CCIT Report #475 March 2004

Mesh Retrieval by Components

Ayellet Tal Emanuel Zuckerberger
Department of Electrical Engineering
Technion
Email: ayellet@ee.technion.ac.il

***Abstract*— We describe an approach for retrieving three-dimensional objects similar to a given one from a database. The key idea of our technique is to decompose each object into its meaningful components, and fit each component to a basic shape. This decomposition is represented as an attributed graph, which is considered the *signature* of the object. Our signature leverages human vision theories such as Marr's and Biederman's. We show that this signature gives rise to a retrieval algorithm which is invariant to non-rigid transformations. Finally, a system which realizes our technique was built and tested on a database of about 400 objects. The paper presents the retrieval results and conclusions are being drawn.**

I. Introduction

Given a database of objects and a specific object, our goal is to retrieve from the database objects similar in shape to the specific one. We assume that the objects are given as polygonal meshes, the most common representation in computer graphics applications. Though the problem has been extensively investigated in the context of images [27], [1] and polygonal curves [2], [13], [3] it is a relatively new research topic for meshes [11], [23], [12], [24], [29].

A common practice is to represent each object by a few properties – a *signature* – and base the retrieval on the similarity of the signatures. Various signatures have been proposed in the literature. Some signatures consist of local properties of the shapes, but not their global structures. For instance, in [24], histograms of properties such as colors and normals are considered while probability shape distributions are discussed in [23]. Another alternative is to voxelize the given mesh and use a spherical harmonic representation [15].

Other papers consider global properties, such as a shape moments signature [11] or a *sphere projection* signature which computes the amount of "energy" required to deform an object into a sphere[18]. In these cases the objects need to be normalized ahead of time.

Our goal is to compare the global structures of the meshes. In [12], it is proposed to use a multiresolutional Reeb graph (MRG) as a signature. In general, the Reeb graph is a skeleton determined using a scalar function. In particular – geodesic distances are used in [12]. We too, propose to represent an object by a graph. However, our graph follows the footsteps of human visual perception theories such as Marr's [21] and Biederman's [6]. Practically, these approaches lead to very small graphs which are advantageous both computationally and storage-wise.

Marr [21] claims that the human brain constructs a three-dimensional viewpoint-independent model of the image seen. This model consists of objects and spatial inter-relations between them. Every three-dimensional object is segmented into primitives, which can be well approximated by a few simple shapes. Biederman's Recognition-By-Components (RBC) theory [4], [5] claims that the human visual system tends to segment complex objects at regions of deep concavities into simple basic shapes, *geons*. The simple attributed shapes along with the relations between them form a stable three-dimensional mental representation of an objects.

Our approach attempts to succeed these theories. The key idea is to decompose each object into its meaningful component and to match each component to a basic shape. After determining the relations between these components, an attributed graph representing the decomposition is constructed and considered the object's *signature*. Given a database of signatures and one specific signature, this signature is compared to other signatures in the database, and the most similar objects are retrieved.

Computationally, constructing this signature for a mesh in three dimensions should be easier than doing so for its projection into an image. After all, the whole object can be "seen", and problems like occlusion, self-occlusion, lighting effects and reflections, are avoided. Thus both segmentation and basic shape matching are facilitated.

Another important benefit of the proposed signature is its invariance to non-rigid-transformations. For instance, given a human object, we expect its signature to be similar to signatures of other human objects whether they bend, fold their legs or point forward. Figure 1 illustrates this as well as the results of our experiments. In this figure, the most similar objects to the human test object at the upper left corner were retrieved. All the 19 humans in a database consisting of 388 objects, were ranked among the top 21 objects, and 17 among the top 17. Invariance to non-rigid-transformations is hard to achieve when only the geometry of an object is considered.

An additional advantage of the proposed signature is being compact. Thus, signatures can be easily stored even for large databases and transfered between databases.

The remaining of the paper is structured as follows. Section II outlines our approach. Sections III– IV address the main issues involved in the construction of a signatures. In particular, Section III discusses mesh decomposition into meaningful components while Section IV describes the determination of basic shapes. Section V presents our experimental results. Section VI concludes and discusses future research directions.