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Computer-Aided Interpretation of Technical Drawings

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***Abstract* - Interpreting technical drawings is not a simple task. This issue has become increasingly difficult today as the general knowledge of spatial geometry in the curriculum has been reduced, leaving learners with insufficient foundational knowledge and weak spatial reasoning abilities. Therefore, integrating 3D (three-dimensional) design software applications to support graphics instruction will help us resolve this difficulty. This article presents a method for analyzing, interpreting drawings, and exploiting the 2D-to-3D application in SolidWorks software. The objective is to enhance the capacity to comprehend 3D models from 2D drawings while simultaneously supporting the learner's spatial imagination.**

Keywords: Technical drawing; Computer-Aided; 2D-3D Design.

I. Traditional Interpretation of Drawings

Historically, in descriptive geometry and technical drawing textbooks, the content regarding drawing interpretation has not been consolidated into a specific lecture. In the mechanical engineering drawing textbook [1], authors Tran Huu Que, Dang Van Cu, and Nguyen Van Tuan merely provided some suggestions and guidelines on how to read two orthographic projections to draw the third. This traditional method can be classified as follows:

- Surface-Oriented Interpretation: First, the reader must observe from the correct line of sight to distinguish the top or bottom, front or back, and left or right faces of the object. On the orthographic projections, each closed contour (polygonal or curved line) represents a surface. Two adjacent or enclosing closed contours represent two surfaces of the object. Next, the reader needs to rely on the remaining projection to determine the relative position between the two adjacent surfaces. Once the positions of the surfaces are grasped, the closed surfaces will form solids, and from these solids, the structure of the object can be recognized (Figure 1).

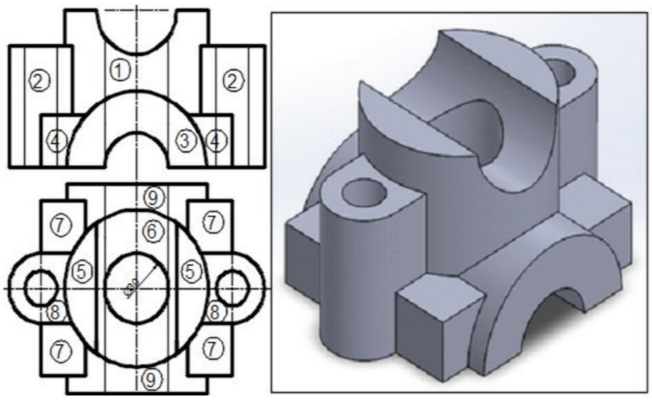

Figure 1: Result of surface-oriented drawing interpretation

- Solid-Oriented Interpretation: According to this method, the front elevation (front view) is divided into geometric modules based on height (e.g., base, body, apex, top or bottom portions). The plan view (top view) is divided based on depth (e.g., the central "core", left or right, inside or outside portions). The reader must carefully inspect projection alignments and projection lines from top to bottom to partition the object into individual geometric solids based on the coordinates on the views. Thus, the requirement is to firmly grasp the projection characteristics of basic geometric solids, then based on the views, divide the object into component solids. After determining the geometric structure of each part, we examine their interactions to derive the final result (Figure 2). These component solids combine with each other under three conditions: union (addition), difference (subtraction), or intersection (common volume).

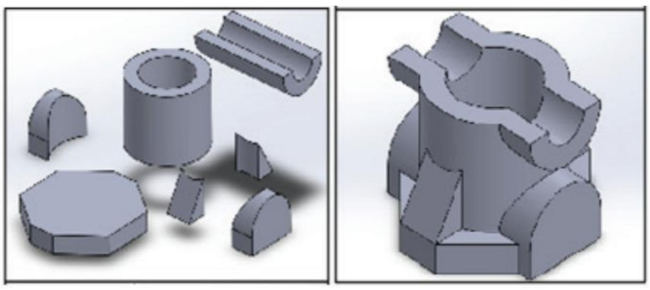

Figure 2: Result of solid-oriented drawing interpretation

Both aforementioned methods lack clarity when applied to a specific object, meaning reliance is still placed on the reader's experience and cognitive habits, thus failing to maximize their effectiveness in teaching.

