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2007 Invited Workshop On Pen Computing

Abstracts

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2007 Workshop on Pen Computing

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SKETCH INPUT OF 3D MODELS

2007 Workshop on Pen-Centric Computing Research

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1. ABSTRACT:

Our overall goal is to create a 3D solid model automatically from a single 2D natural line drawing. A tool which could quickly interpret line drawings of engineering objects as boundary representation CAD models would be of significant benefit in the process of engineering design. It would enable designers to spend more time on the creative aspects of their job and less on the routine aspects, it would reduce time spent correcting mistakes by allowing instant visualisation, and the simpler "what you draw is what you imagine" interface will be less distracting than an array of menus and icons.

CURRENT RESULTS:

Interpretation of drawings depicting extrusions is straightforward, regardless of the complexity of the extruded face.

Interpretation of natural line drawings depicting normalons (polyhedra in which all edges and face normals are aligned with to one of the three main, mutually orthogonal, axes) depends on the ability of the reconstruction engine to determine what lies around the back of the object - the fact that the object can be deduced to be a normalon is often a useful clue to its structure. Typically, a drawing of about two dozen lines is at the limit of what can be interpreted in the domain of normalons, and takes a second or less.

Interpretation of drawings of general polyhedral objects (non-trihedral non-normalons) is less reliable, since there will always be some doubt about the choice of clues used to construct the object. For example, for non-trihedral drawings, which other apparently-trihedral junctions correspond to non-trihedral vertices? For non-normalons, which three sets of parallel lines depict edges aligned with the three orthogonal axes? Typically, a drawing of about a dozen lines approaches the limit of what can be interpreted in the general case.

Interpretation of curved objects is still more difficult, and in most cases is beyond the state of the art. Our demonstration will show how very simple curved objects with a single plane of mirror symmetry can now be interpreted. This work is based on ideas first suggested in (Takahashi, 2004) and (Varley, Takahashi, Mitani and Suzuki, 2004) but has not been demonstrated before. Again, a drawing of about a dozen lines approaches the limit of what can be interpreted.

METHOD: Our demonstration program comprises four stages:

1. Data entry
2. **Creation of 2½D Frontal Geometry**
3. **Creation of a Topologically-Valid 3D Model**
4. Geometric Beautification of the 3D Model

The first and fourth of these stages are common to several other areas of investigation. In recent years, we have concentrated on stage 2, creation of 2½D Frontal Geometry, and have published several papers on this aspect of the problem, most recently (Varley, Martin and Suzuki, 2005). Summarising these, ideas from the 1970s such as line labelling which are excellent in the limited domain of trihedral objects are less effective, and sometimes impossible to use, for more general polyhedra, and we have sought and found alternatives.

In the next year, we shall concentrate on the third stage, that of creating a topologically-valid 3D model by adding the "hidden" topology, that part of the object which is not visible in the drawing. In particular, our research in the next year will concentrate on two aspects of this problem, design intent and detection of symmetry.

DESIGN INTENT: The problem of determining design intent is simple to state: what object did the user have in mind when creating the drawing?

For example, are small geometric subtleties (misplaced vertices, not-quite-parallel lines) deliberate or the result of drawing errors? What is around the back of the object portrayed in a natural line drawing?

Although the problem of determining design intent remains difficult to solve, by making assumptions about engineering objects and the ways people see and depict them, it is often possible to reproduce a single object which humans will agree is the correct interpretation of the drawing.

To a large extent, the problem is as much psychological as geometric. To start our investigation, we intend to carry out a survey of what is considered to be the most plausible interpretation of a drawing. A draft version of this survey can be found at

http://pacvarley.webspace4free.biz/SOTA/Psychology.html#Test1

and readers are invited to send their comments (the more comments we receive, the more statistical validity the survey has!).

In trying to determine design intent, we currently believe (subject to the results of our survey) that we should assume certain regularities whenever it is reasonable to do so. These regularities should be those which are readily perceived, chiefly *perpendicularity* and *symmetry*. Geometrical techniques for identifying and enforcing perpendicularity are well established. (Martin, Varley and Suzuki, 2005) collects several of these. Thus, our other main current interest is identification and enforcement of symmetry.

SYMMETRY: This section discusses various uses of symmetry, especially mirror symmetry, in determining design intent.

