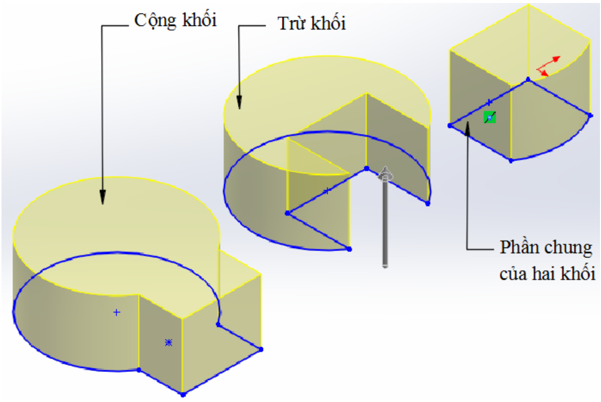
Through these tools, 3D models are built from the identified surfaces, defining their spatial boundaries. Using tools like *Extrude Boss* and *Revolve Boss*, the intersections of two polyhedra are quickly determined.



1. **Union of Solids (Addition):** Created using *Extrude Boss* or *Revolve Boss*.
2. **Subtraction of Solids (Cutting):** Created using *Extrude Cut* or *Revolve Cut*.
3. **Common Volume (Intersection):** Created using *Intersect*.

Interactions between solids are highly diverse, and multiple methods can be employed to create the same object. However, when constructing solids, it is advisable to simplify them into basic forms (e.g., boxes, cylinders, cones).

- **Extrude Boss:** Creates a 3D solid by sweeping a cross-section along a perpendicular direction.
- **Extrude Cut:** Creates a cut by sweeping a cross-section along a perpendicular direction.
- **Revolve Boss:** Creates a 3D solid by rotating a cross-section around an axis.
- **Revolve Cut:** Creates a cut by rotating a cross-section around an axis.

3.2 Finding the Intersection of Two Polyhedra Using Computer Assistance

For the problem of finding the intersection of two polyhedra, the input consists of the basic 2D projections that determine the positions of the two polyhedra. The algorithm for finding the intersection of two surfaces, integrated into SolidWorks, helps quickly determine the location and shape of the intersection.

The 3D modeling process begins once the forms and interactions of the solids are recognized. By importing AutoCAD files into SolidWorks, the software displays the front and top views as primary input data for interpretation and 3D modeling (Figure 6).

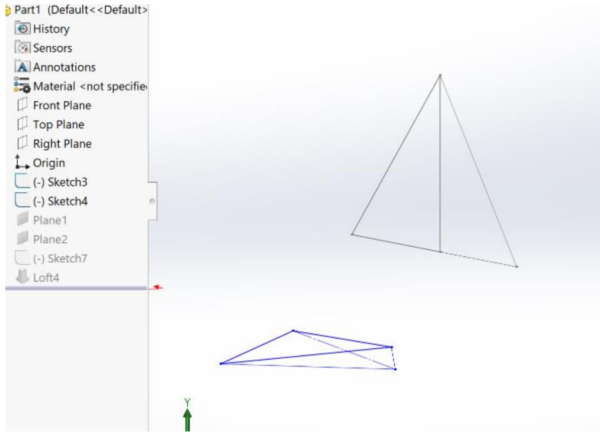


Figure 6: Input data in SolidWork

In traditional 3D modeling, the user must input all dimensions and parameters of the problem. The difference here is that 3D shapes are directly created from the imported 2D drawings without entering dimensions manually (Figures 7 and 8).

