Shape Rank: Efficient Web3D Search Technique Using 3D Features

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ABSTRACT

In recent years, usage of 3D object for various purposes, such as CG movie, games, web 3D and so on, is rapidly increasing. In addition, 3D shape capturing method is also improved and many commercial products are now widely available. As a result, a number of 3D objects those are uploaded and published on the Web is expected to increase greatly in the near future. On the other hand, the method for retrieving 3D objects from the Web is not thoroughly researched yet. Based on the backgrounds, we propose an efficient method to retrieve a 3D object from the Web using both 3D feature of the 3D objects and ranking results of current keyword based web search. In this demo, we will show a real time demo on 3D object search using a number of 3D data we scanned in our lab. and retrieved data from the Web.

Categories and Subject Descriptors

H.3.3 [Information Systems]: Information Search and Retrieval; I.4.9 [Computing Methodologies]: Image Processing and Computer Vision

General Terms

Algorithms

Keywords

3D web object, Image processing, shape rank

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1. INTRODUCTION

In recent years, many techniques to capture 3D shapes from a real object, such as laser scanner and projector-camera system, have been proposed. Especially, a low cost capturing system is now an important research topic and widely develped [2]. In additon, the method to publish 3D objects on the web is also proposed [7]. As a result, a number of 3D objects those are uploaded and published on the web is expected to increase greatly in the near future. Therefore, in this paper, we propose an efficient method to retrieve a 3D object from the Web using both 3D feature of the 3D objects and ranking results of web search.

So far, to achieve such 3D object retrieval on the web, classification and recognition of the 3D object is considered to be most important; the technique is known as general object recognition. For example, 3D object recognition for 3D model made by CG and CAD modeling software has been researched intensively and also competitions have been held for these days; e.g., SHREC(SHape REtrieval Contest). However, those methods currently consider only an entire shape of the object and cannot handle single sided object, such shape is now commonly captured by commercial scanner. In terms of such partial 3D objects, Spin Image [5] and CCHLAC(Color Cubic Higher-order Local Auto-Correlation) [6] are proposed. However, those techniques are for identification of the same objects and not for recognition purpose and it cannot be used for retrieval of 3D object from large quantity of 3D object on the web.

On the other hands, in recent years, Visual Rank is proposed [4][1]; the technique achieves accurate image retrieval from the web. The basic idea of Visual Rank is a simple extension of Page Rank to 2D image by using image features; Page Rank is a famous and powerful search technique for the Web [3]. The basic idea of Page Rank is that "query independent ranking". Visual Rank is designed based on the same idea and uses image features and its similarity as a weight instead of using link between pages on the Web. Search results are more accurate than the method just using a keyword annotated to the image. In this paper, we propose a Shape Rank to achieve efficient Web3D search by using 3D features. Shape Rank can be easily understood as simple extension of Visual Rank for 3D data. Note that recognition of 3D object itself is not a main purpose of the research, rather, accurate 3D object retrieval from the Web when enormous number of 3D objects are uploaded and published is our target.

In this paper, we assume that 3D object can be searched with enough accuracy by keyword search; such assumption is fair by considering an image search based on meta-data. Another important aspect of our method is that our technique is not limited to entire shape of CG or CAD model, but also valid for partial shape such as depth image captured by 3D scanner; this is a important feature, because it is estimated that most of 3D object will be captured by 3D scanner and then uploaded on the Web.

The remainder of the paper is as follows. Sec. 2 describes the overview of the method, Sec. 3 presents a calculation method of shape features, and Sec. 4 describes Shape Rank technique. Sec. 5 shows the experimental result followed by conclusion.

