3D MODEL GENERATION FROM THE ENGINEERING DRAWING

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Abstract

The contribution deals with the transformation of engineering drawings in a paper form into a 3D computer representation. A 3D computer model can be further processed in CAD/CAM system, it can be modified, archived, and a technical drawing can be then generated from it as well. The transformation process from paper form to the data one is a complex and difficult one, particularly owing to the different types of drawings, forms of displayed objects and encountered errors and deviations from technical standards. The algorithm for 3D model generating from an orthogonal vector input representing a simplified technical drawing of the rotational part is described in this contribution. The algorithm was experimentally implemented as ObjectARX application in the AutoCAD system and the test sample as the representation of the rotational part was used for verificaton.

Key words

*3D Model, AutoCAD, ObjectARX, rotational part, reconstruction, engineering drawing*

Introduction

There are several forms of archiving and exchanging the information on products: a classic paper engineering drawing, an electronic raster and vector drawing, and a 3D model. Processing in the direction of a 3D model - paper drawing is a commonly used procedure in modern CAD/CAM systems.

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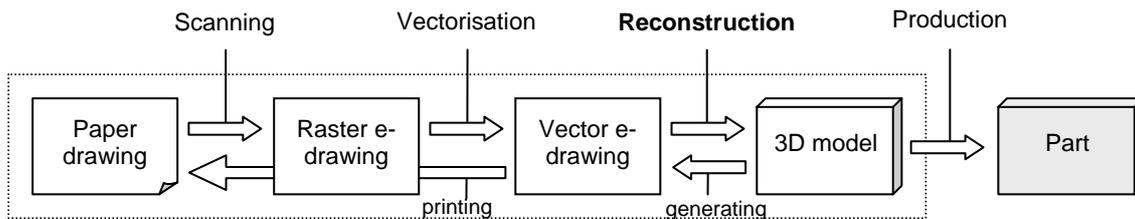
Fig. 1 *Forms of the part representation and transformation drawing-model, and vice versa*

The aim of this article is to introduce an algorithm for a 3D model generating for rotational parts from the vector record of its orthogonal projections. The result of the processing is a solid model described by the CSG representation.

The solution procedure and algorithm

The solution procedure that deals with the 3D model reconstruction of the rotational part from 2D vector drawing was divided into the following steps:
1. Determination of input conditions and restrictive criteria.
2. Selection of an implementation form of the algorithm for verification of a proposed solution.
3. Loading input data from the vector e-drawing of the part.
4. Processing each view.
5. Building a 3D model.
6. Visualization of the reconstructed 3D model.

When choosing the input and output format of the vector record, several options were compared:
- publicly available standard formats (DXF, STEP, IGES),
- proprietary formats of selected CAD/CAM systems (there is a problem with their exact specification),
- use of format and API host CAD or CAD/CAM system.

API allows using the services of the system for prosessing input vector data or for creating 3D objects as well. Another advantage is that we can work with its native file format, possibly with some standard format for product data exchange and do not need to be addressed by implementing the file inputs and outputs. This approach with appropriate application of the proposal can create input/output modules into several CAD/CAM systems and the whole process of the processing vector data up to the reconstruction of the 3D model can be carried out in a common module. Alternatively, the module can be then supplemented with processing of input/output interface for reading and recording the standard formats.

Autodesk AutoCAD was selected from several CAD and CAD/CAM systems for this phase of the project implementation. The API ObjectARX and integrated development environment Visual C ++ were used for implementation.

The algorithm presented in this paper can handle e-drawings that meet the following conditions and limitations.

The drawing of the part can contain three primary orthogonal views – front, side and top. All views must be placed in one layer where no other drawing elements, such as dimensions, separate sections and cross-sections, hatching, text information etc., occur. The following types of lines are accepted:

- bold continuous – for visible edges
- thin dashed (short dashes) - for hidden edges
- thin dot-and-dash - for axis.

These elements must be placed in the first layer of the drawing.

