RECONSTRUCTION OF A ARCHITECTURAL THREE - DIMENSIONAL MODEL FROM ORTHOGRAPHIC DRAWINGS

NORIHIRO KAWASUMI, SHIGEYUKI YAMAGUCHI
Department of Architecture and Design, Kyoto Institute of Technology, Matsugasaki, Sakyo-Ku, Kyoto 606, Japan

Abstract. In this paper, we describe a semi-automatic reconstruction method of a three-dimensional model from orthographic view drawings of architecture. There are several approaches to reconstruct three-dimensional solids from two-dimensional drawings. But most of them deal with mechanical drawings, not architectural drawings. We observed three-dimensional modeling process of design practice and we tried to make clear modeling procedure from architectural drawings, such as plan and elevation views, and classified into seven typical modeling operations on three-dimensional CAD system. Then we proposed a reconstruction method to create a surface three-dimensional model from a set of architectural plan and elevation drawings. Each elevation drawing is defined as polygon elements. The reconstruction system makes each element of elevations built up and then placed each around the contour of the plan drawing. Several illustrative examples are included as results.

1. Introduction

In computer-aided architectural design, we commonly use two-dimensional CAD systems to create projection drawings. Plan, elevation and section views are standard media for design results. Two-dimensional CAD systems are developed based on an analogy with traditional architectural drawings and representation style. So it is easy to create drawings for architects on two-dimensional CAD system. Now, when three-dimensional architectural model on three-dimensional CAD system is available for visual simulation and presentation, it is possible to examine its design volume.

Three major approaches commonly used as modeling methods are: a) to create primitives directly and assemble them, b) to sweep and extrude planar surfaces to solids, c) to construct a three-dimensional model from coplanar projection drawings automatically. The first two approaches are commonly applied to three-dimensional CAD systems in the market. But they are not efficient for architects to

recreate a model again, although two-dimensional drawings are completed on two-dimensional CAD system. Each modeling command and operations are different from system to system. In general, three-dimensional CAD users must get used to unique operations of each three-dimensional CAD system. It is a skillful work to create a model on three-dimensional CAD system.

The last approach is a much more convenient method for architects who have already completed a set of two-dimensional drawings. Three-dimensional CAD user only defines the combination of planar projection drawings to reconstruct a three-dimensional model. This drawing representation is familiar and easy to recognize for architects. However, it is the most difficult approach to computer system without the knowledge of rules of the architectural drawing. In this paper, reconstruction is done by giving computer the least knowledges of drawing names, and so “semi-automatic” reconstruction.

2. Related Works

There are several approaches to reconstruct a three-dimensional model from two-dimensional projection view drawings. Some of them are already applied to practical tools. Significant methods have been proposed since 1970's. Most of them are generally classified into two approaches: object oriented, and wireframe or surface oriented approach. The first is a bottom-up processing method to perform to assemble many candidates of vertices, edges and surfaces in projection drawings. Typical works was proposed by Idesawa (1972) and so on. The second is a top-down processing method to create minimum solid primitives in the projection drawings and assemble them to get the solution. Typical works was proposed by Wesley (1982) and so on. The recognized objects in these methods are usually limited simple geometric and projection view drawings. In this paper, we chose the surface oriented approach. Because an architectural model is already exists in two-dimensional CAD as a set of orthographic views and it is easy to handle surface polygons of elevation drawings on computer system. We try to develop the reconstruction system which is possible to create a three-dimensional model from conventional architectural drawings with the least knowledge provided to system.

3. Observation of Architectural Modeling

As described above, most of the reconstruction algorithms are proposed to create three-dimensional model from mechanical engineering drawings. It is very different from conventional drawings of architectural design. In this section, we intend to investigate the characteristics of architectural drawings, what kind of design

information and description is defined. Then we observed student's design practice. In this study, each student chose a famous architecture and created its computer models on three-dimensional CAD system. We observed that what kind of modeling command they selected and how they created the models, too. We tried to make clear the drawing recognition process and basic operations to create solid objects from drawings.

3.1. ARCHITECTURAL DRAWINGS

There are many traditional rules and representations for architectural design drafting. It is not easy to understand these drawings and recognize spatial volumes on computer system. Several kinds of conventional drawings and their characteristics is shown in Table 1. Mechanical drawings is defined as three orthographic views, such as the front, side and upper side view. They are simple parallel projection of a three-dimensional model. On the other hand, we usually use conventional architectural drawings, such as plan, elevation and section views. These drawings are different from mechanical drawings. Elevations are parallel-projection of three-dimensional model shape. But plan and cross section view are horizontal or vertical sectioned drawings. These drawings are not generally used in mechanical engineering drawings.

