Title:
An Approach for Increasing Convertible Sketches to 3D Models in Feature Extraction Method

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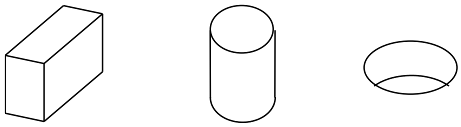
Introduction:
Presently solid modelers have become popular tools in computer-aided design/manufacturing (CAD/CAM) systems. However, for designers, primary ideas of creative objects would be usually drawn with sketches as line drawings because it is time consuming and troublesome to make solid models from the ideas directly. Although several 3D sketching systems have been developed, e.g. [1-2], each of them seems a kind of solid modelers. If there is some system that can automatically convert sketches into 3D models as solid models, it would become an effective tool for considering the ideas. Although many methods have been proposed for the reconstruction of sketches of objects into 3D models, e.g. [4], the objects were limited strictly. Especially curved objects have been difficult for the reconstruction, e.g. [3]. For this issue, we have been developing a method, e.g. [6-7] In the method, firstly several sketch features each of which is a primitive sketch of an object were defined. Fig. 1 shows three examples of them. When a sketch was input to the method, some sketch feature was detected and extracted repeatedly until all lines of the sketch were disappeared. Therefore, a 3D model can be obtained by assembling all extracted 3D sketch features. However, in [7], there has been an important issue that only cylinders and round holes could be handled as in curved objects. In this paper, we propose an approach for increasing convertible sketches to 3D models in our feature extraction method mentioned above. For this approach, firstly we search many sketches from the textbooks of mechanical drawings. Then we classify these sketches by using operations of solid modelers such as “extrude”. Finally, a superior method more than our previous method is indicated in detail.



(a) (b) (c)

Fig. 1: Three sketch features: (a) Cuboid, (b) Cylinder, and (c) Round Hole.

Main Idea:
In the textbooks of mechanical drawings, firstly orthographic views that are two-dimensional (2D) drawings are usually explained. Actually, most of orthographic views of mechanical objects consist of horizontal and vertical straight-line segments, circles and arcs because each mechanical part is often

made from machining centers. Therefore, the sketches of mechanical objects tend to contain parallelograms, ellipses and elliptical arcs. In our previous method, Fig. 1 was applied but there are much more sketch features such as in Fig. 2 derived from the textbooks. If each of them is defined as a class, a great many classes will be defined and it will be difficult to implement and handle them. On the other hand, they have a common property that their shapes can be made with “extrude” operation of solid modelers. Therefore, Fig. 2(a) and Fig. 2(b) can be summarized as the extrusion of elliptical surfaces. Fig. 2(c), Fig. 2(d) and Fig. 2(e) can be summarized as the extrusion of triangular surfaces. As a result, it is found the operations of solid modelers would be effective to classify various kinds of sketch features. The existence of such features was also indicated by Plumed et al. [5].

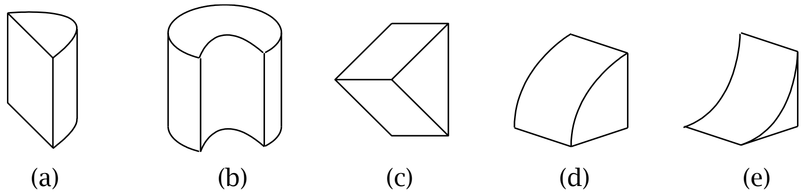


Fig. 2: Sketch features derived from the textbooks of mechanical drawings: (a) Half cylinder, (b) Hollow cylinder, (c) Triangular prism, (d) Convex round corner, and (e) Concave round corner.

Fig. 3(a) shows Example 1 that is a sketch of a holed plate. All points (P_1, P_2, … , P_{11}), straight lines (L_1, L_2, … , L_8) and curved lines (E_1, E_2, … , E_5) of Example 1 are numbered in Fig. 3(b). To reconstruct a 3D model from Example 1, they are classified as follows. Here, each class consists of properties. For example, “Class Point” consists of two properties. Although there are more properties in the classes, it is omitted for clear explanation of our approach in this paper. These classes would be more generalized than our previous method.

Class Point: 1) Number, 2) Position;
Class Straight Line: 1) Number, 2) Two endpoints, 3) Additional line?;
Class Curved Line: 1) Number, 2) Two endpoints or center point, 3) Ellipse?;
Class Relationship between Two Lines:
1) Number, 2) Two lines, 3) Contact?, 4) Parallel?, 5) Same shape? 6) Two T-junction points, 7) Additional lines?;

The representative instances of above classes in Example 1 are as follows.
Point:
1) P1, 2) (20, 50);
Straight Line:
1) L1, 2) P1, P2 3) no;   1) L7, 2) P3, P5, 3) yes;
Curved Line:
1) E1, 2) P1, P8, 3) no;   1) E2, 2) na, 3) yes;
Relationship between Two Lines: (Numbers are omitted.)
2) L1, L2, 3) yes, 4) no, 5) yes, 6) na 7) no;   2) L7, L8, 3) no, 4) yes, 5) yes, 6) na 7) yes;
2) E2, E3, 3) yes, 4) no, 5) no, 6) P9, P10 7) no;   2) E4, E5, 3) no, 4) yes, 5) yes, 6) na, 7) no;

In our previous method, additional lines were drawn at W-junctions and L-junctions of straight lines in an input sketch. In the same way, when Example 1 is input to our new method proposed in this paper, if there are two same curved lines and they are placed in parallel, two additional straight lines can be drawn between two tangent points of them like a making of a curved parallelogram. Therefore, L_7 and L_8 can be drawn as in Fig. 3(b). The properties of L_7 is already indicated above. These additional lines enable to detect many curved sketch features. When the above classes are applied, the following surface classes and their instances (S_1, S_2, .. , S_5) as in Fig. 4(a) can be made. Here, S_2 contains an elliptical arc because it expresses not only surface(s) but also a sketch of a round hole.

