Title:
Introduction of Accessorial Sketch Features for the Automatic Conversion of Mechanical Sketches into 3D Models

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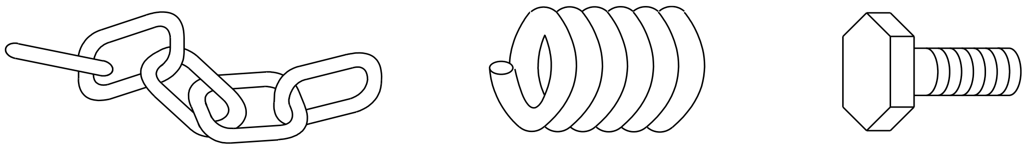
Keywords:
Accessorial Sketch Feature, Sketch, Automatic Conversion, 3D Model, SFBCM

DOI: 10.14733/cadconfP.2021.410-414

Introduction.
Sketches in the form of line drawings are commonly observed in magazines, books, manuals, etc. Sketches are also important for designers, especially mechanical designers, when they invent new ideas of products and their parts. The automatic conversion of sketches into 3D models will be advantageous for several applications. For example, it is expected that robots will be able to understand sketches by their converted 3D models in the future. In the last fifty years, numerous methods to automatically convert sketches into 3D models have been considered and developed. However, no real system for the conversion has been developed till now. We have been developing methods for the conversion of sketches into 3D models for approximately eight years. Consequently, we proposed a method as SFBCM (Sketch Feature-Based Conversion Method) to achieve this conversion [10-11]. In SFBCM, many issues have been still remained for developing the practical conversion system. In this paper, we attempt to handle chains, springs and screws in SFBCM. Generally, they are important machine elements, and often used in mechanical products and their parts. However, their sketches are tend to become symbolic because their shapes are complex. Fig. 1 shows examples of the sketches. Fig. 1(a) shows a sketch of chain. Fig. 1(b) shows a sketch of spring. Fig. 1(c) shows a sketch of screw with a hexagon head. In this paper, Accessorial Sketch Features (ACSFs) are introduced to SFBCM for handling sketches of chains, springs and screws. Generally, the shapes of them contain many kinds of repetitive features, so we define ACSFs from them.



(a) (b) (c)

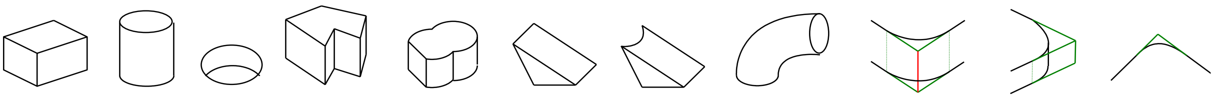
Fig. 1: Sketches of chain, spring and screw.

Proceedings of CAD'22, Beijing, China, July 11-13, 2022, 410-414

<u>Main Idea</u>.

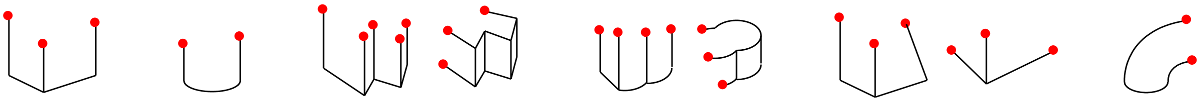
Overview of SFBCM

Fig. 2 shows Sketch Features (SFs) and Fig. 3 shows Abstract Sketch Features (ASFs) in SFBCM [10].



(a) (b) (c) (d) (e) (f) (g) (h) (i) (j) (k)

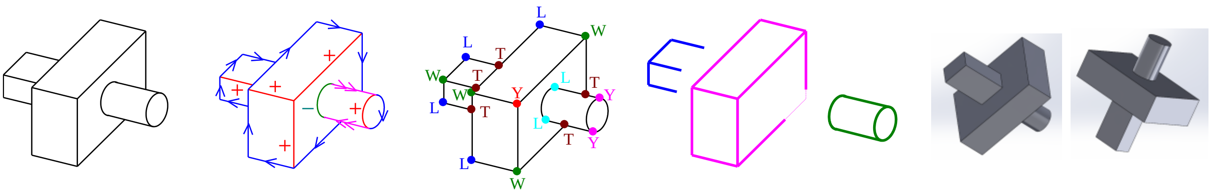
Fig. 2: Eleven SFs: (a) Cuboid, (b) Cylinder, (c) Round Hole, (d) Polygonal extrusion, (e) Multi-extrusion, (f) Rib, (g) Round rib, (h) Pipe, (i) Front fillet, (j) Side fillet, and (k) Hidden fillet.