2. APPROACH & ALGORITHM

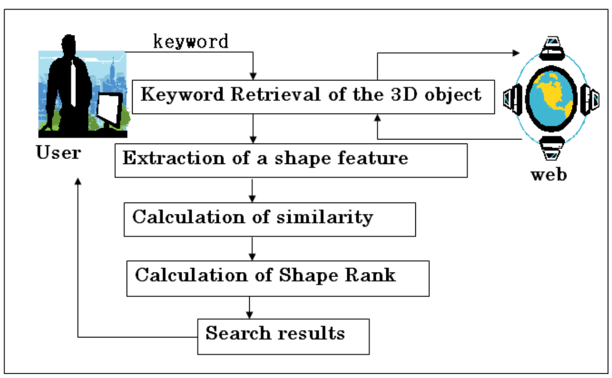

Figure 1: The outline of this method

In this paper, a process as shown in figure 1 that is a simple extension of Visual Rank to 3D by using 3D curvature based features instead of SIFT for 2D image is proposed. With our technique, first, 3D objects on the web are retrieved by keyword search. Next, a shape feature is extracted from a 3D object. Then, the similarity between 3D objects is calculated by using the shape features between 3D objects. Finally, shape rank of 3D object is calculated. Since view of the 3D object drastically changes dependent on a view direction, shape feature should be invariant for view change; such 3D feature is proposed in this paper.

3. THE EXTRACTION METHOD OF SHAPE FEATURES

The shape feature of 3D object is required for calculation of similarity. Method for extracting shape features of real object have been proposed for many purposes. So far, pixel depth [8], topology information and other features are used. In this paper, we propose a feature extraction method using principal curvature for depth image.

3.1 Principal curvature

For analysis of 3D object using curvature, usually a principal curvature is used. Technique for calculating principal curvature of 3D object have been proposed, such as using Hessian matrix, fitting of quadric surfaces and so on [9]. Fitting of quadric surface was used in this research. Fitting of quadric surface is expressed as:

$$h(x, y) = a_1 + a_2 x + a_3 y + a_4 x^2 + a_5 xy + a_6 y^2 \quad (1)$$

where a is parameter of fitting of quadric surface. This equation is a second order polynomial. The optimum solution of a can be calculated as:

$$\mathrm{a} = (\mathrm{X}^T \mathrm{W} \mathrm{X})^{-1} \mathrm{X}^T \mathrm{h} \quad (2)$$

where a is defined as:

$$\mathrm{a} = (a_1, \cdots, a_1)^T \quad (3)$$

and h is defined as:

$$\mathrm{h} = (h_1, \cdots, h_6)^T \quad (4)$$

and X is defined as:

$$\mathrm{X} = \begin{pmatrix} 1 & x_1 & y_1 & x_1^2 & x_1 y_1 & y_1^2 \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ 1 & x_N & y_N & x_N^2 & x_N y_N & y_N^2 \end{pmatrix} \quad (5)$$

where h is a distance value vector. First order partial differential and second order partial differential value can be calculable by coefficient vector a. From the above, maximum curvature and minimum curvature are calculated.

3.2 Shape index

Method of using principal curvature of shape information have been proposed, such as segmentation by using Gaussian curvature. In this paper, shape index value is used in order to calculate curvature for every pixels. Shape index value is defined as:

$$S_I = \frac{1}{2} - \frac{1}{\pi} * arctan \frac{k_{max}(i) + k_{min}(i)}{k_{max}(i) - k_{min}(i)} \quad (6)$$

where, k_{max} is the maximum curvature, k_{min} is the minimum curvature. Shape index value is in range of [0,1]. In this paper, shape index value is normalized between [0,255] in order to output as gray-scale image.

3.3 Solution for view dependency

For calculating the Shape Rank, it should be invariant to view direction, however, shape index image is not; note that shape index itself is invariant to view direction, however, mapped as image is not. To solve the problem, we propose two solutions, one is using SIFT and another is to make multiple shape index images for all view directions. To implement the second solution, we set cameras on the vertex of geodesic dome around the object, as shown Figure 2. For simplicity, if input is a depth image from a single view direction and not an entire shape of the object, we do not make multiple SIFT index images for calculation, because, view changes for such data make a visible area to be very small, resulting in no feature extracted after SIFT calculation. Thus, when a target 3D object was a single view (range image), we decided to use the Shape index image of a single view in order to make process simple.