Edges and axis of the part displayed in orthogonal projections may comprise only the elements of the type of line segment, circle and circular arc. Geometric shapes that can be divided into the elements above are replaced automatically after data reading from a vector drawing. Dimensioning was excluded from the processing so far. However, it is not possible to transform the drawing to the 3D model automatically without information from them; therefore, they will need to be considered in the subsequent stages of the processing. All dimensions are processed as they were drawn on the drawing, namely 1:1. Three primary orthogonal projections are automatically recognized. If the drawing contains only a front view, the part is created by operation of profile rotation around the main axis. If there is more than one view in the drawing, there is a high probability, that it is not possible to reconstruct the rotational part by using only profile rotation, as it contains either the elements axially and potentially symmetrically distributed around the perimeter (e.g. coaxial holes, grooves, etc.), or the ones located radially around the perimeter (e.g. radial holes, cuts, grooves, etc.).

The proposed algorithm for a 3D model generating by using reconstruction from 2D vector drawing was divided into the following steps:

- Input of vector data
- Line segmentation
- Recognition of line groups and views
- Front view processing
- Identifying of the major axis and other axises of rotation
- Recognition of distance circles
- Detection of the contour
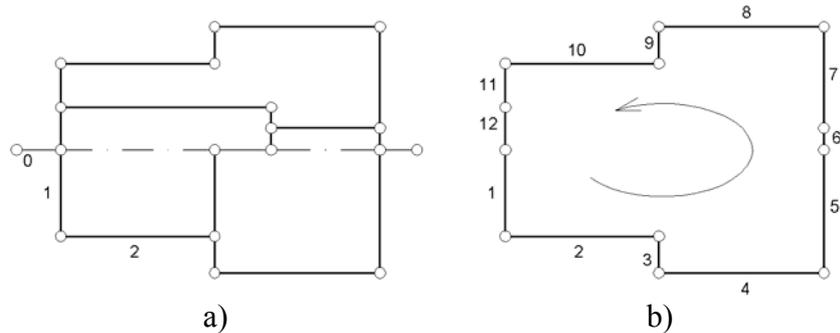- Identification of internal edges
- Processing of additional views.

Recognition of distance circles
Besides the axis consisting of abscissa-segments, also the distance circles or their parts can be in the drawing, so in our case, there are dot-and-dash circular arcs. These sequences of arcs are detected in the same way as abscissa-segments of straight axis.

Detection of the contour
The outer edge contour is detected by the smallest angle method, because only lines with the smallest angle towards the current segment are included in the boundary area (Fig. 3).
This way of projection lines scanning leads to the acquisition of area borders represented as an oriented graph, where the internal surface area is located on the left from the direction of the border traversing.

Fig. 2 *Outer contour detection: a) the source b) the result*

Identification of internal edges

All lines which are not a constituent of the contour are scanned by using the similar manner as the search of groups of lines is running throughout the whole drawing. The lines forming individual groups of edges inside are called islands. These inner islands, separately from each half of the projection are analyzed in order to find how they were created.

Algorithm distinguishes the following types of inner islands:

- A - Hole through in the axis of rotation
- B – Blind hole in the axis of rotation
- C – Side taking-out in the edge of the part away from the axis
- D – Side taking-out of the another part
- E – Line through away from the axis of rotation
- F – Hole through away from the axis of rotation
- G – Inner island in the axis of rotation
- H – Inner closed island away from the axis of rotation
- I – Inner island connected to another line that is different from perpendicular contour line
- J - Perpendicular abscisses associated with the contour and the axis
- K - Other types of internal lines.
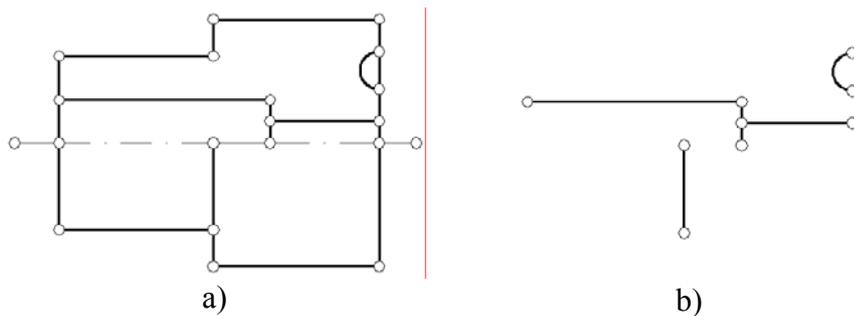
Fig. 3 *Inner edges detection: a) the source b) the result*

Each island is categorized and then compared with the lines of islands in the other half of the projection and in the other projections. Thus, their inclusion was confirmed, or if is necessary, it can be adjusted and made more accurate. Elements that were not successfully detected were not used in the reconstructed 3D model.