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II. Interpreting Drawings Using Computer Software

Today, with the advent and robust development of design software, several scientists worldwide have researched methods to automatically reverse-engineer 3D models from 2D drawings. The designer creates or provides an existing 2D drawing, and the software automatically interprets it to construct a 3D model. This method was proposed by Idesawa in 1970 [2], based on boundary representation (B-Rep) and a bottom-up approach. 2D points and lines on orthographic projections are converted into 3D vertices and edges. Invalid vertices and edges are eliminated. Subsequently, 3D faces are generated, and invalid faces are discarded. Finally, the software generates the 3D object based on computationally valid solids.

Following Idesawa, numerous scientists around the world also engaged in research in this direction [3]. Their works are divided into two categories: those using the B-Rep (Boundary Representation) structure and those using the CSG (Constructive Solid Geometry) structure. B-Rep is a data structure containing coordinate lists of surface, edge, and vertex elements. The CSG structure builds objects through the combination of simple solids using relational operators. Its data structure is built using a binary tree. The nodes represent 3D transformations (rotation, translation) or Boolean operators (union, difference, and intersection). Basic geometric primitives (prisms, cylinders, cones, spheres, tori, etc.) or displacement parameters act as the leaves of the tree.

Figure 3 illustrates the general steps of automated reverse-engineering methods for 3D model interpretation via software, consisting of 8 steps. The primary steps are the formation of pseudo-edges, face creation, pseudo-solid creation, and rendering the final decision.

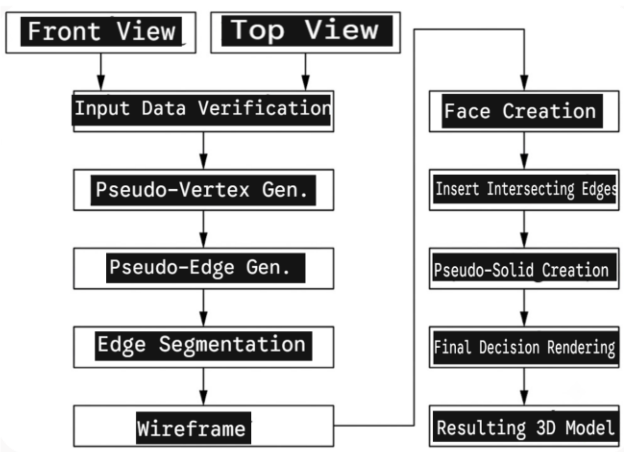

Figure 3: Flowchart of the software-based automated 3D reconstruction procedure

Most recently (2011), scientists Y. Volpe, R. Furferi, L. Governi, and M. Palai [4-5] presented reverse-engineering procedures from a practical standpoint. Their research based on the B-Rep approach was presented in detail and successfully validated on MATLAB using a polyhedral model, as shown in Figure 4.

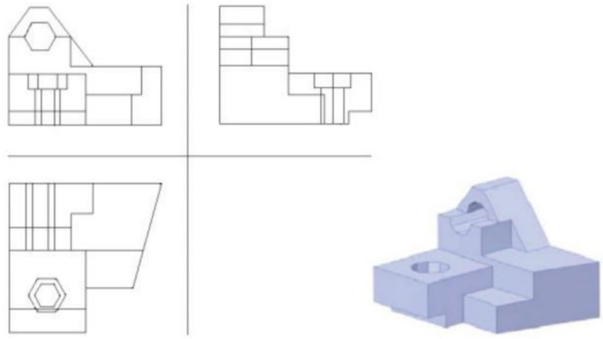

Figure 4: The 3D reconstruction work of researchers Y. Volpe, R. Furferi, L. Governi, and M. Palai

Examining these research works allows for the following assessments:

- The elimination of invalid entities is not thorough, failing to fully utilize visible and hidden topological information. There are instances of redundant, incorrect, and overlapping solutions.
- The scope of applicable objects remains limited; many methods are only suitable for polyhedra, while others that have expanded to secondary curved surfaces cannot process complex intersection lines and the interactive structures of the basic solids containing those curved surfaces.
- Currently, automated reverse-engineering software remains at the research stage and has not been deployed for practical use.