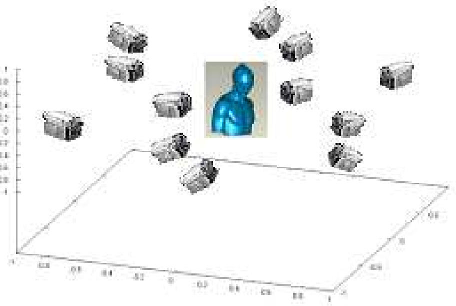

Figure 2: Position of virtual cameras.

4. SHAPE RANK

Shape rank is the same structure as Page Rank and defines similarity of each object by using 3D features instead of hyper link. Ranking result of 3D object by keyword search will be re-ranked by Shape Rank. This is the similar approach of Visual Rank.

4.1 The shape similarity

In order to calculate Shape Rank, the adjacency matrix M which uses the similarity between features is required. The number of corresponding points of SIFT defines the degree of similarity, such as (C_{ij}). C_{ij} is defined as

$$C_{ij} = \frac{M_{ij}}{(T_i + T_j)/2} \tag{7}$$

where M_{ij} is the number of corresponding points between each image, and T_i and T_j are the number of SIFT key point between images. The SIFT descriptor from a single view can be acquired by using the vertex of a geodesic dome. For a entire shape, all the SIFT descriptors acquired from all view points are used. To compare with other objects for calculating the similarity, decision for which view direction is to be used is required, and for solution, we count the number of correspondences and find maximum value. Based on the , it is also possible to calculate the similarity between an entire shape of object and a range image (one sided depth data) using a formula(7).

4.2 Calculation of re-ranking

Using formed adjacency matrix M as described above, calculation will be repeated until it converges and finally we have re-ranking result by using a formula (8).

$$r = (1 - \alpha)Mr' + \alpha P \tag{8}$$

This is the same method as Page Rank and α is the weight of the ranking vectors r.

5. EXPERIMENT AND RESULT

5.1 Experimental environment

We use the range sensor consists of a projector and camera for the experiment. Entire shape are produced by integrating multiple range data scanned from various view directions. The measured examples of entire shape are shown in shown 3.

5.2 Ranking by Shape Rank

Ranking calculation was carried out by using scanned data and our proposed method. We assume that one keyword is given by user and we have 80% of correct 3D objects by

Figure 3: The measured example

keyword search. In this experiment the keyword is "plaster Figure of Mars" and sample 3D objects are shown in fig4. Entire shape of the plaster is shown in fig4 right. 14 of the range images from single view direction (No.1-14) and one entire shape and single view (No.15) are the input of the re-ranking test.

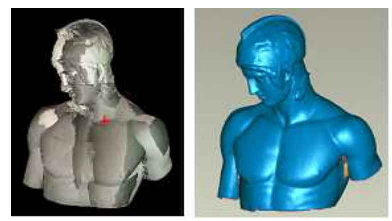

Figure 4: Plaster figure and Entire shape

We also added four noise 3D object of range data (No.16-19) and one noise data of an entire shape (No.20) for this test. The ranking result is shown in Fig5. And the top five ranked results are shown in Fig6. Fig5 shows that the entire shape of a plaster figure is top ranked which proves the effectiveness of our method. However, the noise object of entire shape is ranked in 5th. This is because entire shape has many 3D features and has high similarity to many objects. The solution is our future work.