(a) (b) (c) (d) (e) (f)

Fig. 3: Six types of ASFs: (a) Partial cuboid, (b) Partial cylinder, (c) Two types of partial polygonal extrusion, (d) Two types of partial multi-extrusion, (e) Two types of partial rib, and (f) Partial pipe.

In these figures, each ASF is made as a part of an SF, and each red point of ASF indicates a *T*-junction (mentioned below) in sketches. In our SFBCM, when a sketch is input, an SF or ASF is detected and extracted repeatedly until there are no lines in the sketch. Then each extracted SF or ASF is changed into a 3D model as a 3D feature, and a 3D model of the sketch can be obtained by combining 3D features in accordance with the sketch. Fig. 4(a) shows Example 1 that is a sketch of a mechanical part drawn correctly in a 2D CAD. In Fig. 4(b), each line segment of Example 1 is labeled "+", "-", or arrow(s). This technique was called "line labeling" that is a basic technique for the conversion since the beginning of this research [2],[6],[7]. In the technique, after line labeling, each vertex can be classified into several types of junctions by using junction dictionaries. For example, a *Y*-junction is consisted of three lines forming the font of "Y", and a *T*-junction is consisted of three lines forming the font of "T" as shown in Fig. 4(c). In SFBCM, these processes are the preprocessing for detecting SFs and ASFs. For example, a cuboid sketch shown in Fig. 2(a) can be defined that three parallelograms are sharing three straight line segments forming a *Y*-junction. Fig. 4(d) shows detected two SFs and an ASF separately. This detection is executed as follows. First, a cylinder sketch (green) as shown in Fig. 2(b) can be detected and extracted. Second, a cuboid sketch (pink) as shown in Fig. 2(a) can be detected by extending two lines. Third, a partial cuboid sketch (blue) as shown in Fig. 3(a) can be detected, and also extracted as a 3D cuboid by predicting its length. Consequently, a solution of Example 1 can be obtained as shown in Fig. 4(e). The detailed explanation of the detection and extraction in this example can be referred in [10].



(a) (b) (c) (d) (e)

Fig. 4: Example 1: (a) Example 1, (b) Line labeling, (c) Junctions, (d) Separated Two SFs and an ASF, and (e) Two overviews of solution.

Proceedings of CAD'22, Beijing, China, July 11-13, 2022, 410-414

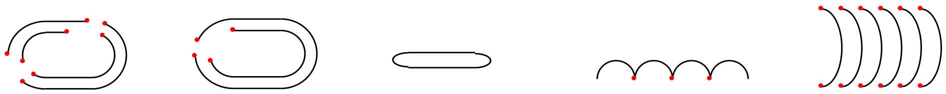
Related Works

The related works of this paper are described as follows. Except line labeling technique, "cubic corner" proposed in [8],[12] was effective to make 3D models from sketches. In this technique, when a sketch is drawn in *x*-*y* coordinate system, the *z* value of each vertex can be calculated with an equation exactly. However, the equation often does not be fit to human perception. So, we have developed SFBCM to simplify the implementation of the conversion using human perception [11]. In addition, ASFs for predicting hidden shapes in sketches has been proposed [10]. Moreover, ACSFs are introduced in this paper for handling sketches in Fig. 1.

In recent years, Company et al. [3] investigated techniques to detect junctions from hand-drawn sketches using human perception. Interactive or semiautomatic systems for conversion were previously proposed although they are no fully automatic systems for conversion, e.g. [1]. Further, 3D sketching systems were also developed [4-5] although they would be no more than new types of solid modelers. Neural network techniques especially deep learning techniques have also been actively used for conversion, e.g. [9]. The techniques would be effective for simpler shapes such as polygons, and known objects such as tables, chairs, cups because it is based on image processing essentially. However, it will be difficult to convert sketches of mechanical objects especially creative ones into 3D models precisely and geometrically.

