Towards a Sketching Tool for Architects: 3D Reconstruction of Polyhedron

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This paper presents a tool for assisting 3D modeling from perspective projections. The proposed system uses a projective geometry engine capable of rebuilding a 3D model from a set of lines and geometric constraints. A dialogue interface assists the user in expressing geometric constraints. The system finds out the relevant geometrical components in the sketch and automatically posts the constraints. The system is limited to rebuilding polyhedrons. If we can deduce, from a perspective sketch of a polyhedron, the planar constraints of the faces and the parallelism constraints of the edges that meet in the same vanishing points, the geometric engine will be able to build a 3D model of the polyhedron.

Keywords: *sketching; 3D reconstruction; projective geometry.*

Introduction

The ARIAM-LAREA laboratory of the school of architecture of Paris La Villette is engaged in researches whose aim is developing new interfaces for assisting architectural 3D modeling. These interfaces can be used for the restitution of existing buildings or monuments (Guéna 2005) or during the preliminary design phases of a new building. This paper is rather concerned with modeling tasks for preliminary design phases.

Most of architects still use freehand sketching during conceptual design. 3D modelers offer operations to build an architectural 3D scene from solid primitives or surfaces but it is generally necessary to have a precise idea of the objects we want to build. To study the project the architects use pencil and paper to sketch plans, front elevations, axonometric or perspective projections. When the project is sufficiently well-defined they use software tools for producing 2D documents or 3D models from scratch.

Why computer could not assist architect in modeling from freehand drawings? Thus, an architect could communicate his ideas to computer in a very natural manner and the computer could communicate a 3D model to the architect. Such an objective requires that the computer understands what the architect is drawing.

Several researches aim to interpret freehand architectural sketches (Juchmes and Leclercq, 2004; Do, 2002 for example) but most of them do not tackle the issue of interpreting perspective projections.

This paper presents a tool which assist architect to build a 3D model from a perspective projection. We use the same method proposed to assist in modeling an existing building from documents (Guéna, 2005). This method is founded on the interpretation of simple lines that the user quickly draws over a sketch. The proposed system use a projective geometry engine capable of rebuild a 3D model from the set of lines and geometric constraints.

A projective geometry engine

The projective geometry engine used by the system this paper is presenting has been developed as the main part of the GINA project. The GINA project (Geometry Interactive Natural) began in the Ecole des Mines de Nantes (Kuzo and Macé, 1999). The ARIAM-LAREA research group has been cooperating in the GINA project for a long time and has now the responsibility to carry on developing this project.

The geometric engine is founded on the Grassmann-Caley algegra (Sosnov, 2003). It can compute a 3D model from constraints posted on lines, faces and points of the 2D sketch: parallelism constraints, incident constraints et orthogonal constraints. The user does not have to draw an exact perspective. The engine corrects drawing to fulfill the constraints. However the number of constraints the user has to post may be very large for rebuilding a 3D model of an architectural object. Expressing a large amount of constraints may be a very difficult and tedious task.

A possible research way is to develop a dialog interface between architect and the geometric engine which assists architect in providing geometric constraints. This interface could find out the relevant geometrical components in the sketch and automatically could post the constraints.

Interpreting architectural sketches

Our research is founded on the assumption that, if the system can interpret the sketch and find out architectural elements which compose the drawing, it could automatically deduce a part of the geometric constraints that the geometric engine requires to rebuild the architectural object. Thus, the geometric engine and its architectural interface would be a tool for assisting modeling from sketch that architect could use during conceptual design phases.

We are obviously aware that it will be difficult to develop such a system. Geometric and architectural knowledge and also user's drawing habits will be certainly required by the system to understand any perspective projection sketch. Therefore, our first aim is to develop a system limited to rebuilding polyhedrons from simple lines that the user quickly draws over a sketch. If we can deduce, from this set of lines, the planar constraints of the faces and the parallelism constraints of the edges that meet in the same vanishing points, the geometric engine will be able to build a 3D model of the polyhedron.

Interpreting polyhedrons

The prototype we have developed is an AutoCAD ARX application. It runs as a reverse modeling tool. The user inserts a sketch as a raster image in the paper space (Figure 1) and quickly draws over this image the lines which describe the edges of the polyhedron. The user draws the visible edges with thick lines and the hidden edges with thin lines (Figure 2).