The elements A, B, C and D are subsequently processed. These elements must have their projection in the direction of the main axis of rotation in the form of one or more concentric circles centered on the central axis.

The islands, successfully detected as parts created by rotation around the main axis of rotation are supplemented with the missing segments that completed the contour of enclosed area. The axis line and the line of the outer edge are used as the missing segments. Finally, the outer contour of these internal areas is detected.

The interior areas acquired this way can be used as a template to create a 3D model by profile rotation method. Created solids and rings with the respective cross-section are successively taken away from the main solid made by rotation of the outer profile of the part.

Processing of additional views

Side elevation and top view are processed only as a supplement to the front one. They serve mainly as a source of decision-making elements in assessing the elements identified in front elevation. Besides, they provide additional information on the dimensions of structural elements and their location on the perimeter, respectively their distribution along the perimeter of the rotary solid.

CSG representation

The part is composed of the objects created in the previous steps, using the Boolean volume operations. The main solid is made up by the operation of rotation of the outer half-contour of the part around the main axis of rotation. The volumes resulting from the processing of internal edges are subsequently subtracted from it. These units are placed into a binary representation of the CSG tree.

This processing is based on a postorder method for tree processing [1] [2]. It starts in the lowest left arm of the whole tree. Coming back to the root of the tree all right nodes and their possible nodes on the left side is subsequently gone through. The part is completely reconstructed after reaching the root node.
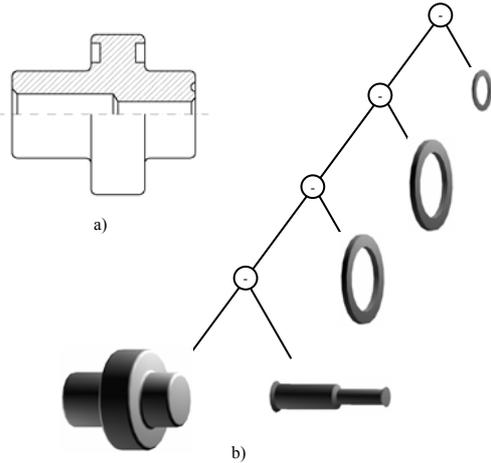
Fig. 4 *CSG part representation: a) the original projection b) CSG tree*

Visualisation of a 3D model

Visualization of a 3D model is implemented using the appropriate graphics API from AutoCAD. Module intermediated communication between this graphic system and the performing module will get a command to draw the object, along with the CSG tree structure entirely describing the complete 3D model delivered to. Then the actual graphics output is executed by processing the CSG tree and the successive building of the resulted model of the part using means of the graphics system.
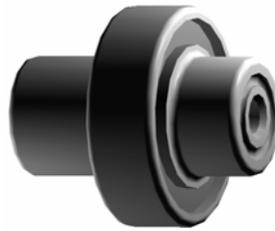
Fig. 5 *Visualization of the part*

Possibilities of a future development

The proposed methods and generated application will be considered as a pilot project, especially the implementation of processing various types of construction elements. Other development possibilities of automation of 3D model reconstruction can be outlined as follows:

- To process dimensions. This is one of the most important elements that will have to be resolved. If there are less than two or three projections, we are not able to identify and reconstruct some construction elements correctly. This concerns mainly the cylindrical elements whose projection is identical with the prism projection.
- To process sections and cross-sections, which do not occupy the position of the primary view. This is the question of the sections location, which are marked with the cutting plane (eg. A-A) and their detection in the drawing.
- To automatically verify the successful reconstruction of 3D model by generating the projections and compare them with the original vector record.
- To design and implement I/O modules for some other CAD/CAM systems, such as e.g. Inventor, SolidWorks, ProEngineer.
- To design and implement I/O modules for the separate processing of DXF, STEP and IGES standard file formats.

Conclusion

The solved task is very complex, even after the significant limitation of elements of engineering drawing that enter the processing are taken into account. Just about the class of rotational parts, which the submitted paper is imed at, involves a number of shape elements that should be taken away from the basic solid. At the same time, each additional design

element bringing about the rise in asymmetries increases the difficulty of 3D reconstruction of the object.

*The contribution deals with a partial task solved within the frame of the **VEGA** project **1/0282/08 by the title "3D model generation from the orthogonal views of the engineering part drawing for using in CAD and visualization".***

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