# A METHOD OF EXTRACTING GEOMETRIC INFORMATION FROM THE POINT CLOUD OF BUILDING

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**ABSTRACT:**

The purpose of this article is to extract geometric features and other information for polyhedron, then using these features and information to build the model of object. In this essay, polyhedron refers to objects such as buildings. Unlike modelling objects in other fields, like reverse engineering, buildings' surface usually consists of large amount of big and plane surfaces. Among these surfaces, there are distinct points and lines of intersection (the edges and vertices of the polyhedron). In this article, Triangles classification and Surface extraction, Surface contiguous relations restoration, and Polyhedron Vertices solution and Polyhedron model Reconstruction constitute the main research of extracting geometric features and building the model of the object. In this contribution, some examples of extracting information from the point cloud are presented to demonstrate the method, which is put forward in this essay. Besides, the results prove that when the geometric information of vertices, edges and surfaces, together with the topological relations among them, are extracted from the point cloud, the model of polyhedron, representative of building in this essay, can be built effectively. Equally important, models generated from this method, while occupy less memory space, they can store more comprehensive structural information, and have a better exhibitive effect.

## 1. INTRODUCTION

During the passing years, the computer-assisted technology of building 3D surface model, which is based on the surface point cloud of 3D entity, has gradually become the foundation of virtual reality, decision analysis and computer-assisted design. And the sources of point cloud show the trend of diversification. The objects of model building in the fields of surveying, urban designing, and urban 3D landscape planning are normally buildings, which consists of polyhedron in most case. Therefore, the research of polyhedron model building, utilizing the information extracted from the corresponding point cloud, has highly practical merits.

The main characteristics of these modelling targets are: 1.The object has many entities. 2. It is composed of vertices, edges and planes (or it can be approximately thought as basic and sample geometries, such as the simple polyhedrons). The characteristics determined that it is necessary to use the different method from that in Reverse engineering [1] and other fields [2]. At the same time, extracting geometric features such as vertices, edges and planes and getting the topological relationships among these elements are determined to one of the most critical parts.

To achieve the goal mentioned above, there are several processes must be done: 1. Error Elimination [3]. 2. Triangle mesh model generation [4]. Besides, in the focus of the research, extracting basic geometric features such as vertices, edges and planes base on the triangle mesh model of 3D object, topological information transmission and spatial index methods are used to solve the problem of the shortage of the geometric and topological information.

Then after the three main process, Triangles classification and Surface extraction, Surface contiguous relations restoration, and

Polyhedron Vertices solution and Polyhedron model Reconstruction, the 3D object can be expressed by the simple and abstract geometric features.

## 2. MAIN PARTS IN THE RESEARCH OF EXTRACTING GEOMETRIC INFORMATION FROM THE POINT CLOUD OF BUILDING

### 2.1 Triangles classification and Surface extraction

The process of triangles classification is taken out from the triangle mesh of the polyhedron's surface, as well as the normal and the topologic relationship of the triangles. In this paper, the method used to achieve this aim is Growth Triangles Classification—starting with a initial growth triangle, based on the share relationship of edge among triangles, this approach classify the triangles, whose normal's differences are small in a continuous region, into one class.

The "Class" here means a surface. To the polyhedron, the surface is represented by a mathematic plane. The equation of each surface could be calculated, using the vertices' coordinates of the triangles, which belongs to the same class. Due to the data loss at the vertices and edges of the polyhedron in the sampling process of point cloud, some originally non-existed surfaces appear in the model; therefore, these falsely added surfaces should be eliminated from the final result.

### 2.1.1 Normal distribution analysis: In order to obtain the approximate number, normal distribution of the main surfaces of the object, Normal distribution analysis is used in this paper.

First, the Normal distribution analysis counts the weighted normal of all the triangles, and the normal vectors are normalized. In the statistics, the area of the triangle is

considered to be the weight of its normal. Second, according to the statistics distribution getting from the first step, the three-dimension normal vectors are projected to two-dimension space (like the definition of longitude and latitude). As result of these two steps, a statistics chart of the triangles' normal shows the distribution of these three-dimension vectors. Third, to find a gray-scale image threshold, the image getting from the second step is processed by Otsu algorithm [5]. Then the weighted average normal and the approximate number of the object's major surfaces can be obtained.