The system uses graphic properties (color, line type or thickness) to distinguish between the two kinds of lines (if the input device is a tablet, the system can use pressure). The application has to com-

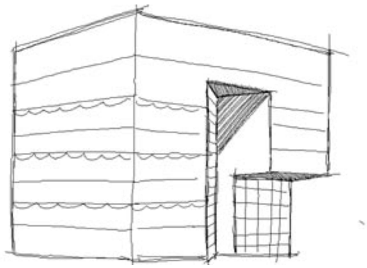

Figure 1
A sketch after M. Botta

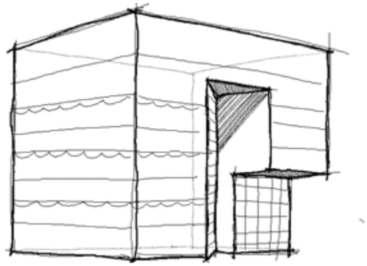

Figure 2
The visible and hidden lines

pute a 3D model of the polyhedron in the object space.

Building the 3D model of the polyhedron is operated in three steps: searching for the planarity constraints, correcting the drawing, searching for the parallelism constraints and at last build a 3D model.

Searching for the planarity constraints

The system begins to build a graph from the lines drawn by the user (Figure 3). If a tablet is used the strokes are first segmented in polylines and the system uses pressure for separating in two sets the polylines, corresponding to visible edges, from the polylines, corresponding to the hidden edges. The polylines are intersected and points are computed. If a new point is near enough an already computed point, they are gathered in an unique point. Each point memorizes all the incident polylines. The lines are arranged according to their directions.

The system tries to find out in the graph the cycles that represent the projection of the faces of the polyhedron (Figure 4). The algorithm uses the fact that an edge must belong to only two faces.

This first step provides the planarity constraints for the geometric engine.

Searching for the parallelism constraints

During the second step the system iteratively corrects the drawing until it be a possible projection of a polyhedron. We use an algorithm developed by D. Michelucci at the University of Bourgogne in France (Michelucci and Macé, 2004): the vertices are moved in a minimal manner with a least square method until the drawing satisfies consistence projective constraints (Desargue theorem). At the end of this step parallel lines which support edges meet at vanishing points (Figure 5).

The system tries to find out the most likely three vanishing points. The system makes the assumptions that the three vanishing points have the larger number of incident lines supporting the edges, two of them are on an horizontal line and the third is often located at infinity.

At this point a dialogue begins between the user and the system. The system proposes a corrected perspective and the three possible vanishing points. The user can accept or refuse the correction before the 3D rebuilding step. In fact the corrected perspective may be correct from the projective geometry point of view (the drawing is a projection of a possible polyhedron) but not valid from the architect point of view. If it is the case the user has to correct the drawing proposed by the system. He can align vanishing points or directly designed the edges which are parallel. An alternate would be using a dual graph as presented in an other paper of this ECAADE 2006 conference (Ciblac, Untersteller and Macé, pp. 840-847).

After the second step the system can provide parallelism constraints for the geometric engine.

Build a 3D model

The last step consists in asking the geometric engine for building a 3D model of a possible polyhedron in the model space of AutoCAD. The user can open a new window in the paper space and ask AutoCAD to compute an other projection.

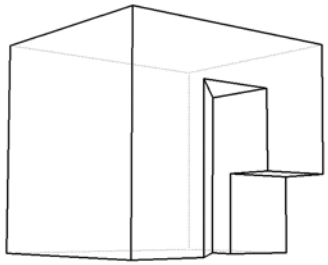

Figure 3
The of visible and hidden lines after segmentation

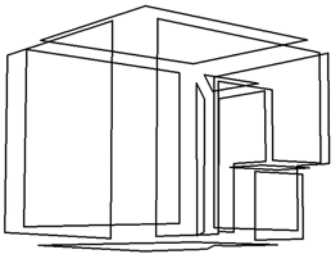

Figure 4
The set of faces

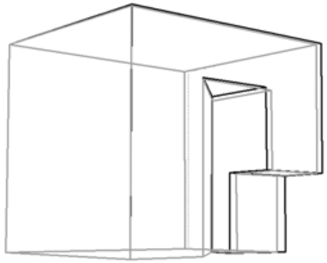

Figure 5
The correction proposed in gray lines

Figure 6
The 3D model proposed by the system

Conclusion

This paper has presented a tool for assisting modeling from perspective projections. This kind of tool could be useful during preliminary design phases. It could help an architect to quickly produce a 3D model from the first ideas. The user could take advantage of the two mixed approaches: a reverse modeling approach from freehand sketch as this paper presented and a 3D modeling approach.

Currently the main problem comes from the sensitiveness of the system when one of the vanishing point is located to infinity. It is usually the case in architectural perspective projections. This problem can lead to a fastidious dialog between the user and the system. Using more projective geometry properties is probably a relevant way of research.

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