No	Rank
images15	0.1916
images2	0.0763
images6	0.068
images12	0.0661
images11	0.0604
images20	0.0568
images13	0.0544
images9	0.044
images3	0.0431
images7	0.0416
images14	0.0415
images1	0.0406
images5	0.0372
images10	0.0355
images4	0.0336
images18	0.0252
images17	0.0246
images19	0.0225
images8	0.0199
images16	0.0169

Figure 5: Ranking result

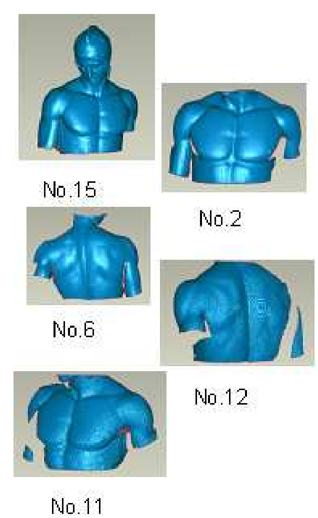

Figure 6: Object of rank in to the high order

5.3 Visualization of similarity between objects

In order to check and analyze the relationship between objects, visualization is required. The graph with weighted edges between 3D objects is shown in Fig7. We can see that all the range images of the plaster figure are tightly linked to the entire shape of the plaster figure. Although the similarities between No.19 and other objects are observed, it is very low and high rank is not given successfully. We can still find that several plaster figures are not linked to other plaster figures; mainly because view invariancy is not enough solved with our method. The reason why the entire shape of Duck toy (noise data), is high ranked can be understood with the visualization.

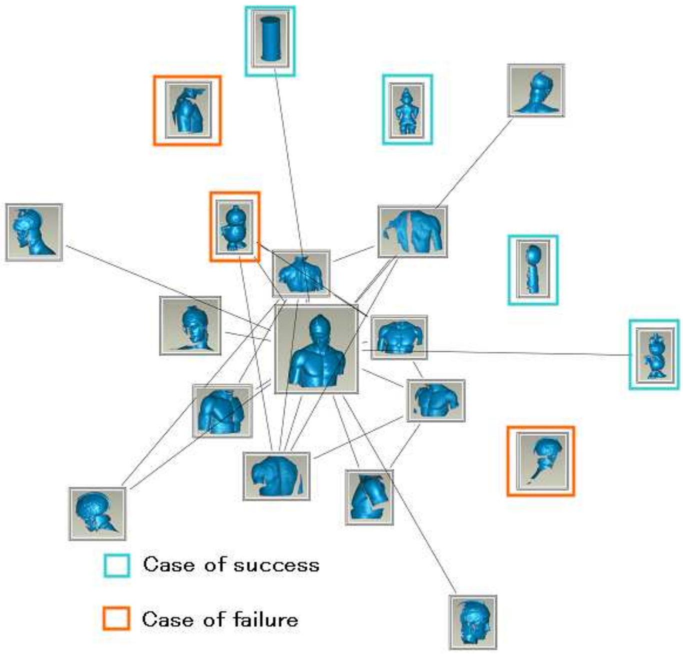

Figure 7: Similarity graph

In addition, the correct corresponding points and incorrect corresponding points by SIFT of index image is shown in figure8. The Figure8 (left) shows the correct corresponding points between single range data and the entire shape and Figure8 (right) shows the incorrect corresponding points between the entire shape of noise object (Duck Toy) and the range image of Plaster figure. To eliminate such wrong correspondence is required to achieve more accurate results.

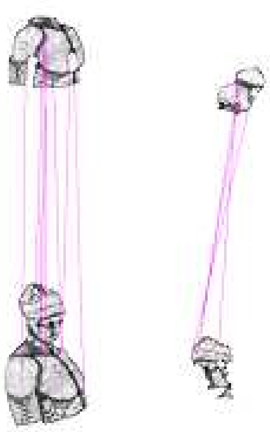

Figure 8: The corresponding points between shapes

6. CONCLUSIONS

In this research, Shape Rank technique to retrieve 3D object from the web using 3D feature of the shape and ranking result of keyword search is presented. Shape Rank is a simple extention of Page Rank using 3D feature similarity instead of link between pages. We conduct experiments using real data and showed the strength of our method. We will present realtime search demo using a number of data we scanned and searched on the web.

7. ACKNOWLEDGMENTS

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