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Geometric and Photometric Data Fusion in Non-Rigid Shape Analysis

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Abstract. In this paper, we explore the use of the diffusion geometry framework for the fusion of geometric and photometric information in local and global shape descriptors. Our construction is based on the definition of a diffusion process on the shape manifold embedded into a high-dimensional space where the embedding coordinates represent the photometric information. Experimental results show that such data fusion is useful in coping with different challenges of shape analysis where pure geometric and pure photometric methods fail.

AMS subject classifications: 65M10, 78A48

Key words: Laplace-Beltrami operator, diffusion equation, heat kernel descriptors, 3D shape retrieval, deformation invariance.

1. Introduction

The birth of the World Wide Web and the explosive growth of text content has brought the need to organize, index and search text document, which in turn fueled the development of text search engines. In the past decade, the amount of geometric data available in the public-domain repositories such as Google 3D Warehouse, has grown dramatically and created the demand for shape search and retrieval algorithms capable of finding similar shapes in the same way a search engine responds to text queries. While text search methods are sufficiently developed to be ubiquitously used, the search and retrieval of 3D shapes remains a challenging problem. Shape retrieval based on text metadata, like annotations and tags added by the users, is often incapable of providing relevance level required for a reasonable user experience (see Fig. 1).

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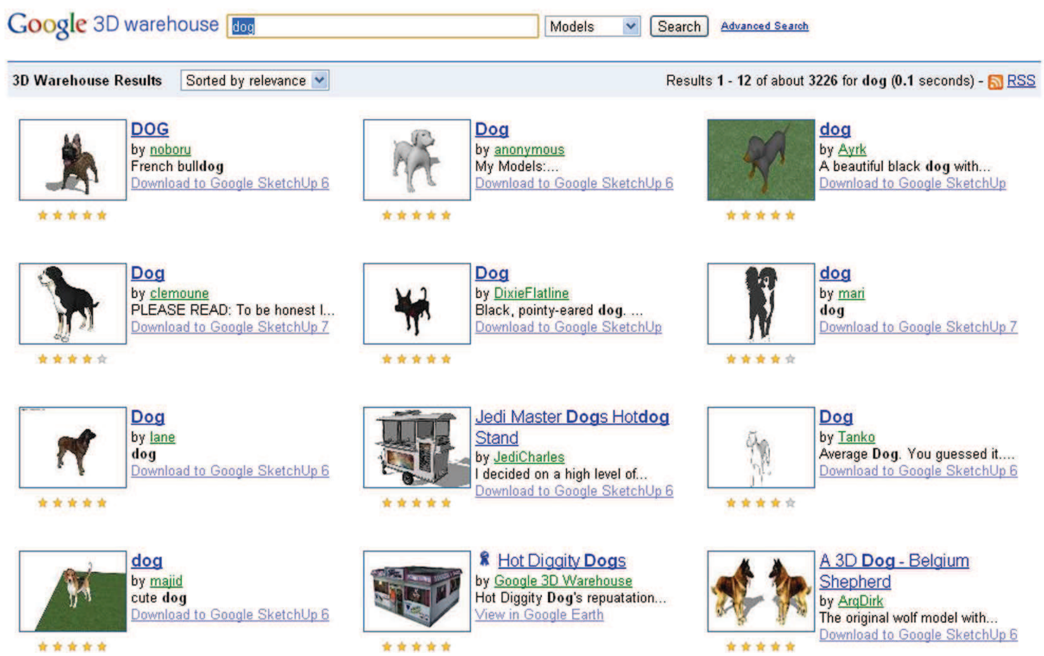

Figure 1: The need for content-based shape retrieval: text-based search engine such as *Google 3D Warehouse* returns shapes of dogs as well as hot-dog cabins in response to the query "dog". The later is obviously irrelevant.

Content-based shape retrieval using the shape itself as a query and based on the comparison of geometric and topological properties of shapes is complicated by the fact that many 3D objects manifest rich variability and shape retrieval must often be *invariant* under different classes of transformations. A particularly challenging setting is the case of non-rigid shapes, including a wide range of transformations such as bending and articulated motion, rotation and translation, scaling, non-rigid deformation and topological changes. The main challenge in shape retrieval algorithms is computing a *shape descriptor*, that would be unique for each shape, simple to compute and store and invariant under different type of transformations. Shape similarity is determined by comparing the shape descriptors.

1.1. Prior work

Broadly, shape descriptors can be divided into *global* and *local*. The former consider global geometric or topological shape characteristics such as distance distributions [37, 43, 50], geometric moments [29, 60], or spectra [49], whereas the latter describe the local behavior of the shape in a small patch. Popular examples of local descriptors include spin images [4], shape contexts [2], integral volume descriptors [24] and radius-normal histograms [45]. Using the bag of features paradigm common in image analysis [19, 51], a global shape descriptor counting the occurrence of local descriptors in some vocabulary can be computed [16].