III. Interpreting Drawings Integrated with 3D Design Software Applications

To overcome the limitations of the aforementioned interpretation methods, the newly proposed methodology specifies and details traditional interpretation theory and applies it appropriately alongside the application of popular 3D design software (SolidWorks). The sequence of this method is to identify the object sequentially starting from edges, followed by surfaces, geometric solids, and finally recognizing and modeling the entire structure of the object using software (Figure 5).

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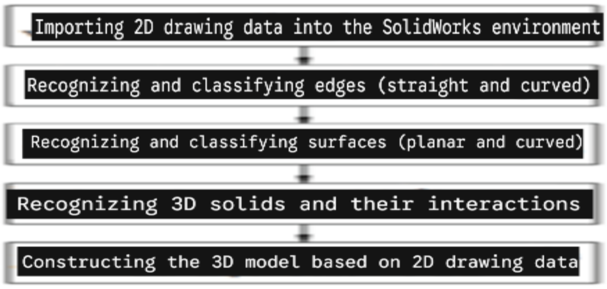

Figure 5: Workflow of the drawing interpretation method using design software

Edge Recognition

Edges are divided into two types: line segments and curves. The majority of recognized line segments have the geometric characteristic of being parallel or perpendicular to the principal planes of projection. A small number of line segments are arbitrary (i.e., neither parallel nor perpendicular to the projection planes). Recognizing curves is more complex and depends on the remaining projection view. That curve could be a circle, an ellipse, or a spatial curve (spline).

Surface Recognition

A surface must be interpreted from a closed sequence of straight or curved segments (without visible dividing lines). Surfaces are divided into two types: planar surfaces and curved surfaces. The majority of planar surfaces are identified as projecting or level planes (perpendicular or parallel to the principal planes of projection). The remaining few are arbitrary surfaces. Most curved surfaces commonly encountered in mechanical structures are cylindrical surfaces. In addition, there are other basic surfaces such as cones, spheres, and tori.

IV. Determining the Position, Characteristics, and Correlation between Surfaces

The surfaces are determined based on the projection alignment between two orthographic views. To facilitate the classification of planes, we denote parallel plane 1 as M, and parallel plane 2 as B. The remaining surfaces will be projecting planes. For projecting surfaces represented by hidden lines that constitute the surface of a hollow cut into the object, they are denoted as K. On the front elevation, it is necessary to distinguish the depth (distance) of the surfaces. The further a surface is from the x-axis, the closer it is to the viewer, and vice versa. Similarly, on the plan view, we distinguish the elevation of the surfaces. The further a surface is from the x-axis, the higher its elevation, and vice versa. Following this, the exact spatial positions of the surfaces on the 2D drawing are located, as exemplified in Figure 6.

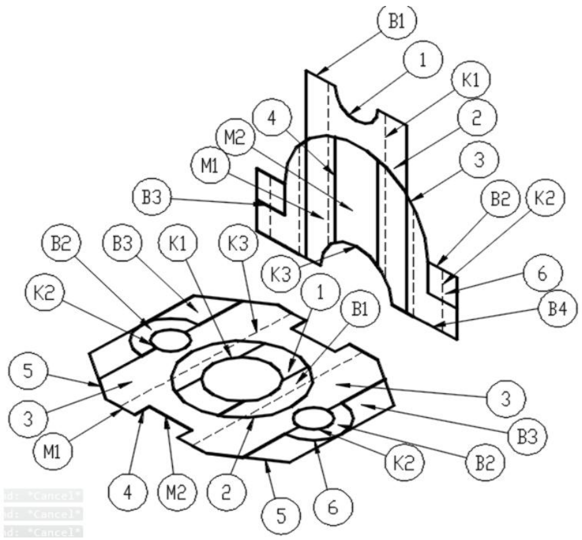

Figure 6: Determining and identifying surfaces

V. Solid Recognition and Software-Based Modeling

From the recognized surfaces, we proceed to construct 3D geometric solids. A 3D solid must originate from a closed surface. The position of a remaining surface acts as the boundary limit of the solid. The 3D modeling process will commence once we have identified sufficient solids and the interactions between them.

After using SolidWorks to import the AutoCAD file containing the 2D technical drawing, the front view and top view appear in the environment containing the 2D-to-3D toolbar (Figure 7). While conventional 3D modeling requires manually inputting full dimensions and data from the problem, the distinction here is that 3D modeling is executed directly from the imported 2D drawing without the need to input dimensions, utilizing the exact lines of the 2D technical drawing.