3.2. OBJECT OPERATIONS

We classify modeling activities into several typical operations. The typical operations are illustrated in Fig.1. Each of the operations is classified as: a) raising up objects, b) moving a polygon onto plan, c) rotating a polygon, d) making a planar surface extruded to a solid, e) stretching shape or vertex, f) giving a depth, such as a window and g) joining separated polygons.

TABLE 1. Characteristics and descriptions of architectural drawings

Drawing:	**Characteristics and desicription**
Plan:	Horizontal section view drawing, Non simple projection of upper side view. Location and direction of vertical elements are indicated such as: wall, window, door etc.
Elevation:	Projection view of the main facades or exterior of architecture. Represents only visible shape of architecture, hidden part is not represented.
Section view:	Height relation of architecture is described Main section view only described.
Roof plan:	Outline figure is described of roof. Simple projection of upper side view.

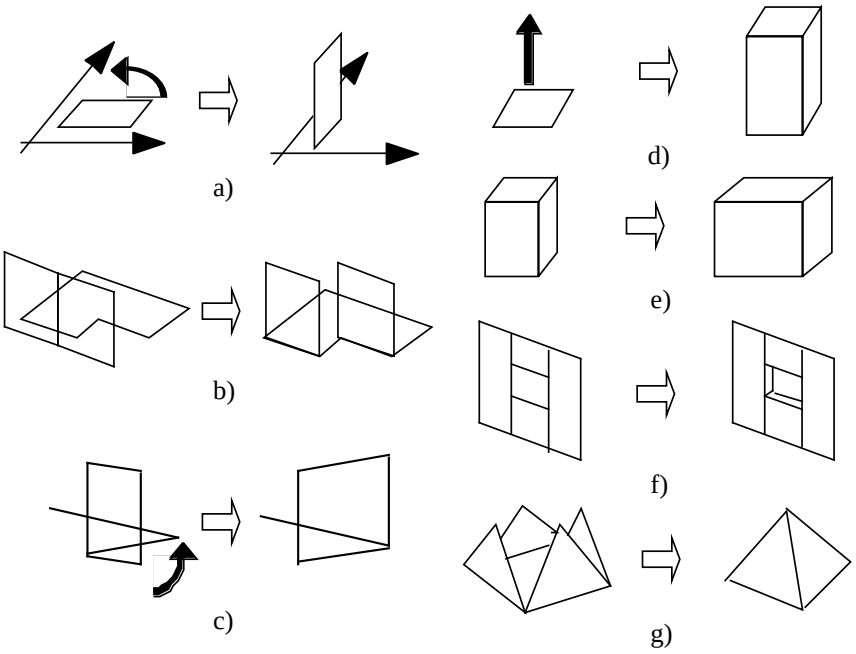

Figure 1. Seven typical operations in architectural modelig.
a) Rasing up a planar surface, b) Moving a surface, c) Rotating a surface, d) Extruding a surface to solid, e) Stretching shape and vertex, f) Giving a depth and g) joining separated polygon's vertices

3.3. MODELING PROCEDURE

The construction procedures observed in design practice are classified into two approaches. The first is a method to create primitives directly and assemble them. The user mainly refer to its axonometric view and photograph images of the architecture. The second is a method to build up polygon elements of elevation around the contour of plan drawings. The primitive modeling method is easy to create complex shape model, for example free-curved surface, but particular modeling operations are required. The building-up method is suitable for simple shape model relatively, but the modeling operations is easy to understand because the modeling method is similar to making a paper model of architecture.

