Title:
Isometric Conversion of Mechanical Sketches into 3D Models

Authors:
Masaji Tanaka, tanaka@mech.ous.ac.jp, Okayama University of Science
Motoki Terano, m_terano@mech.ous.ac.jp, Okayama University of Science
Chiharu Higashino, higashino@aikoku.com, Aikoku Alpha Corporation
Tetsuya Asano, t-asano@aikoku.com, Aikoku Alpha Corporation

Keywords:
Isometric, Sketch, Automatic Conversion, Sketch Feature, 3D Model, Cubic Corner

DOI: 10.14733/cadconfP.2020.391-394

Introduction:
We have been developing a method to automatically convert sketches as line drawings into 3D models. However, the implementation of the method was tended to be ignored because it seemed to be difficult. Therefore, it has been an important issue for the method. Recently when we retrieved various kinds of sketches in mechanical objects, we could find an important cue for the implementation as follows. Suppose that there is a long bar. When a person draws a sketch of it, Fig. 1(a) will be preferred to Fig. 1(b) because he/she must emphasize that the object is long. Therefore, it can be assumed that people prefer more isometric and easier sketches to more precise but difficult sketches. This assumption can be proved in Fig. 2. This figure shows three sketches of a cube. Fig. 2(a) shows a precise sketch that is a copy of a screen in a solid modeler (SolidWorks). Fig. 2(b) shows an isometric sketch. Fig. 2(c) shows a sketch that is not precise but understandable for people. These three sketches can be perceived as the same sketch of a cube by people. We found that this human perception enable easier implementation of the method. In this paper, a new effective approach of the implementation is proposed. This approach is based on the human perception described above.

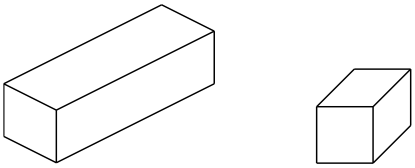

Fig. 1: Two sketches of a long bar: (a) Natural sketch and (b) Another sketch.

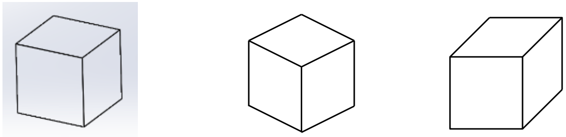

Fig. 2: Three sketches of a cube: (a) Copy from SolidWorks, (b) Isometric sketch, and (c) Another sketch.

Proceedings of CAD'20, Barcelona, Spain, July 6-8, 2020, 391-394
© 2020 CAD Solutions, LLC, http://www.cad-conference.net

Main Idea:
In our method, firstly sketch features are defined. Fig. 3 shows three samples of them. These are a cuboid sketch, a cylinder sketch and a hole sketch respectively. Each sketch feature is a primitive sketch that can recognize and draw by people easily. Also, most of machined mechanical parts consist of these objects. In the method, a complex sketch is divided into the sketch features for the conversion as follows. Fig. 4(a) shows Example 1. In the method, firstly additional lines are drawn from *W*, *L*, *T* junctions. So, an additional line can be drawn as red dotted line as in Fig. 4(b). From this figure, a cylinder sketch can be detected and extracted as a 3D cylinder as in Fig. 4(c). Next, a cuboid sketch can be detected as a 3D cuboid as in Fig. 4(d). More detailed explanation of these processes are indicated in [5-6]. Next, the 3D cylinder and the 3D cuboid can be combined in accordance with Fig. 4(a). As a result, a 3D model of Example 1 can be obtained. However, there are no 3D coordinate systems in Example 1. Therefore, the method was too theoretic. In order to form a 3D coordinate system to a given sketch, we found that Perkins's "cubic corner" [3] was simple and effective.

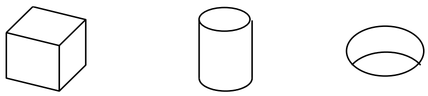

Fig. 3: Three samples of sketch features: (a) Cuboid sketch, (b) Cylinder sketch, and (c) Hole sketch.

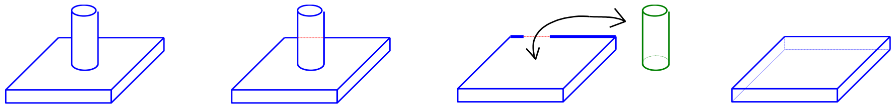

Fig. 4: Example 1: (a) Example 1, (b) Additional line, (c) Extraction of a cylinder, and (d) Detection of a cuboid.

