Title:
Feature Extraction from Sketches of Objects

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Introduction:
Generally, line drawings as sketches of 3D objects are widely used in designing products. The automatic reconstruction of the solid model of an object from a sketch has been very crucial research area since decades. Most of proposed methods have applied the technique of line labelling. However, generally, this technique could be difficult for the reconstruction when input sketches include many curves. Main references related to this paper are as follows. Company et al. [3] presented a survey about the reconstruction. Huffman-Clowes labelling was established for polyhedrons, e.g. [2],[4]. Cao et al. [1] inferred the hidden structure of a polyhedron drawn in a sketch. Also, Malik [5] handled curved objects. Although [5] indicated how to label curves in sketches, how to reconstruct solid models from sketches of curved objects was not indicated. On the other hand, Robert [6] attempted to extract polyhedral primitives such as cubes from the sketches of polyhedrons to obtain 3D models. Also, Wang [7] attempted to extract cylindrical primitives from sketches. However, their methods did not handle features such as holes and various kinds of fillets that are important shapes of products. In this paper, a method for the reconstruction by extracting features such as cubes, holes and fillets from sketches repeatedly is proposed. Basically, we assume that a child firstly learns how to sketch primitives and features such as cubes, cylinders, holes, etc. of objects. In this method, primitives are included into features. Then he/she could draw sketches of objects whose shapes are more complex by applying sketches of features. We assume that the recognition processes of sketches could be considered as the reverse processes to draw sketches in a human. This method applies this recognition process.

Main Idea:
In our method, a sketch of a 3D object is viewed from a general viewpoint, and it is perfectly drawn in a 2D CAD. The hidden lines of the sketch are not drawn. Each input sketch consists of ellipses, arcs and straight lines. Straight lines are divided at their intersections but curves are not divided. A point is defined as an endpoint of a line. A region is defined as a closed loop of lines. They correspond to an edge, a vertex, and a face in solid models. At present, seven types of sketches of features are defined as follows.

- Cube: Three parallelograms are connecting at their three straight lines and they form a Y junction.
- Cylinder: Two parallel lines connect to an ellipse and an arc respectively and tangentially.
- Round hole: An arc is placed inside of an ellipse and they are connected to each other. The arc is a part of the ellipse placed inside of some region.
- Rectangular hole: Three lines forming a Y junction are inside of a parallelogram. One of them connects to a point of the parallelogram and the others form a part of the parallelogram and connect to that.

- General fillet: Two arcs are placed like a part of the sketch of a cylinder. Each pair of parallel lines connects to the arcs individually and tangentially.
- Partial fillet: Two arcs are placed like a part of the sketch of a cylinder. Three lines connect to the end points of the arcs individually and tangentially. One line connects to both of the arcs tangentially.
- Hidden fillet: Two straight lines connect to an arc tangentially.

When a sketch is input to this method, the following processes are executed and a solid model could be obtained.

(1) Draw additional lines: Each of two lines forming an L junction is extended to the nearest solid line. Each of two lines in both sides of a W junction is extended to the nearest solid line. The extended parts of the lines are additional lines and they are drawn as dashed lines.

(2) Search a feature: Holes, general fillets, partial fillets, hidden fillets, cylinders and cubes are searched in this order.

(3) Recognize and extract a feature: When a feature is recognized, its hidden lines are drawn as additional lines. When a hole or a cylinder is extracted, all of its lines are removed. When a cube is extracted, all of its solid lines are removed. A fillet is changed into a cubic corner. After this process, if there are no lines, go to (6).

(4) Restore isolated additional lines and then remove additional lines forming T junctions: After a feature is extracted, additional isolated lines each of which does not form any regions can appear. Since they and additional lines forming T junctions are tend to prevent making contact faces between two 3D features, they are removed.

(5) Recognize contact faces and then restore isolated lines: Contact faces are used in combining 3D features. Each of isolated lines is restored to make some region. In this step, if some line exists in the sketch, go to Step 2.

(6) Make 3D features: All of extracted 3D features are combined except hidden fillets. The way to combine them is the same way as solid modelers.

Fig. 1(a) illustrates Example 1 imaging a palette. In our method, firstly three round holes are extracted as in Fig. 1(b). In Fig. 1(c), two general fillets, two partial fillets and four hidden fillets are recognized and bold. When they are extracted, a rectangular hole can be recognized as in Fig. 1(d). In Fig. 1(e), this hole is extracted and then a cube is recognized finally. When all of extracted features except hidden fillets are combined, a solid model can be generated. The hidden fillets are recognized in the solid model as in Fig. 1(f), and when they are combined, the solution can be obtained as in Fig. 1(g). Fig. 2(a) illustrates Example 2 that is referred from a figure of [1]. In this figure, a fillet is newly added. In the method, firstly a hidden fillet is extracted and then a cube is recognized as in Fig. 2(b). When the cube is extracted, another cube is recognized as in Fig. 2(c). When the cube is extracted, the third cube is recognized as in Fig. 2(d). After all of extracted cubes are combined, the hidden fillet can be added. As the result, the solution of Example 2 is obtained as in Fig. 2(e).

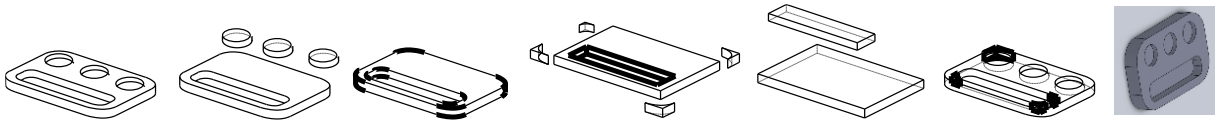

Fig. 1: Example 1: (a) Example 1, (b) Extraction of round holes, (c) Recognition of fillets, (d) Extraction of the fillets and recognition of a rectangular hole, (e) Extraction of the hole and recognition of a cube, (f) Addition of 3D hidden fillets, and (g) Solution.

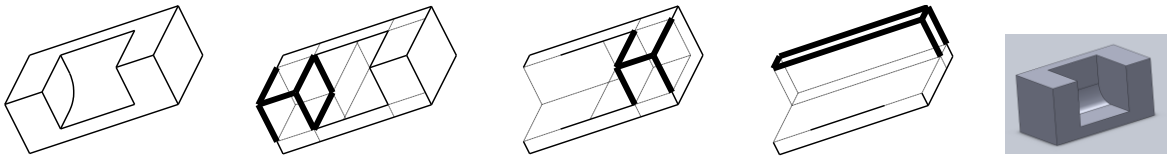

Fig. 2: Example 2: (a) Example 2, (b) Extraction of a hidden fillet and recognition of a cube, (c) Recognition of the second cube, (d) Recognition of the third cube, and (e) Solution.

Conclusions:

In this paper, we define seven types of sketches of features. When a sketch of an object is input to our method, each of the features are recognized and extracted repeatedly, and all of extracted features could generate the solid model of the object. Two examples that are difficult for conventional methods are shown. More definitions of new features would be applied to more complex shapes of objects.

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