There are three examples of using Normal distribution analysis methods to analysis.Fig1 (a) shows weighted normal distribution of hexahedral object. The object is similar to that of the mathematic hexahedral object, but all the surfaces of the object are not a plane. Fig1 (b) shows the normal distribution of the green rectangle region in Fig1 (a). The background colour of Fig1 (b) is yellow, that represents the absence of the corresponding normal in the actual surface, while the graduated tint from white to black represent the concentration degree from low to high.

Fig2 shows the weighted normal distribution of car. Fig3 shows the weighted normal distribution of human face.

Compared Fig1 (a) and Fig1 (b), there are six significantly concentrated distribution points in Fig1 (a). And every concentrated distribution point represents a major surface. As a result, the weighted average normal (the Pixel coordinates of corresponding pixel), area (the sum of all the pixels' gray in one concentrated distribution point) and the number of major surface (the number of concentrated distribution points) can be extracted from the statistics chart.

Compared Fig1 (a), Fig2 and Fig3, a special phenomenon of normal distribution concentration can be found that the polyhedron is most obvious, the human face is the least and the car is between these two situations. The human face has amount of complex surface, as a result, the normal distribution concentration of is least. While the surfaces of the car are curved surface, the main shape of the car is approximate to a complex polyhedron, so the statistics chart of it show some concentrated points.

Though these examples, Normal distribution analysis can get the number, average normal and area of the major surface of polyhedron object.
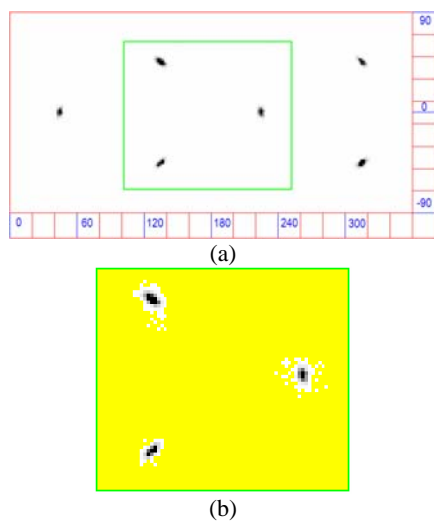


(a)



(b)

Fig.1 Statistics chart of hexahedral object. Fig.1 (a) shows the weighted normal distribution of hexahedral object. Fig1 (b) shows the normal distribution of the green rectangle region in Fig1 (a).
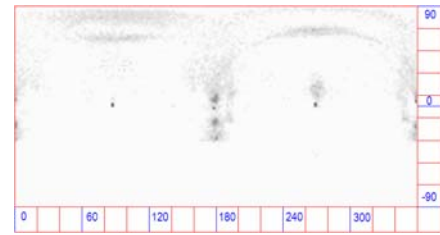


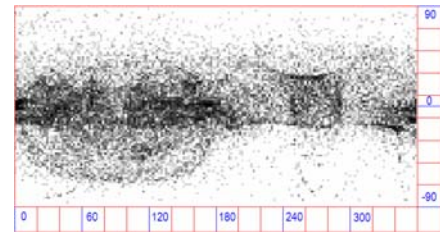Fig.2 Statistics chart of the weighted normal distribution of car.



Fig.3 Statistics chart of the weighted normal distribution of human face.

**2.1.2 Recursive algorithm of Growth Triangles Classification:** All the triangles, through recursive algorithm, are classified into several classes, according to the normal and the contiguous relation of the triangles.

The main processes of the Growth Triangles Classification are as follow:

1. Input one triangle as the initial growth triangle (from the triangle mesh of the object), and add its adjacent triangles into the growth candidate array.

2. Traverse the adjacent triangles of the initial growth triangle, if the difference of the normal between the initial growth triangle and its adjacent triangle is less than the threshold provisions, its adjacent triangle is classified as the same class of itself. And its adjacent triangles are also added to the growth candidate array.

3. Calculate the average normal and the total area of the current class.

4. Traverse all the triangles in the growth candidate array, and use the triangle as input of step 1. The process from 1 to 3 will repeat until no triangle meets the condition of step 2.

5. Traverse all the unclassified triangles, and use the triangle as input of step 1). The process from 1) to 3) will repeat until all the triangles are classified.