4. Reconstruction of Three-Dimensional Model

The reconstruction procedure consisted of several steps. Each step and operation flow are shown in Fig.2. We have developed a prototype of reconstruction system with Visual BASIC on Windows platform. Data input of a set of the drawings and

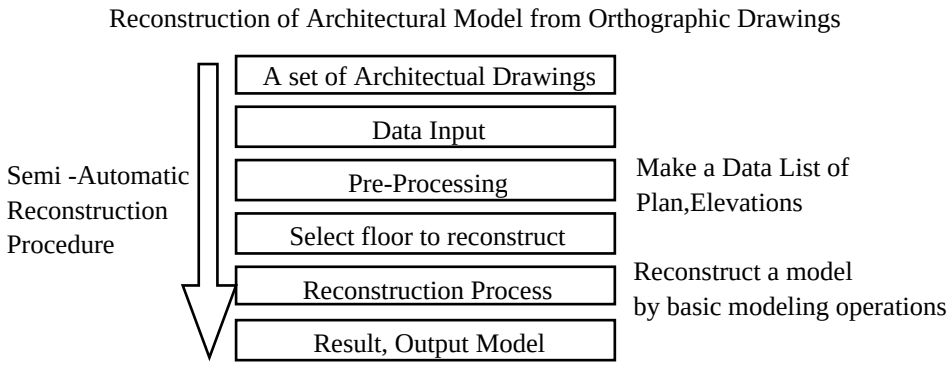

Fig.2. Operation flow of reconstruction processing

output of reconstructed model is executed by DXF format files on this system.

4.1. RESTRICTIONS OF DRAWINGS AND SHAPE

It is not possible to reconstruct any shape model from any drawings in this prototype system. We defined the following restrictions for orthographic drawings and three-dimensional model shape. The restrictions of a set of the drawings is below.

a) Drawings consisted of only polygon surfaces
b) Only complete drawings, have no conflict to each other
c) Each elements, such as wall, window, roof, are separated by layer attributes
d) Non inclusion of free-curvelinear elements
e) At least a plan and a elevation drawing are required
f) A set of drawings that is not ambiguous nor complete
g) Only a model is reconstructed from a set of drawings, not supported multiple solutions on this prototype.

The restrictions of three-dimensional model shape are as follow:

h) It does not include a free curved surface and sphere.
i) Location of each wall element can be referred from plan drawing.
j) Column and curved surface are set along the horizontal or vertical projective axis.

We supposed to make a set of the drawings by polygon oriented two-dimensional CAD tools, for instance AutoCAD on Windows platform or MiniCAD on MacOS platform.

4.2. RECONSTRUCION STEPS OF THREE-DIMENSIONAL MODEL

The reconstruction procedure in this paper is explained in the following.

4.2.1. Pre-processing

The first step of the reconstruction procedure perform data input. Drawings data is converted to files in AutoCAD/DXF format. The reconstruction system reads these drawings data. The type of drawing views is distinguished by layer attribute and keeps them as separated. These polygon of elevation drawings are stored as geometric verticies list. The contour shapes of the plan drawings are also stored in the verticies list in order to place the elevation polygon to the correct location.

4.2.2. Selection of Plan and Elevation to Reconstruct

The second step, the user should select the floor to reconstruct the model from a set of plan and elevation drawings. The geometric elements in a data list are indicated by the layer name, for example “1F Plan”, “1F South Elev”, “2F East Elev” and so on. The user is required to input a layer name to reconstruct a model.

4.2.3. Reconstruction of Three-Dimensional Model

The third step, elevation data of the indicated floor are reconstructed on plan. First, each polygon elements of elevation are raised up around plan drawing. Each polygon is moved and rotated to fit to outline shape of the plan. Three basic operations, which were already defined as “Raise up”, “Move” and “Rotate”, are used. Next, pre-constructed model shape is compared with each elevation view. If model’s shape is not fit to elevation, the ill-position vertex is stretched to correct point in which edge line is fit to elevation. For example, slant roof shape is reconstructed with the following steps: a pair of the polygon is checked, which has common vertex to each other. These adjacent polygons on plan should have a common edge line. If there is no common edge line , it is necessary to join separated verticies to the other end to form a common edge. Exceptional complex forms are not able to be processed in this study, these elements are left out. These processes, described above, is executed automatically in the prototype system.

4.2.4. The Result

The reconstruction system output the reconstructed three-dimensional model as DXF format file. The illustrated reconstruction flow is shown in the Fig. 3.

5. Result and Analysis

Case study and Examples is shown in Fig. 4.

