3D Object Retrieval with Semantic Attributes

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ABSTRACT

Humans are capable of describing objects using attributes, such as "the object looks *circular* and is *man-made*". Motivated by these high-level descriptions, we build a user-friendly 3D object retrieval system, where the user can browse the database and search for targeted objects using semantic attributes. The main advantage of our system is that it does not require the user to find or sketch a 3D object as the query for 3D object retrieval. Besides, to the best of our knowledge, our system has obtained the best retrieval performance on three popular benchmarks.

Categories and Subject Descriptors

H.3.3 [**Information Search and Retrieval**]: Query formulation, Search process; H.5.2 [**User Interfaces**]: User-centered design

General Terms

Design, Experimentation, Human Factors

Keywords

3D object retrieval, attribute

1. INTRODUCTION

3D data have become more and more common in not only research and industry but also entertainment, such as computer vision, CAD, computer game, and digital city. As a result, 3D object retrieval draws more and more attention from researchers. Some experimental search engines have been developed [1], [2], [4]. Google 3D Warehouse [3], an online repository for sharing 3D models, also provides the functionality of allowing users to search for 3D models.

One key issue for a user-friendly search engine is how to deliver user search intention to the system. This problem is even more important in the 3D search scenario due to two facts: 1) Text-based query can only search for a small part of existing 3D objects because currently most 3D objects are pure shapes without well textual descriptions or tags. 2) Content-based retrieval, *i.e.*, using a 3D object as the query, causes great trouble for the user who does not have a 3D query that is similar to his/her targeted objects in the database. To circumvent this problem, some systems allow the user to form a query by sketching the object's silhouette or skeleton [4], [8]. The main drawback of these systems is that a 2D sketch has only a small part of shape information of a 3D object, leading to less retrieval accuracy.

In this paper, we develop an alternative solution. In our system, the user searches for targeted 3D objects in mind by simply clicking attribute bars (see Figure 1). This is a natural way of delivering search intentions to the system for common users, because humans tend to describe an object using high-level semantic attributes, such as "the object is man-made" and "the object is symmetric". Moreover, these semantic descriptions of 3D objects are good complement to low-level shape features, and thus can be used to improve existing 3D object retrieval algorithms. To the best of our knowledge, our system obtains the best retrieval accuracy on three popular benchmarks.

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2. SYSTEM OVERVIEW

2.1 User Interface

As shown in Figure 1, the user interface (UI) of our system consists of two parts. On the left part, attributes are listed for the user to describe targeted objects in mind. Each attribute is accompanied with an input bar. The user clicks the bars to set the values of the attributes. Three values are used: 0 for having no this attribute, 1 for having this attribute, and 0.5 being the default value for not sure[1].

Search results are shown on the right part of the UI. The user can also trigger a new search by clicking the "Similar" button under an object. In this case, this object serves as the query. Besides viewing the images of the retrieved objects, the user can also observe the 3D models from different angles by clicking the "3D" button under each object.

The user can conveniently browse the database with the attributes. For example, if the user sets the value of "circular" to 1, the system will rank objects that look circular at top and display them on the UI. The most important application of the system is that the user can search for targeted objects naturally. Suppose that the user wants to find out object $\mathcal{O}$ in the database or objects similar to $\mathcal{O}$. Then he/she conducts the search in two steps:

Step 1: Set the values of some attributes to describe $\mathcal{O}$. After each input (a click on an attribute bar) by the user, the system returns top ranked objects on the right

[1]Since various symmetry exists on most objects, we use 0 for both rotational symmetry and no symmetry and 1 for reflectional symmetry to improve its distinguishing ability.

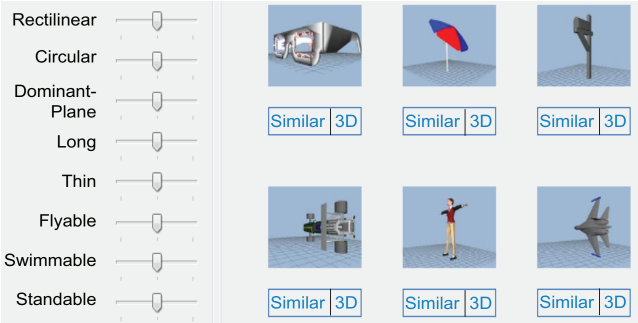

Figure 1: Part of the user interface of our 3D object retrieval system. On the left part, the user clicks the attribute bars to describe targeted objects in mind. After each click, a search is triggered and results are shown on the right. The user can also click the "Similar" button under an object to search for similar objects in the database. The "3D" button is for viewing the a 3D object from different angles.

part of the UI in real time (the ranking procedure is explained in Section 2.2).

Step 2: Search the database by clicking the "Similar" button if $\mathcal{O}$ has not appeared yet. During the process in Step 1, some object(s) similar to $\mathcal{O}$, denoted as $\mathcal{O}^*$, may appear on the UI. Therefore, the user can stop setting the attributes and click the "Similar" button under $\mathcal{O}^*$ to find $\mathcal{O}$.

The two steps can be carried out multiple times to search for more similar objects. The user study of our system on a public testing database, Princeton shape benchmark (PSB) containing 907 3D objects [6], shows that most users can find out their targeted objects within 5 clicks, which includes 2 to 4 clicks on the attribute bars and 1 to 3 clicks on the "Similar" buttons.

2.2 Technical Details

We explain the technical details of our 3D object retrieval system in this section. The system so far provides eleven attributes for the user to describe 3D objects, including shape characteristics (symmetric, rectilinear, circular, planar, long, and thin), object functionalities (flyable, swimmable, and standable), and some semantic classifications (natural and flexible). The framework of the system is shown in Figure 2. At the training stage, we train a detector $\mathcal{D}$ for each attribute based on a public training set provided in PSB using a binary support vector machine. The detector $\mathcal{D}$ is then used at the testing stage to measure the corresponding attribute of a 3D object x with output $\mathcal{D}(x)$ representing the probability of x having this attribute. Besides the attribute measurements, we also extract traditional shape features from each object in the database. The retrieved objects are ranked according to their similarities to the user input. When the user describes the targeted object by clicking the attribute bars, the similarities are calculated using the attribute measurements only. When the user clicks a "Similar" button under an object, both the attribute measurements and the shape features are used to compute the similarities. The shape features and attribute measurements are mutually complementary. To the best of our knowledge, our system has obtained the best retrieval precision in terms of evaluation methods such as first tier and discounted cumulative gain [6] on three common benchmarks: PSB [6], watertight models used in SHREC'07 [7], and NTU 3D model benchmark [5].

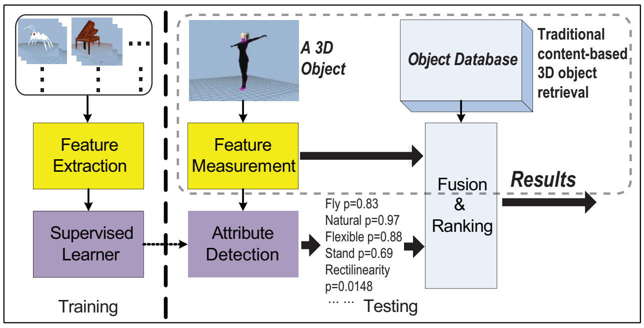

Figure 2: Framework of our system.

3. CONCLUSION

We have built a user-friendly 3D object retrieval system. With this system, the user is able to search the database using semantic attributes to describe targeted objects, instead of finding or sketching a 3D object as the query. So far there are eleven attributes in our system. This set can be enriched in future work.

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