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Combining color and shape descriptors for 3D model retrieval

Giuliano Pasqualotto, Pietro Zanuttigh *, Guido M. Cortelazzo

Dept. of Information Engineering, University of Padova, Italy

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ABSTRACT

Nowadays many three dimensional models feature color information together with the shape description. However current content-based retrieval schemes for 3D models are based on shape information only and ignore color clues. The significance of shape vs. color clues for 3D model retrieval is instead a fundamental issue still almost unexplored at this time. A possible approach is to extend shape-based 3D model retrieval methods of proven effectiveness in order to include color. This work follows such rationale and introduces an extended version of the spin-image descriptor that can account also for color data. The comparison of color descriptors is performed using a novel scheme that allows to recognize as similar also objects with different colors but with the same color distribution over the shape. Shape and color similarity are finally combined together by an algorithm based on fuzzy logic. Experimental results show how the joint use of color and shape data allows to obtain better results than each of the two types of information alone. Comparisons with state-of-the-art content-based retrieval methods for 3D models also show how the proposed scheme outperforms standard solutions on object classes with meaningful color information.

1. Introduction

Nowadays more and more 3D models are becoming available on the web and large 3D databases, e.g. Google's 3D warehouse [1], which requires efficient searching techniques tailored to this type of data. Many different schemes have been proposed for content-based retrieval of 3D data based on different feature descriptors representing both global and local properties of the objects' shape. However most current content-based retrieval schemes for 3D models exploit only shape information while other attributes, especially the color information, are not considered for retrieval purposes. In fact most of the currently available 3D models have also color information associated to them which is a very relevant clue in order to distinguish between different objects. A possible approach in order to exploit color information is to extend standard descriptors used to represent the shape of the objects in order to encompass also the color data and in particular its distribution over the shape.

This paper builds over this rationale and presents a novel content-based retrieval method for 3D models that exploits both shape and color information. Following the idea firstly introduced in [2], an extended version of the spin-image descriptor [3] that can account also for color information is presented. This is not the only point of interest of this work, since combining shape and color clues for 3D model retrieval introduces other original elements. Among them there is a new way of computing the similarity between the color spin-image descriptors that allows to recognize as similar also object with different colors but distributed in the same way over the shape, differently from [2] where this type of objects was considered different. This paper introduces also a global index combining shape and color similarity based on fuzzy sets theory. The experimental results confirm the effectiveness of using color information together with shape information by the proposed method. Indeed the

* Corresponding author. Tel.: +39 049 827 7782.
E-mail address: zanuttigh@dei.unipd.it (P. Zanuttigh).

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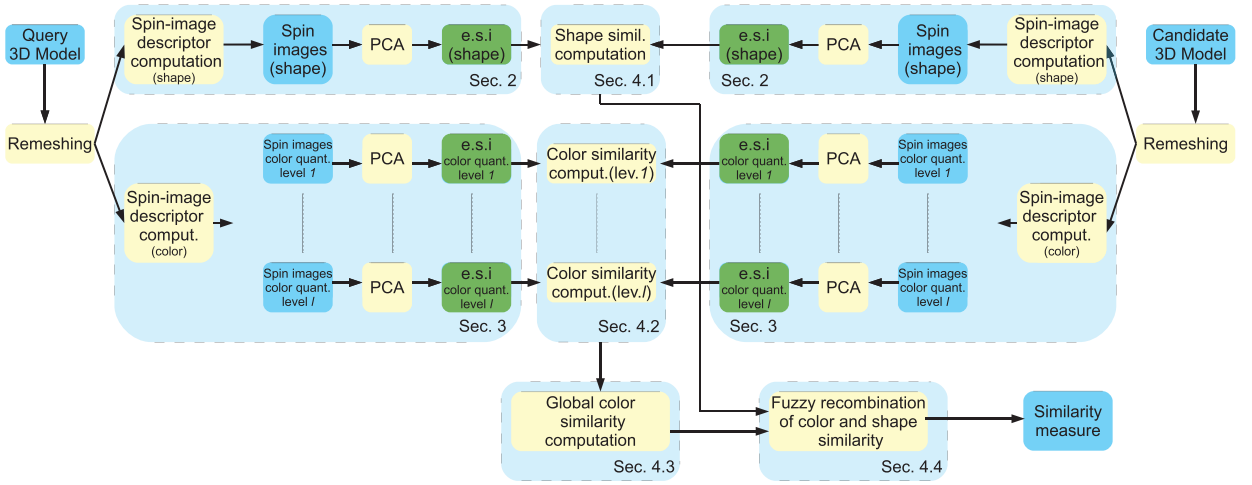