Definition of ACSFs

In the sketches of chains, springs and screws, when their profiles are observed, repetitive features can be found. We call them ACSFs. Fig. 5 shows each ACSF detected from Fig. 1.



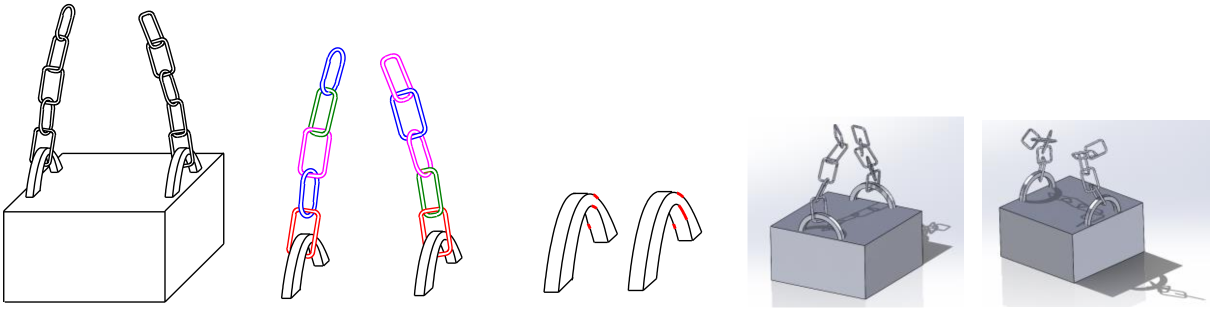
(a) (b) (c) (d) (e)

Fig. 5: Five ACSFs: (a) Double-lacked ring, (b) Single-lacked ring, (c) Stick-typed ring, (d) Continuous arcs, and (e) Wrinkled arcs.

For example, the definition of double-lacked ring is that there are four polylines of which terminals are *T*-junctions (red), and when these *T*-junctions are extended, a toroidal shape like a ring can be formed. Also, some double-lacked ring and/or single-lacked ring is connected to the ring at the *T*-junctions. The definition of continuous arcs is that almost same sized three or more arcs are connected straightly and all their contact points are *T*-junctions, and these points form a dotted straight line. The definition of wrinkled arcs is that same sized three or more arcs are placed straightly at equal intervals like a wrinkle, and the terminals of the arcs form a pair of dotted parallel lines. From these ACSFs, SF of chain, ASF of partial chain, ASF of partial spring and ASF of partial screw can be defined and added to Fig. 2 and Fig. 3. The definition of chain SF is that two or more ACSFs of rings are connecting to each other. All 3D models of the rings are the same to each other. ASF of partial chain is defined as cut SF of chain. The definition of ASF of partial spring is that two ACSFs as continuous arcs and an ACSF as wrinkled arcs are contacted tangentially at the both sides of the wrinkled arcs. The definition of ASF of partial screw is that an ACSF as winkled arcs is contacted to two parallel lines tangentially at its both sides. It is important thing that SF of ring cannot be defined because it is difficult to see the sketch of toroidal shape as a ring for people. They might see it as a tapered plate and so on.

Example

Fig. 6(a) shows Example 2 that is a sketch of a box pulling with two chains. When Example 2 is input to our new method that is SFBCM with ACSFs, first, all lines are divided at their intersections, and all junctions are detected. Here, in previous SFBCM, although additional lines as dotted lines are drawn from *T*-, *W*-, and *L*-junctions by extending their straight lines or curves to the nearest solid lines of the input sketch, it is complex to draw them in Example 2. Therefore, the second step of our new method becomes detecting ACSF(s), its ASF(s) and/or SF(s). The detailed explanation of additional lines can be referred in [11]. Consequently, ten ACSFs of rings and also two ASFs of partial chains can be detected as shown in Fig. 6(b). In this figure, each ACSF of ring is colored red, blue, green or pink. Although the shapes of two red rings are occluded partially with two hooks, the occluded parts of the rings can be restored with adding additional lines in conventional SFBCM. Therefore, two SFs of chains can be detected and extracted. After the chains are extracted, two SFs of polygonal extrusion as two hooks can be detected and extracted by adding additional lines (red) as shown in Fig. 6(c). Finally, an SF of cuboid can be detected and extracted. So, the solution of Example 2 can be obtained as shown in Fig. 6(d).