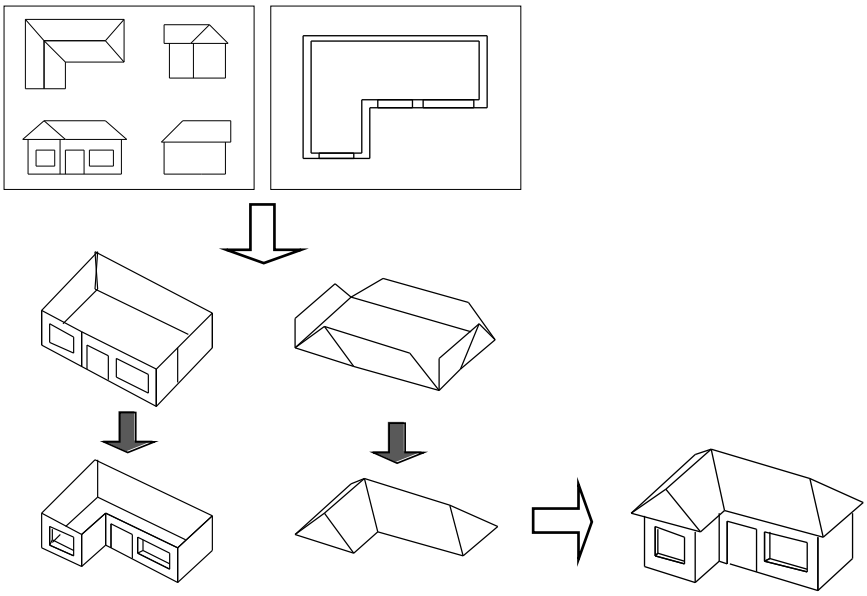

Fig. 3. Illustrated reconstrucion process

6. Conclusion

In this paper, we made it partially possible to reconstruct a three-dimensional model from orthographic views described as conventional architecture drawings. In order to make clear problems to recognize and reconstruct architecture model, we observed modeling process of three-dimensional CAD system. As results of the observation, we found seven basic modeling operations to create a model on three-dimensional CAD system in architectural design. Then we tried to develop a prototype of semi-automatic reconstruction system implemented on Windows PCs. It is possible to make a three-dimensional model using a set of plan and elevation drawings of each side view. A set of drawings and reconstructed model must satisfy several restrictions, for example not included curved line, limited only flat shape, non conflict and ambiguous drawings, and so on.

Our proposed method in this paper deals with the limited types of drawings and shape which satisfied the restrictions. However, it is a convenient and quick method for architects to create a model from already completed drawings in two dimensional architectural design system.

References

Aldefeld, B.: 1983, On automatic recognition of 3D structures from 2D representations, *Computer-Aided Design* 15(2) , pp. 59-64