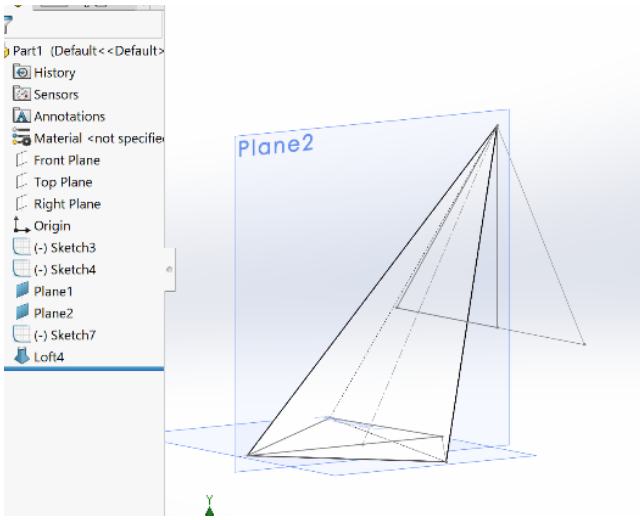


Figure 7: 3D model from 2 views

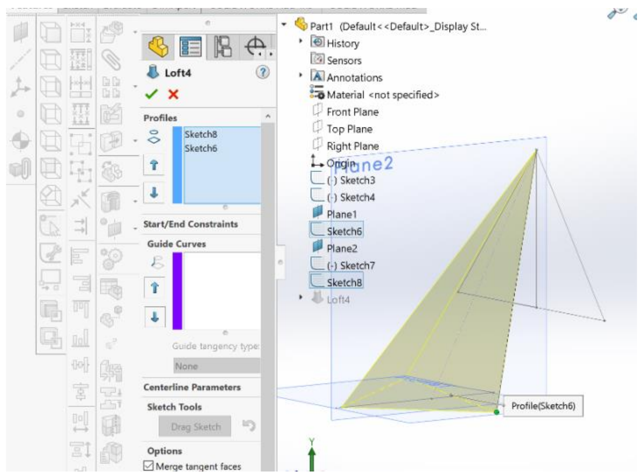


Figure 8: 3D model from 2 views

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Using the data from the two projections of the pyramid and prism, with computer-assisted tools to find the common points between the two surfaces, the intersection is displayed on the screen (Figure 9).

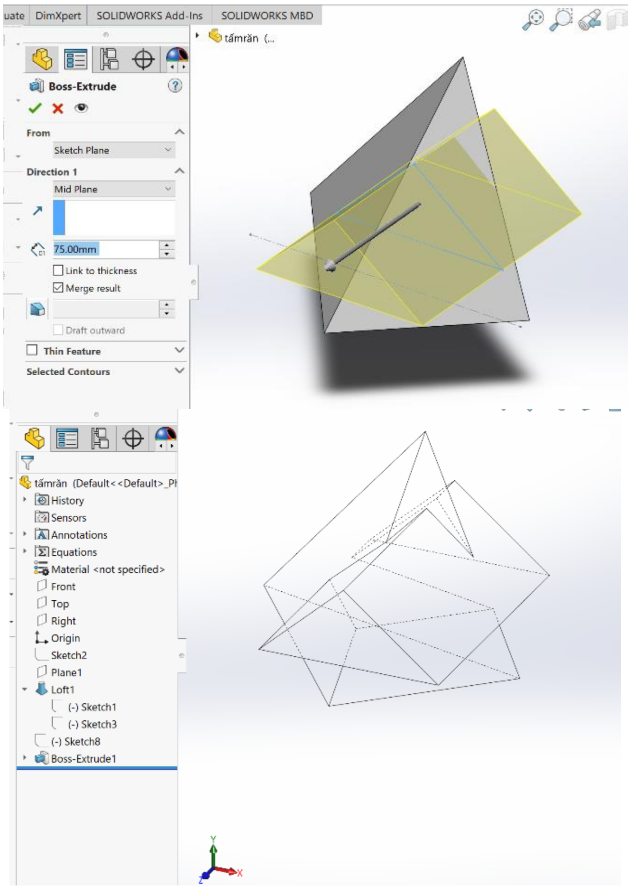

Figure 9: intersection between the two surfaces

From this intersection on the 3D model, standard projections are generated, resulting in a top view of the intersection (Figure 10). The results resemble those achieved by manual drafting with rulers and pens.

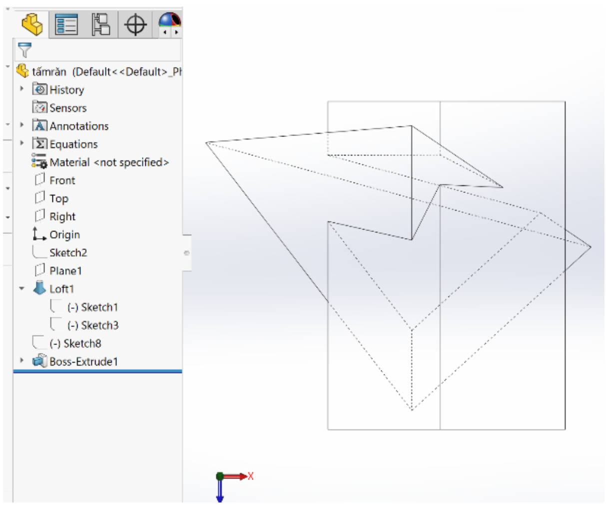

Figure 10: Resulting in a top view of the intersection

IV. Conclusion

This paper presents a method for finding the intersection between two polyhedra that is simpler than using traditional unfolding diagrams. This method is applicable to any intersection problem involving two polyhedra in arbitrary positions.

Additionally, it introduces a new way to interpret objects based on the positions and relationships of the identified surfaces. Combining this interpretative approach with the ability to create 3D models directly from 2D projections and employing automated intersection functions offers greater visual clarity compared to traditional methods.

Thus, this method can be integrated into technical drawing instruction to enhance students' comprehension and align with the trend of increasing 3D computer graphics in place of manual drafting.

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