

A SURVEY OF METHODS FOR 3D MODEL FEATURE EXTRACTION

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Abstract. This paper deals with problems that are related to a feature extraction from 3D objects. The main aim of the feature extraction is to describe a shape of 3D object by a feature vector. Then the elements of this feature vector characterize the shape of the own 3D objects and they can serve as a key in searching for similar models. In this paper are introduced current methods for the feature extraction of 3D models and their classification. These methods are based on different mathematical background and according to that they are separated into several groups.

Key words: feature extraction, retrieval system

1. Introduction

Everyday, giga-bytes of data are generated and they are sent all over the world by the internet. They carry large collections of various types of information, which are organized in Database Management Systems (DBMS). That database system should allow efficient browsing, searching, retrieving and updating entries in the database. Therefore, research centers started to be interested in this issue that becomes popular.

Text-based retrieval systems were designed in early era of the research. It was a powerful tool in the organization of articles and some other text based information. Unfortunately, for visual based information (images, 3D models, etc.) this approach did not become useful. In the late 1970's the first text based image retrieval system was designed. Each image was annotated by keywords and then the text based DBMS could be used (e.g., see [16], [18]). However, there are two disadvantages in this approach. The keywords of each image have to be assigned manually. If a collection of images in database is very huge, the time that a person has to spend by assigning keywords to each image is excessive. The second, more important disadvantage is a subjectivity of human perception. If two people independently try to describe the same picture with a rich content, the resultant sets of keywords could be different. This fact has negative influence on the using of DBMS for this purpose.

Solution of the mentioned disadvantages of the text based retrieval systems are content based retrieval systems. In that system, the keywords are substituted by own visual content. The first systems were proposed for collections of images in the early 1990's. Nowadays many image retrieval systems exist (QBIC [12], PhotoBook [14], etc.) which are based on different techniques describing visual content of image.

However, the development in content based retrieval systems did not stop. Using CAD systems and many others that work with 3D data brought extensive collection of visual data describing 3D objects. Unfortunately, the systems that are proposed for image data cannot be used for 3D data, therefore, new content based retrieval systems have to be proposed.

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2. Requirements on feature extraction

This paper is dedicated to outline the most common 3D content based retrieval systems. Exactly, the main attention is pointed to the way of feature extraction, i.e., a shape description of 3D object by a feature vector that consists of real digits. We can say that this is the most important part of the whole system. The shape of the 3D object is described by feature vector that serves as a search key in the database. If an unsuitable feature extraction method had been used, the whole retrieval system would not be usable. Therefore, the following text is dedicated to properties that an ideal feature extraction method should have.

At first, we have to realize that 3D objects can be saved in many representations such as polyhedral meshes, volumetric data, parametric or implicit equations, etc. The method for feature extraction should accept this fact and it should be independent on data representation. The method also should be invariant under transforms as translation, rotation and scale of 3D object. Perhaps it is the most important requirement, because the 3D objects are usually saved in various poses and scales. The 3D object can be obtained either from a 3D graphics program or from a 3D input device. Second way is more susceptible to some errors, therefore, the feature extraction method also should be insensitive to noise. Perhaps the last requirement is that it has to be quick to compute and easy to index. The database can contain thousands of objects and agility of the system also would belong to main requirements.

The feature method that would have all the mentioned requirements does not probably exist. For all that, some methods that try to find a compromise among ideal properties exist. They can be classified into several basic groups such as follows.

3. 2D view based methods

In the introduction it was mentioned that image content based retrieval systems were created early than retrieval systems for 3D objects. Therefore, it can be expected the image retrieval systems are explored in more detail. This group of methods uses this fact. 3D objects are represented as series of 2D images that are obtained from different views on the object. Those series of images can be compared by a developed method for images that is only modified for working with series of images instead of one image.

Nowadays many implementations exist that use various methods, e.g., Löffler [9] describes a method based on comparing shape of images, Cyr and Kimia [2] use an aspect graph, or Min at al. [10] presents 2D sketch interface for searching 3D objects.

4. Histogram based methods

Second group of methods for feature extraction from 3D object is based on mathematical background that can be used for describing 3D object. The object is usually decomposed to several parts from which representing values are computed. These values can be represented as a histogram or a distribution encoding properties of 3D models and that description just can be used for comparing 3D objects.

There are many methods how to describe 3D object. Some methods are simpler, others are more complex. Tangelder and Veltkamp [19] divide the object into a grid cell (the invariant under transformations is obtained in preprocessing by PCA - Principal Component Analysis) and they compute a key value representing the object in each cell. They try different values such as Gaussian curvature, a normal variation or a midpoint. Next methods [1], [11], [15], [20] use differential mathematics to obtain a description of 3D object. They estimate Gaussian and mean curvature on the surface of the object and these curvatures are used to compute a descriptor of the object. On the other hand, Funkhouser at al. tries to describe object by a so called reflective symmetry descriptor [7], [8] or by a spherical harmonics descriptor [3]. This

enumeration could be followed by many other methods (e.g., using moment-based classifier, shape description, etc.).

5. Topology based methods

This group contains methods that are based on a description of object topology. Generally, the resultant structure representing an object can be a graph. However, it can be a problem of these methods, because the exact comparing of two and more graphs is computationally expensive (it is usually replaced by a heuristic method). For all that, Hilaga [5] proposed the method that uses a so called Reeb graph. The topology is encoded in the graph by geodesic distance that is computed for all points on the surface of the object. Naturally, this is not the only method based on topology of the object. For example the next representative of this group are methods based on medial axis description (e.g., see [6], [17]). However, these methods are more computationally expensive and more sensitive to noise.

6. Error based methods

Last group of methods is based on the measuring of error between objects. These methods have to solve two problems. The first problem is the pose estimation and the second one is the calculation of a volume error between surfaces of the comparing objects. The method has to estimate the pose of the object as accurately as possible. The reason is obvious from the calculation of the error. Each inaccuracy appears in the calculation of the resultant error. Novotni and Klein [13] present the method that falls into this group.

7. Conclusion

This paper presents a short overview and classification of methods for 3D feature extraction. Unfortunately, it is very hard to say that one method is either better or worse than the other. Each person has different visual reception and therefore it is practically impossible to say what is better result in some case (e.g., what object from a chair and a cube is more similar to a car?).

Finally, note that the feature extraction is a very interesting and important geometrical problem as well and it can be used within recognition systems too. A method that should have ideal properties (see second section of this paper) still has not been proposed, therefore, many research centers are still interested in this issue and new methods are still in development. Our goal is just to contribute in development of a new method.

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