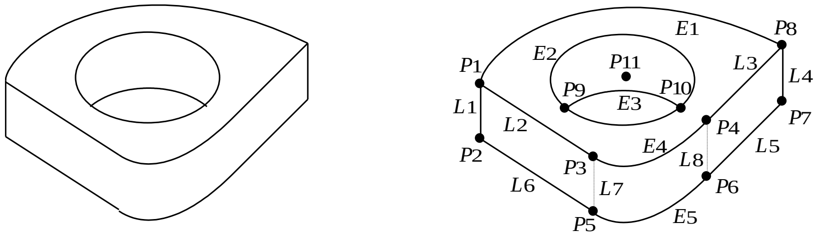


Fig. 3: Example 1: (a) Example 1 and (b) Points, straight lines and curved lines in Example 1.

Class Parallelogram: 1) Number, 2) Four straight lines, 3) Four contact points;
Class Curved Parallelogram:
1) Number, 2) Two parallel straight lines, 3) Two parallel curved lines, 4) Four contact points;
Class Complex surface: 1) Number, 2) Contour lines, 3) Contact points of 2);
Class Relationship between Two surfaces: 1) Number, 2) Two surfaces, 3) Sharing line, 4) Inclusion relation?;

The representative instances of above classes.
Parallelogram:
1)S3, 2)L1, L2, L6, L7, 3)P1, P2, P3, P5;
Curved Parallelogram: 1) S4, 2) L7, L8, 3) E4, E5, 4) P3, P4, P5, P6;
Complex surface: 1) S1, 2) L2, E1, L3, E4, 3) P1, P3, P4, P8;
Class Relationship between Two surfaces:
2) S1, S2, 3) na, 4) yes; 2) S1, S3, 3) L2, 4) no; 2) S2, S3, 3) na, 4) no;

When the above classes are applied, the following two classes of sketch features and their instances can be made. When two 3D sketch features are made from these two instances and they are assembled, a 3D model of Example 1 can be obtained as in Fig. 4(b).

Class Round Hole:
1) Number, 2) Ellipse, 3) Elliptical arc, 4) Two T-junction points;
Class Extrusion of Complex surface:
1) Number, 2) Complex surface, 3) Contact (curved) parallelograms, 4) Sharing lines between 2) and 3), 5) Sharing lines in 3);

The instances of above classes.
Round Hole: 2) E2, 3) E3, 4) P9, P10;
Extrusion of Complex surface: 2) S1, 3) S3, S4, S5, 4) L2, E4, L3 5) L7, L8;

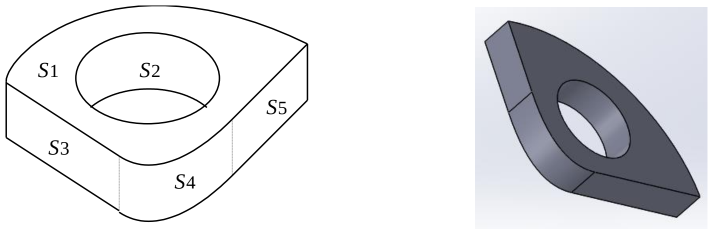


Fig. 4: Surfaces and a 3D model of Example 1: (a) Surfaces of Example 1 and (b) An overview of a 3D model in Example 1.

Fig. 5 shows two effective examples for the method mentioned above. Fig. 5(a) shows Example 2 that is a sketch of a gear. Fig. 5(b) shows an overview of a 3D model in Example 2. Fig. 5(c) shows Example 3 that is a sketch of a spanner. Fig. 5(d) shows an overview of a 3D model in Example 3.

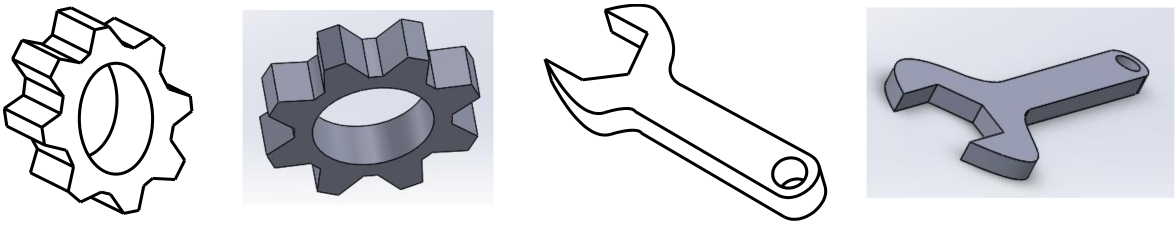


Fig. 5: Examples: (a) Example 2, (b) An overview of a 3D model in Example 2, (c) Example 3, (b) An overview of a 3D model in Example 3.

Conclusions:

Generally, it is difficult to automatically reconstruct 3D models from sketches because they are usually drawn ambiguous and contain many hidden lines especially in curved objects. Therefore, it has been an important issue to increase convertible sketches that can be handled by our method. In this paper, a new approach to increase them is proposed, and a new method is indicated. This approach is based on the shapes of simple mechanical parts described in the textbooks of mechanical drawings and the operations of solid modelers. As a result, various kinds of geometric classes can be defined and we can indicate the conversions of three sketches that illustrate complex mechanical parts to 3D models in this paper. To handle more complex sketches of mechanical objects, more classification of complex sketch features and how to detect them from input sketches would become the issues.

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