(a) (b) (c) (d)

Fig. 6: Example 2: (a) Example 2, (b) Detection of two partial chains, (c) Detection of two polygonal extrusions as hooks, (d) Two overviews of the solution.

Obviously, there are many issues in our new method when it is applied to more complex sketches including chains, springs and/or screws. Therefore, we indicate the possibility to handle sketches including them by this method. Although ASF of partial ring exists, SF of ring cannot not exist because the sketches of rings seem to be tapered plates or holes for people. In the same way, the definition of ACSFs and ASFs without SFs might be effective for the mechanical parts of which shape contains many cured faces. This application becomes an issue. Also, the conversion of chain, spring and screw sketches to 3D models correctly and to apply the other types of rings, springs and screws to this method becomes an issue.

Conclusion.

In this paper, we introduce Accessorial Sketch Features (ACSFs) to our SFBCM for handling sketches of chains, springs and screws in sketches of mechanical objects. The shapes of them contain many kinds of repetitive features so we can define ACSFs from them. The results of this paper can be summarized as follows.

1. Five ACSFs, three ASFs and one SF can be defined in the sketches of chains, springs and screws. Consequently, our new method that is SFBCM with ACSFs can be developed for handling them.
2. An example is indicated to explain the algorithm and the effectiveness of ACSFs of this method.
3. Several issues are discussed for the future works in this method. For example, the definition of ACSFs and ASFs without SFs might be effective for the mechanical parts of which shape contains many cured faces.

References:

[1] Bobenrieth, C.; Cordier, F.; Habibi, A.; Seo, H.: Descriptive: Interactive 3D Shape Modeling from A Single Descriptive Sketch, Computer-Aided Design, 128(102904), 2020, http://doi.org/10.1016/j.cad.2020.102904

[2] Clowes, M.B.: On seeing things, Artificial Intelligence, 2(1), 1971, 79–116, https://doi.org/10.1016/0004-3702(71)90005-1
[3] Company, P.; Plumed, R.; Varley, P. A. C.; Camba, J. D.: Algorithmic Perception of Vertices in Sketched Drawings of Polyhedral Shapes, ACM Transactions on Applied Perception, 16(3), 2019, Article 18, https://doi.org/10.1145/3345507
[4] http://help.solidworks.com/2021/English/SolidWorks/sldworks/c_3d_sketching_top.htm
[5] https://www.sketchup.com/
[6] Huffman, D. A.: Impossible objects as nonsense sentences, Machine Intelligence 6, 1971, 295–323.
[7] Malik, J.: Interpreting line drawings of curved objects, International Journal of Computer Vision, 1, 1987, 73–103. http://dx.doi.org/10.1007/BF00128527
[8] Perkins, D. N.: Cubic Corners, Quarterly Progress Report 89, MIT Research Laboratory of Electronics, 1968, 207–214.
[9] Tahir, R.; Sargano, A.; Habib, Z.: Voxel-Based 3D Object Reconstruction from Single 2D Image Using Variational Autoencoders, Mathematics, 9(18), 2288, 2021, https://doi.org/10.3390/math9182288
[10] Tanaka, M.; Asano, T.; Higashino, C.: Abstraction of Sketch Features for Predicting Hidden Shapes of Sketches for The Automatic Conversion into 3D Models, 19(5), 2021, 977-987, https://doi.org/10.14733/cadaps.2022.977-987
[11] Tanaka, M.; Asano, T.; Higashino, C.: Isometric Conversion of Mechanical Sketches into 3D Models, 18(4), 2021, 772-785, https://doi.org/10.14733/cadaps.2021.772-785
[12] Varley, P. A. C.; Martin, R. R.; Suzuki, H.: Frontal geometry from sketches of engineering objects: is line labelling necessary?, Computer-Aided Design, 37(12), 2005, 1285–1307, https://doi.org/10.1016/j.cad.2005.01.002