Enforcing symmetry is also straightforward, but techniques for identifying candidate symmetries and evaluating their merits are still work in progress. Nevertheless, the power of symmetry as a tool is evident, as its use in interpreting wireframe drawings shows (Piquer, Company and Martin, 2003). For example, once we have determined that the object depicted in

http://pacvarley.webspace4free.biz/Sketch/Sketches/EG-P2-14.Sketch.gif

is mirror-symmetric or the object depicted in

http://pacvarley.webspace4free.biz/Sketch/Sketches/XK800.Sketch.gif

is axis-symmetric, we are close to reconstructing them entirely.

Identification of candidate symmetries in 2D natural line drawings remains a problem. For example, we know of no algorithm which can detect the "obvious" (to a human) topological mirror symmetry in this sketch

http://pacvarley.webspace4free.biz/Sketch/Sketches/TakahashiFace.gif

and we should welcome a contribution from anyone who does!

HARDWARE: In aiming to duplicate the human ability to interpret natural line drawings as 3D objects, we aim to make our implementation entirely independent of the means by which the drawing is created. Obviously, one natural way of entering a drawing into a computer is via pen and graphics tablet, and (subject to hardware availability and compatibility) our demonstration will use this method, but others are possible. One intriguing possibility, suggested by (Farrugia et al, 2004), is that of transmitting pictures of hand-drawn sketches by cellphone.

2. DESCRIPTION OF DEMONSTRATION

As noted above, there are several other groups working on conversion of sketch input to properly-joined line drawings. Our demonstration will focus on our own contribution, which takes natural line drawings as its starting-point. We shall demonstrate:

DATA ENTRY: Entry of a very simple drawing (of an L-block or other similar simple polyhedron) by hand, and creation from it of a 3D solid model of the corresponding object. The creation process will be seen to be very fast, taking less than a second.

NORMALON: Entry of a pre-created drawing, either the one shown here:
http://pacvarley.webspace4free.biz/Sketch/Sketches/HBlock100.Sketch.gif
or one of a similar level of complexity, and creation from it of a 3D solid model of the corresponding object. The creation process will again be seen to be very fast, taking less than a second.

NON-NORMALON: Entry of a pre-created drawing, either the one shown here:
http://pacvarley.webspace4free.biz/Sketch/Sketches/Tdcb100.Sketch.gif
or one of a similar level of complexity, and creation from it of a 3D solid model of the corresponding object. The creation process will again be seen to be very fast, taking less than a second.

CURVED OBJECTS: Curved objects remain a problem. Our demonstration will include successful interpretation of two very simple curved objects, and also failure to interpret a (not particularly complex) third curved object.

3. REMAINING RESEARCH ISSUES

Interpretation of natural line drawings of general-case objects (non-trihedral non-normalons) remains disappointing. We hope that as our investigation into design intent progresses we shall be able to improve our topological reconstruction engine so that it can interpret more complex drawings than the one in the demonstration.

Interpretation of drawings of curved objects is also disappointing. This should improve considerably if we can improve on existing algorithms for detecting candidate topological mirror symmetry in natural line drawings.

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REFERENCES

Martin, R.R., Varley, P., Suzuki, H, 2005. Perpendicularity as a Key to Interpreting Line Drawings of Engineering Objects, in *Proc. Digital Engineering Workshop: 5th Japan-Korea CAD/CAM Workshop*, 115–120.

Farrugia, P.J., Borg, J.C., Camilleri, K.P., Spiteri, C. and Bartolo, A., 2004. A Cameraphone-Based Approach for the Generation of 3D Models from Paper Sketches, in *ed. J. F. Hughes and J. A. Jorge, Sketch-Based Interfaces and Modelling, Eurographics Symposium Proceedings,*33–42.

Piquer, A., Company, P. and Martin, R.R., 2003. Skewed Mirror Symmetry in the 3D Reconstruction of Polyhedral Models, *J. Winter School on Computer Graphics 11(3)*, 504–511.

Takahashi, Y., 2004. *Constructing 3D from Sketch Portraits according to Prepared Templates*, MSc Thesis, The University of Tokyo. In Japanese.

Varley, P.A.C., Martin, R.R., Suzuki, H, 2005. Frontal Geometry from Sketches of Engineering Objects: Is Line Labelling Necessary? *Computer Aided Design 37 (12)*, 1285–1307.

Varley, P.A.C., Takahashi, Y., Mitani, J., Suzuki, H., 2004. A Two-Stage Approach for Interpreting Line Drawings of Curved Objects, in *ed. J. F. Hughes and J. A. Jorge, Sketch-Based Interfaces and Modelling, Eurographics Symposium Proceedings*, 117–126.