Varley et al. [7] indicate the cubic corner in detail. Also they compared the other methods such as Kanade's "skewed symmetry" [2]. Fig. 5 shows the explanation to make a cubic corner in [7]. In this figure, a *Y*-junction of three lines (*VA*, *VB*, *VC*) is shown in *x*-*y* coordinate system. *E*, *F* and *G* indicate angles *BVC*, *AVC* and *AVB* respectively. If the *Y*-junction is a part of cuboid sketch, the *z* coordinate of *A* (Z_A) can be calculated by the following equation (1).

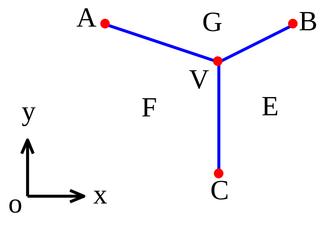

Fig. 5: Cubic corner.

$$|Z_A - Z_V| = l_{VA}/\sqrt{(\tan F \tan G) - 1} \qquad (1)$$

Here, the value of Z_V can be zero. l_{VA} is the length of *VA*. In the same way, Z_B and Z_C can be calculated. It is found that this equation is precise and effective for the conversion of sketches into 3D models. However, there are some problems to use it for the conversion as follows. In Example 1, if the equation

© 2020 CAD Solutions, LLC, http://www.cad-conference.net

is applied, tan(π/2) is appeared. Therefore, the equation cannot be applied to Example 1 although it is easy to draw and recognize it for people. As a result, for the implementation of the method, we apply the human perception that he/she draws sketches as isometric as possible.

In the human perception, it can be assumed that a cylinder stands on a plate vertically in Example 1. This assumption can be proved in Fig. 6 as follows. There are five sketches in this figure. These are copies of a screen in a solid modeler (SolidWorks). Fig. 6(a) shows a sketch of a holed plate. In this figure, the axis of the hole is vertical to the plate. Although Fig. 6(b) is similar to Fig. 6(a), in Fig. 6(b), the axis of the hole is not vertical to the plate such as in Fig. 6(c). In addition, although Fig. 6(d) is similar to Fig. 6(a), the shape of the hole is not a cylinder but a taper such as Fig. 6(e). It can be natural that generally people look at Fig. 6(b) and Fig. 6(c) like Fig. 6(a). This human perception is also effective for the implementation. On the whole, using sketch features in the method are effective for the implementation in the following three points.

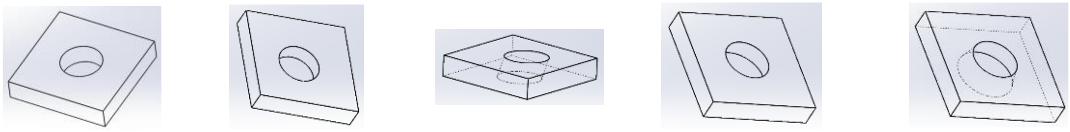

Fig. 6: Sketches of holed plates: (a) Precise sketch, (b) A sketch of a slant holed plate, (c) The other view of (b), (d) A sketch of a taper holed plate, and (d) (c) with hidden lines.

(1) In the method, 3D models as solutions can only be generated from defined sketch features such as cuboids and cylinders. Therefore, it is needless to consider the possibility to exist the other shapes in the solutions. For example, although to draw precise sketches of pyramids was a classic problem such as in Fig. 7, e.g. [4], it is meaningless for the method because defined sketch features are only handled. In this case, the method can handle that after pyramids are defined as a sketch feature.

(2) In the method, correct line labelling is not necessary and it is easy to handle sketches including curved lines if they are defined in some sketch feature. In addition, it is no problem to handle multiple junctions of lines such as K-junctions [7].

(3) In the method, all hidden lines of each sketch feature are clear. Therefore, hidden lines of each sketch can be generated uniquely.

Fig. 7: Two sketches of pyramids: (a) Incorrect sketch and (b) Correct sketch.

