Non-complete Topological Analysis in Image-Based 3D Building Reconstruction

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Abstract. 3D reconstruction from single view is a very difficult problem in computer vision and computer graphics. Much different from method using presently, we proposed a feasible and efficient method of 3D building reconstruction method by using non-complete topological analysis in this paper, which rapidly achieves the process of recognizing architectures based one or two images. Firstly, the outline of visible parts of architectures is extracted from image and is analyzed to get the incomplete topology of architectures. Next, the resulted topology will be divided into different primitive geometries, and these geometries are used to match models in databases finally. Experiments show that our method has better effectiveness and feasibility.

Keywords: non-complete topology analysis, 3D reconstruction, weighted recognition algorithm.

1 Introduction

Image-based 3D building reconstruction is a very active subject in the field of computer vision, computer graphics and virtual reality, and it can be applied to many areas. Great advances have been made in such reconstruction in the last years, and many efficient algorithms have been presented. Image-based 3D building reconstruction usually uses multiple images for sufficient information extraction and matching. Because single view often can not provide sufficient 3D information, 3D reconstruction from single view is a very difficult problem in computer vision and computer graphics. Some algorithms have to use additional constrains [6,7] and some manual interactions [1,2,3,5], which limits the type of buildings and the speed of recovery. In order to solve this problem, we proposed one efficient and feasible 3D building reconstruction method in this paper with very little input data: one or two pictures.

Building recognition is an important process of 3D building reconstruction and is also a difficult problem, which key point is how to quickly and accurately recognize the buildings in images. At present the recognizing algorithm of buildings is usually based on architectural edge features. Most of them require complete outline of buildings, and the missing parts have to be added by manually [4]. Too much artificial interactive reduces the matching speed, which results a low efficient algorithm. Under such situation, this paper presents a weighted building recognition algorithm. It

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doesn't require complete building outlines, and all needed is the non-complete topological analysis of visible parts of buildings. At last 3D construction of building can be obtained by matching the models stored in databases.

This paper is organized as follows: Section 2 describes the topology analysis and databases. Non-complete topology extraction and process is presented in section 3. Section 4 draws the match method. Section 5 shows the experimental results, and the conclusion and future works are given in Section 6.

2 Topology Analysis and Databases

2.1 Topology Analysis

The overall shape of a building can generally be characterized by combining primitive geometries such as cubes, prisms, pyramids, spheres and so on. The interpretation of geometry primitives in outlines extracted from images depends heavily on the projected topology, that is, the layout of vertices and edges. Therefore, it is needed to analyze the topology of vertices and edges in models.

Vertex Analysis: Each vertex is given a weight for speeding up the matching with databases in this paper. The weight represents the number of edges connected to a vertex, and the bigger weight means more edges are connected. These weights are used to match with models stored in databases.

Edge Analysis [1]**:** We assume that our building consists of three groups of edges that are parallel to the X, Y and Z axis in 3D-space axis respectively. So they are mutually perpendicular. From the viewpoint obtained before, we get three vanishing points p_{vo}, p_{v1} and p_{v2}. Each vanishing point is associated with an axis direction. The edges are grouped by the next formula:

$$g(e, p_v) = \begin{cases} 1 - \dfrac{d(e, p_v)}{T_\alpha} & \textit{if} \quad d(e, p_v) < T_\alpha \\ 0 & \textit{otherwise} \end{cases}$$

Where $d(e, p_v)$ is the distance function between edge e and the obtained vanishing point P_v. For an infinite vanishing point, the distance is the angle between the edge and the direction of the vanishing point. For a finite vanishing point, the distance is the angle between the edge and the vector joining the middle point and the vanishing point. T_α is a sensitivity parameter.

2.2 Databases

There are several databases according to different camera viewpoint. Each database consists of topologies of primitive geometry at the same viewpoint and the corresponding constraints. The topology stores in graph $G_{mx}(V, E)$ and the constrain stores in matrix A_{mx}. The dimension of A_{mx} is the number of edge in topologies. The constrain means the relationship of edges: equal, parallel or perpendicular.

3 Extracting and Processing Non-complete Topology

3.1 Extracting

We first obtain the outline of buildings that is visible in image by edge detection, and progressively build a graph G (V, E). G (V, E) is a null set initially. When an edge is detected, the information of it and its vertices will be added to G (V, E). Vertices will be added to V and edges will be added to E. Vertex information consists of the vertex number and a weight which is 0 initially, and the weight will plus one when an edge