Fig. 1. Architecture of the proposed content-based 3D model retrieval system. (For interpretation of the references to color in this figure caption, the reader is referred to the web version of this article.)

proposed technique when compared with state-of-the-art content-based retrieval methods for 3D models outperforms them on object classes exhibiting meaningful color data.

After reviewing the related work in Section 2, the rest of the paper is organized as depicted in Fig. 1. Section 3 introduces the proposed shape descriptor. Section 4 builds the color descriptor on top of the shape one. Section 5 presents the proposed similarity measures for shape and color information and an efficient way to combine the two measures. Then the experimental results are shown in Section 6 and finally Section 7 draws the conclusions.

2. Related work

Although content-based retrieval of 3D models is a quite recent research field, many different methods have been proposed, some of them will be briefly recalled next. Extended reviews of the literature in this field can be found in [4–7] while a very recent benchmark of the best performing techniques is presented in [8]. Content-based retrieval methods usually encompass first the extraction of a set of feature descriptors from each object and then their comparison for searching purposes. In the case of 3D models these features need to be highly descriptive as well as invariant with respect to many transformations such as changes in the object's pose, scale or mesh resolution.

A first group of methods uses global features characterizing the whole shape of the objects. In [9] a set of different global descriptors was proposed, including cords-based, moments-based, and also wavelets-based features. Other global descriptors use voxel-based spherical harmonics [10] or spherical wavelets [11]. There are also solutions that use statistical models based on the distribution of the vertices in the 3D space. Osada et al. [12] introduced a set of shape functions measuring distances, angles, areas and volumes between random surface vertices. Such distributions are then compared in order to evaluate object similarities. This method was extended in [13] by computing the distances on a regular voxel grid. Gao et al. [14] introduced the spatial structure circular descriptor that allows to capture the spatial structure of the 3D model into a set of images that can then be compared for retrieval purposes. Another global method, the *relativistic impact descriptor* [15] associates to each 3D object a curved space modified by its mass from which two invariant descriptors are extracted.

An alternative class of approaches is based on the use of local features. These methods exploit descriptors representing the surface in the proximity of a vertex, like the *bag of features* based approach of [16], the *3D shape spectrum descriptor* used within the MPEG-7 framework or the spin-image descriptor, firstly introduced in [3] for object matching and then used for 3D retrieval in the schemes of [17] and [18]. There are also methods that combine both local and global descriptors, e.g., in [19] the global 3D shape is represented by the spatial configuration of a set of specific local shapes.

Finally view-based methods represent 3D objects by a set of views taken from different viewpoints and then exploit content-based image retrieval techniques to perform the comparison. In [20] five different groups of views are extracted from the model and then a probabilistic approach is used to find the models that maximize the a posterior probability given the query model. The method of [21] instead extracts 2D rotation-invariant shape descriptors from a set of views and combines this information into a global shape similarity measure. Chen et al. [22] compute the light fields of the 3D objects and extract the descriptors from their silhouettes. A similar scheme based on spherical correlation [23] offers better performances and overcomes some limitations of the approach of Chen et al. The views can be standard images but it is also possible to describe the three dimensional structure of the object through image representations. Examples of this approach are depth maps or of the above mentioned spin-image descriptor which represents 3D point displacements by way of images. Depth maps obtained from the rendering of the 3D object have