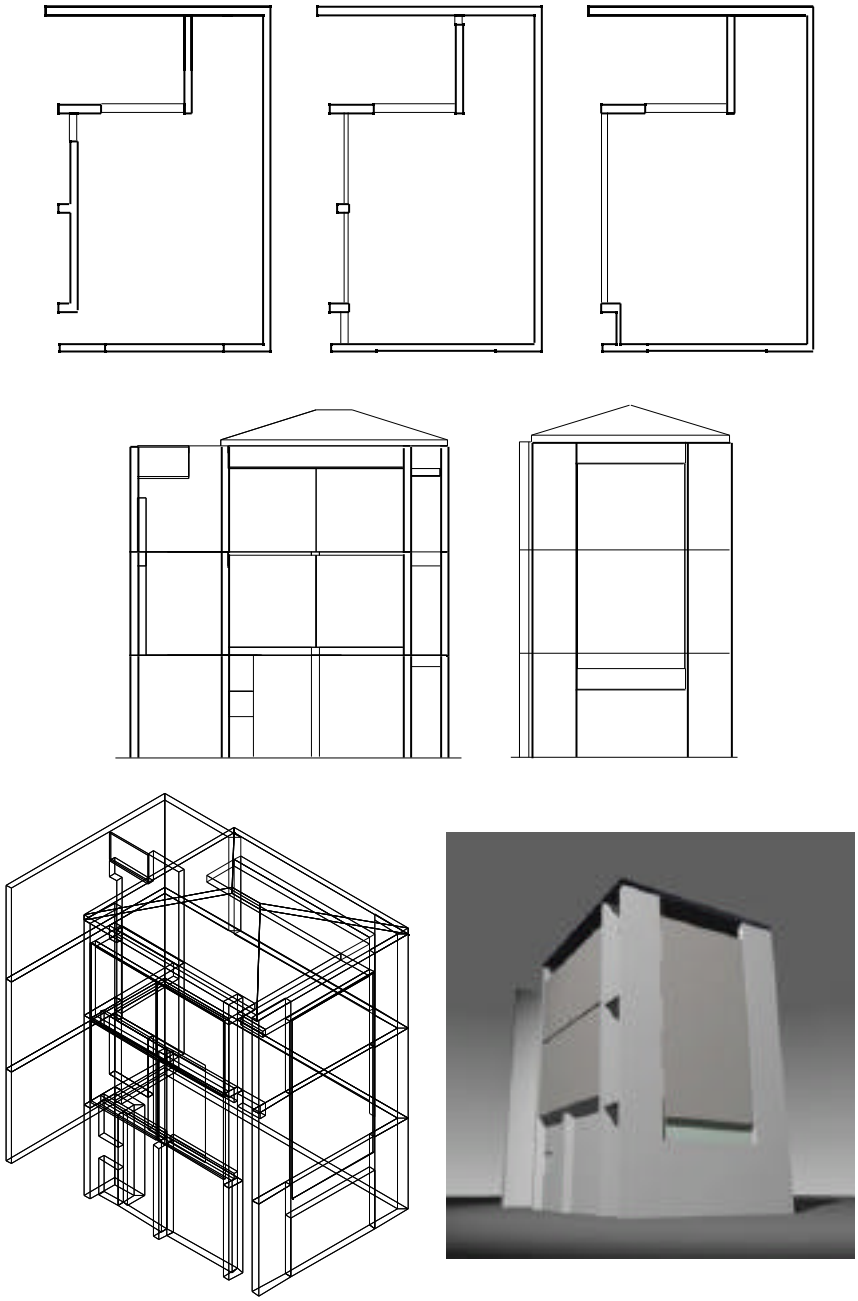

Fig. 4. Example of reconstructed model from orthographic drawings.

A set of drawings is defined only polygon surface and three-dimentional model is assemble them on plan shape.

Chun-Fong You and Shih-shing Yang : 1996, Reconstruction of Curvilinear Manifold Objects From Orthographic Views, *Computer & Graphics* 20(2), pp. 275-293

Dori, D. Tombre, K. : 1995, From engineering drawings to 3D CAD models: are we ready now?, *Computer-Aided Design* 27(4) , pp. 243-254

Idesawa, Masanori: 1972, A System to Generate a Solid Figure from a three view, *Bulletin of Japan Society of Mechanical Engineering* (16), pp. 216-225

Kawasumi, N. and Yamaguchi, S.: 1997, A Study of Intelligent Design Modeling Interface -The Method to Reconstruct the architectural 3D model from orthographic view.- *Proceedings of the Twentieth Simposium on Computer Technology of Information, Systems and Applications*, pp.169-174

Kawasumi, N., Toizumi, K. and Yamaguchi, S.: 1996, A Study of the System to Reconstruct of Architectural 3D Models from 2D Drawings. *Proceedings of AIJ Kinki Chapter*, pp. 617-620

Kawasumi, N., Toizumi, K. and Yamaguchi, S.: 1995, A Study of Methods about the Reconstruction of Architectural 3D Models from 2D CAD Drawings. *Proceedings of the eighteenth Simposium on Computer Technology of Information, Systems and Applications*, pp.211-216

Markowsky, G. Wesley, M. A. : 1980, Fleshing Out Wire Frames, *IBM Journal Research & Development* 24(5) , pp. 582-597

Nagendra, I. V. Uday G. Gujar : 1988, 3-D Objects from 2-D orthographic views - A SURVEY -, *Computer & Graphics* 12(1) , pp. 111-114

Numao, Masayuki Masuda, Hiroshi : 1996, Current Status of the Technologies for Constructing Solid Models from Orthographic Views, *Journal of Japanese Society for Artificial Intelligence* 11(4), pp. 542-549

Qing-Wen Yan, C L Philip Chen, Zesheng Tang : 1994, Efficient algorithm for the reconstruction of 3D objects from orthographic projections, *Computer-Aided Design* 26(9), pp. 699-717

Uday G. Gujar, Nagendra, I. V. : 1989, Construction of 3D solid objects from orthographic view, *Computer & Graphics* 13(4) , pp. 505-521

Wesley, M. A. Markowsky, G. : 1981, Fleshing Out Projections, *IBM Journal Research & Development* 25(6) , pp. 934-954