Fig. 1. The original image (left) and extracted topology (right) of a building

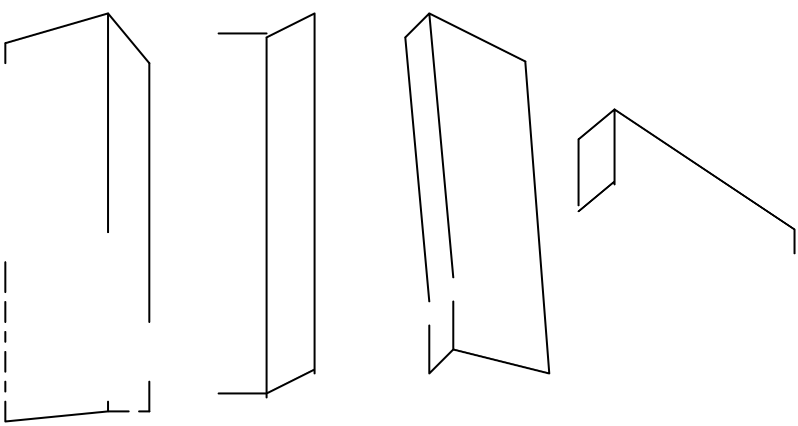

Fig. 2. Different primitive topologies divided from the building. Because of the symmetry of the building, only some parts are analyzed. The second one isn't a part of the building, and it is only used to derive the 3D model of the building.

is added to this vertex. Edge information includes its vertices and a group number that indicates it associates with which axes, that is, the edge belongs to which group. Fig. 1 shows a building and its topology extracted using edge detection.

3.2 Primitives Division

The non-complete topology directly extracted from image is the combination of primitive topologies. For matching models in database, the combined topology needs to be divided to primitive topology. The connectivity between topology and some reference information will be stored in the dividing process. If there are several identical primitive topologies, only one will be used. Fig. 2 shows the results of dividing the topology of building in Fig. 1.

4 Matching Algorithm

The camera viewpoint is derived from the single image of building firstly, according to which the database will be selected.

To simplify the matching process and improve the matching speed, we first implement the following operation to the model in database by the primitive topology divided above:

Some parts of objects may be sheltered or missing in a building image, so the topology extracted from the image often is non-complete. In these situations, the number of vertices and edges in such topology should be less than or equal to the number of corresponding topology in database. Therefore, we compare the number of some weights from extracted topology with the number of equal weight from model in database. If the former is bigger, the compared model will not be what we are looking for, so it doesn't need to match these models in the following algorithm. We just match the other models.

Our matching algorithm:

1. Select an arbitrary model $G_m(V,E)$ from database, and select a vertex v which has the largest weight in vertex set V of $G(V,E)$. Search vertices that have equal weight with v in vertex set V_m of $G_m(V,E)$ and compare the group number of edges connected to them. If the group number is same, go to step (2), otherwise, go to step (3).
2. Select an arbitrary vertex v that has the largest weight in the rest set of V again. Search vertices that have equal weight with v in the rest set of V_m and compare the group number of edges connected to them. If the group number is same, repeat step (2) until all the vertices in V whose weight is more than one are traversed. Then this model is our target model, the matching finish. If the group number is not same, go to step (3).
3. Select another vertex that has same weight with v from V_m and compare the group number of edges connected to them. If the group number is same, go to step

(2), otherwise, repeat step (3) until all vertices in V_m that have same weight with v are traversed, then go to step (4).

4. Select another model form database, repeat steps (1)-(4) until all models are matched. Calculate the matching rate of each model, and the biggest is our target model. Matching rate means vertices that have been matched divide all vertices in a extracted topology.

5 Results

In order to test the limitations and advantages of our algorithm, we present the reconstruction results of primitives of Fig. 2 with our proposed non-complete topological analysis approach in Fig. 3. The extracting time is about 10s, the analysis time is about 50s and the matching time is about 45s.

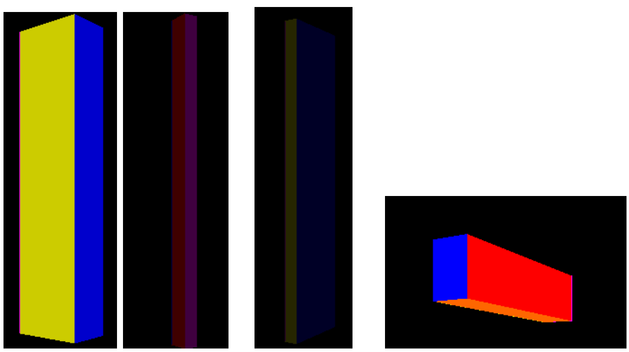

Fig. 3. The 3D model of primitives

6 Conclusion and Future Work

The non-complete topological analysis generally comprises three stages in our system: (1) Create databases. Topologies of primitive geometries at some viewpoints store in databases; (2) Simply extracting the outline of the building that is visible in image. The more complicated of the building, the more time it will cost to extract topology from image and the lower of the matching efficiency; (3) Matching. This is a crucial question. The matching algorithm puts a great influence on the whole system.

The approach taken by this paper is simple and efficient. It only processes the topology of visible parts and it doesn't require complete information. This is very helpful in the reconstruction of buildings sheltered. It avoids complex mathematical calculations, which can save much time.

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