In this process, Recursive algorithm can accelerate the Growth Triangles Classification. The main substance of recursive algorithm is expressed in Fig 4. At end of every recursive process, there is a new class.
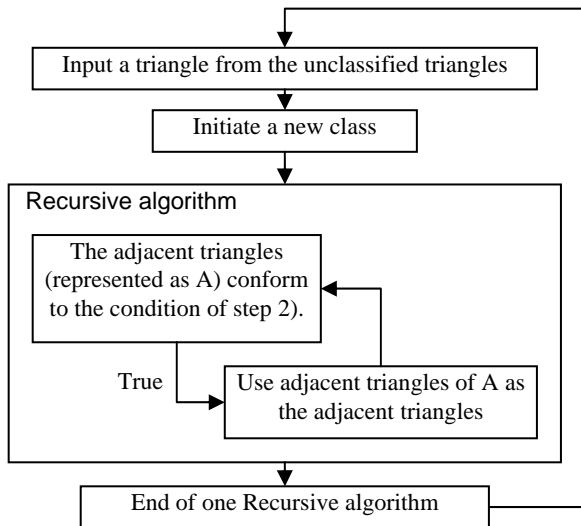
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Fig4 Recursive algorithm of Growth Triangles Classification

Fig5 shows the result of Recursive algorithm of Growth Triangles Classification. Different blue level in Fig5 represent different surface (one class in the triangle classification) of the object.
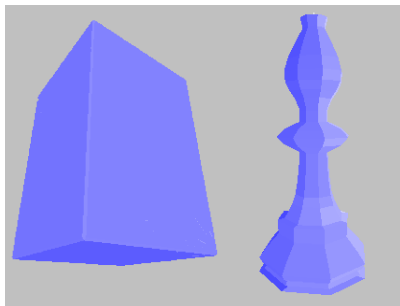


Fig5 examples of Growth Triangles Classification

**2.2 Surface contiguous relations restoration**

Due to the unorganized discrete sampling of point cloud data, the major surfaces extracted in the Triangles classification and Surface extraction (2.1) lack the contiguous relations. But these relations are significant and basic information to get the geometric features and building the model of the object.

There are two methods used in this paper to help restore the surface contiguous relations. The first method is based on a 3D spatial index. Like Fig7 shows that, the space, containing the point cloud, is first subdivided into small commensurate cubes, whose size is determined by sampling density. Under this circumstance, every surface of the polyhedron penetrates a set of cubes, therefore the spatial range of each surface, known as its buffer could be expressed by the very set of cubes. Finally, the contiguous relations of the surfaces could be obtained through comparison among buffers, if two buffers include same cubes, the two surfaces are contiguous; else they are not. (The contiguous relations cannot be directly taken out from the contiguous relations of the triangles, because data might get lost in the sampling process of point cloud at the vertices and edges of the polyhedron.) In Fig7, the contiguous relations of the three 3D surfaces (not plane) can be built by the spatial index.

The second method is based on the transfer of surface contiguous relations. Because there are many small surfaces (considered as noise) between the major surfaces, the

contiguous relations of major surfaces are lost, which actually exist between the real surfaces. So this method use these small surfaces (considered as noise) transfer the contiguous relations between the major surfaces. Like Fig8 shows that, surface 4, 5, 6 are noise surfaces, and the contiguous relations between major surfaces 1, 2, 3 are lost. As an example of this method, the noise surface 4 is the contiguous surface of major surface 1 and 2. So the surface 4 will transfer this contiguous relation to the major surface 1 and 2. In this way, the surface contiguous relations among the major surfaces can be restored.
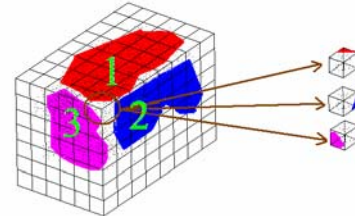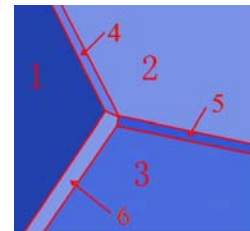


Fig7 3D spatial index



Fig8 transfer of surface contiguous relations

**2.3 Polyhedron Vertices solution and Polyhedron model Reconstruction.**

After the twice step, the contiguous relations of polyhedron surfaces could reveal that which two surfaces share an edge and which three or more surfaces share a vertex. Then the coordinates of all vertices, together with the equations of all edges, could be calculated based on the equations of the surfaces[6]. Furthermore, the contiguous relations of polyhedron surfaces helps to determine which two vertices of the polyhedron are the terminal points of a certain edge, and which edges of the polyhedron surround a certain surface [7][8]. At this point, the whole polyhedron model is built from the point cloud. The geometric features, containing vertices, edges and surfaces, are already extracted from the point cloud data. And the topological relationships among the geometric features are also obtained. The results are expressed in Section 3 Examples.