Although Eqn. (1) cannot be applied to Example 1 because of its *Y*-junction, in this approach of the implementation, a 3D plate can be obtained from the figure because we can apply a cuboid sketch as a sketch feature. In this case, all lengths of three lines forming the Y-junction can be considered as actual sizes in the method because of the human perception to draw sketches as isometric as he/she can. Fig. 8 shows an application of this consideration. When a sketch of a cuboid is input to our experimental system as in Fig. 8(a), Fig. 8(b) can be obtained as a 3D wireframe model of it easily. In this figure, all corners are cubic corners. This approach can be applied to sketches each of which consists of plural parts. Fig. 9(a) shows Example 2. In the sketch, there is a junction consisting of four lines. The junction is indicated as a red point in Fig. 9(b). In this figure, first a cuboid sketch can be detected as blue lines.

© 2020 CAD Solutions, LLC, http://www.cad-conference.net

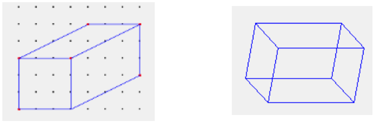

Fig. 8: Conversion of cuboid sketches in our experimental system: (a) A sketch of a cuboid and (b) The 3D model converted from (a).

To extract the cuboid, solid lines of it can be removed except lines that form T-junctions. These T-junction lines can be changed into hidden lines and also blue hidden lines can be changed into solid lines except for an isolated purple line as in Fig. 9(c). This purple line can be removed. The detailed explanation of these processes are indicated in [5-6]. As a result, a green cuboid sketch can be detected as in Fig. 9(d). When the blue 3D cuboid and the green 3D cuboid are combined in accordance with Fig. 9(a), a contradiction is occurred that two solid lines that are shared by the two cuboids cannot be removed such as in Fig. 9(e). Therefore, it is found that Example 2 consists of two parts. As a result, a 3D model of Example 2 can be obtained as in Fig. 9(f).

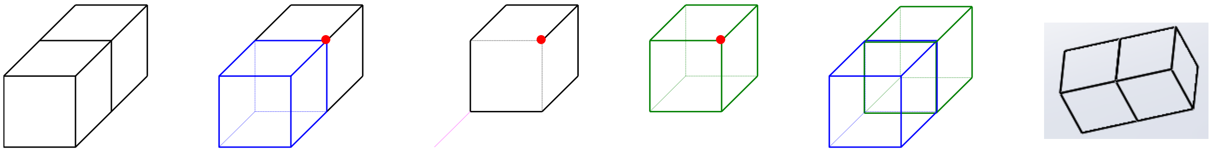

Fig. 9: Example 2: (a) Example 2, (b) A multiple junction and the detection of a cuboid sketch, (c) Extraction of the cuboid, (d) Detection of the other cuboid sketch, (e) The combination of two 3D cuboids, and (f) The 3D model converted from (a).

Conclusion:
In this paper, we proposed a new approach to implement our method. Human perceptions are more important than geometric precision in the approach because generally people would like to draw sketches as isometric as they can for easier understanding to the other people. Also, it is found that sketch features are effective for the approach because each of them corresponds correctly to a 3D model. As a result, simpler implementation approach for the conversion than conventional ways is proposed in this paper. The effectiveness of that can be indicated in many figures in this paper.

References:
[1] Grimstead, I. J.; Martin, R. R.: Creating solid models from single 2D sketches, Proceedings of the third ACM symposium on SMA '95, 1995, 323–337. https://doi.org/10.1145/218013.218082
[2] Kanade, T.: Recovery of the Three-Dimensional Shape of an Object from a Single View, Artificial Intelligence, 17, 1981, 409–460. https://doi.org/10.1016/0004-3702(81)90031-X
[3] Perkins, D. N.: Cubic Corners, Quarterly Progress Report 89, MIT Research Laboratory of Electronics, 1968, 207–214.
[4] Sugihara, K.: Machine Interpretation of Line Drawings, MIT Press, 1986.
[5] Tanaka, M.; Kaneeda, T.: Feature extraction from sketches of objects, Computer-Aided Design & Applications, 12(3), 2014, 300-309. https://doi.org/10.1080/16864360.2014.981459
[6] Tanaka, M.; Terano, M.; Higashino, T.; Asano, T.: A Learning Method for Reconstructing 3D Models from Sketches, Computer-Aided Design & Applications, 16(6), 2019, 1158-1170. https://doi.org/10.14733/cadaps.2019.1158-1170
[7] 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

© 2020 CAD Solutions, LLC, http://www.cad-conference.net