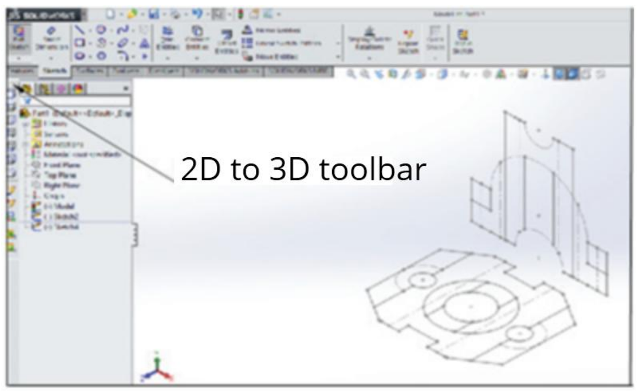

Figure 7: Importing an AutoCAD file into SolidWorks

The interaction between 3D solids is categorized as shown in Figure 8.

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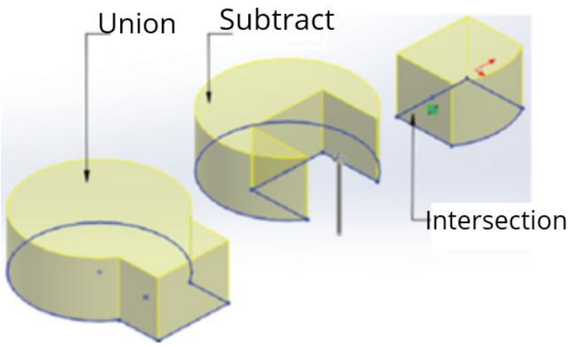

Figure 8: Boolean operations on 3D solids

The interactions between solids are diverse, and there can be multiple solid creation methods for the same object. However, when creating solids, we strive to reduce them to their most basic forms (box/prism, cylinder, cone, etc.). When executing modeling in SolidWorks, we typically utilize the following command groups:

- Extrude Boss command: Creates a 3D solid by sweeping a profile in a perpendicular direction.
- Extrude Cut command: Creates a 3D cut volume by sweeping a profile in a perpendicular direction.
- Revolve Boss command: Creates a 3D solid by revolving a profile around an axis.
- Revolve Cut command: Creates a 3D cut volume by revolving a profile around an axis.

In cases where the object requires more complex modeling commands, users can fully expand and exploit additional applications within the software while retaining the available coordinates from the 2D technical drawing (Figure 9).

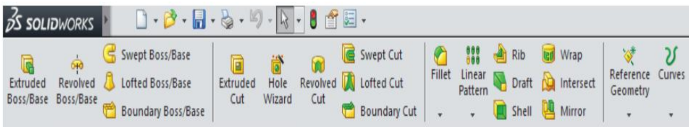

Figure 9: Basic modeling menu in SolidWorks

Errors during the modeling process are easily rectified in the highly intuitive 3D environment. The resulting 3D model of the 2D drawing (Figure 6) is illustrated in Figure 10.

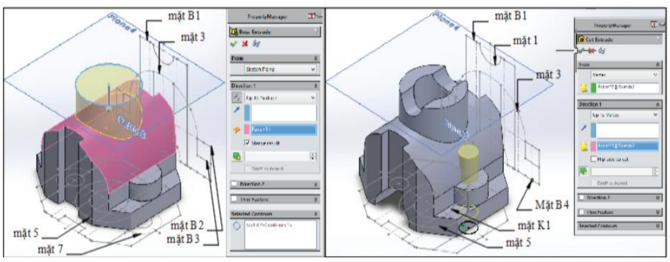

Figure 10: 3D model generated from 2D drawing coordinates

VI. Conclusion

The article has proposed a novel object interpretation methodology based on the position and correlation of recognized surfaces. The integration of these comprehension elements with direct 3D modeling features on 2D orthographic projections yields significantly higher visual intuition compared to traditional interpretation methods. Therefore, this method can be supplemented into technical graphics pedagogy to enhance learners' reading and comprehension abilities, simultaneously aligning with the trend of increasing computer-aided 3D design to gradually replace manual drafting.

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