## 3. EXAMPLES

In this section, the research of extracting geometric information from the point cloud of building in this paper is proved by several examples. The geometric features, containing vertices, edges and surfaces, and the topological relationships among them are extracted from the point cloud data. In Fig9, there are four examples of the combination of the polyhedrons (from example 1 to 4), and one of car as contrast. And the related information is showed in Tab1. From these five examples, to the object, this can be approximately considered as polyhedron, the method introduced in this paper can effectively extract the geometric features. To the object (like the car in example 5), whose surface is the curved surface, the result is not complete.
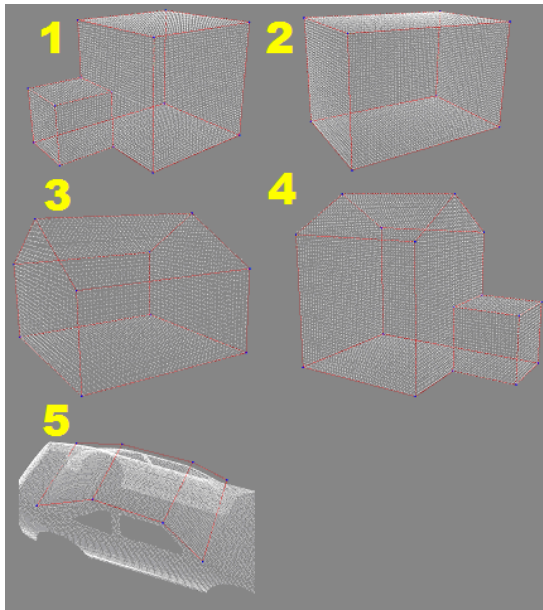
Fig9 results of extracting geometric information from the point cloud

| Example ID | Points(k) | Triangles(k) | Vertices | Edges | Faces |
|---|---|---|---|---|---|
| 1 | 12 | 23 | 14 | 21 | 9 |
| 2 | 13 | 26 | 8 | 12 | 6 |
| 3 | 8 | 21 | 10 | 15 | 7 |
| 4 | 13 | 27 | 16 | 24 | 10 |
| 5 | 21 | 41 | 8 | 10 | 3 |

Tab1 Related information of the examples

In Fig10, there are two complex building from the LiDAR data of Lu Jia Zui district in Shanghai, China. Due to the complex and curved surface of the building, the result can not give the complete geometric features and other information.

The two main reasons for this problem are as follow: 1) the object has a great quantity of complex, small, curved surfaces. So it is difficult to get the ideal triangle mesh [9]. 2) the method in this paper is not aimed at this condition.
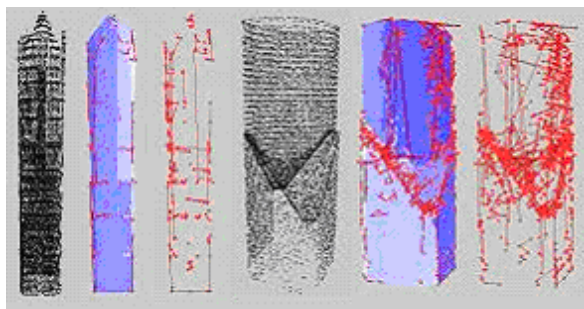


Fig10 results of extracting geometric information from the buildings with complex surface

## 4.CONCLUSIONS

In this article, Triangles classification and Surface extraction, Surface contiguous relations restoration, and Polyhedron Vertices solution and Polyhedron model Reconstruction constitute the main research of extracting geometric features and building the model of the object. And from result of examples, those used to prove these algorithms, four conclusions can be summarized as follow:

1. To the polyhedron and the object, that has the features of polyhedron, the method raised in the paper can effectively and completely extract the geometric features and topological information among them.

2. To the object, that has a great quantity of complex, small, curved surfaces, this method can not effectively and completely extract the geometric features and topological information among them.

3. The quality of triangle mesh of the surface has a great impact on the final result.

4. This method only uses the geometric features (vertices, edges and surfaces) and the topological information among them to model the object, while occupy less memory space, and it can store more comprehensive structural information.

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