Fast Polygon Mesh Querying by Example

The reusability of three-dimensional models has lead to a proliferation in the number and size of 3D object repositories. These typically store objects in some polygon mesh file format and allow selection by means of categories and keywords. While keyword searches are useful in many circumstances, they suffer from the subjectivity, ambiguity and resolution difficulties inherent in natural language. These problems become more acute as database sizes increase and may force users to sift through large numbers of returned thumbnail images.

One solution is to query the object database by example. The user constructs a rough low-resolution query model with the shape characteristics of the target object. This is then compared against entries in the database and the closest matches returned in order of similarity. The core of this method is the matching algorithm.

We advocate the use of wavelet decomposition [2] because this technique:

(a) accepts objects at widely differing resolutions,
(b) allows an overall reduction in fine detail by truncating wavelet coefficients, thereby mimicking the human focus on global shape characteristics, and
(c) has, as will be shown, fast search times.

Our implementation is an extension of wavelet-based image querying [1] to three-dimensional polygon mesh objects. As shown in figure 1, wavelets can be used to derive a ‘signature’ from the original object in four steps: normalization, voxelization, wavelet decomposition and signature extraction.

Polygon Mesh Objects: Our implementation imposes two restrictions on the input objects.

(a) Only shape is considered and surface details are discarded. In future work, this limitation could be overcome by a secondary image query on any texture maps.
(b) A standard ‘natural’ orientation and position are assumed. For instance, the positive *y*- and *z*-axes represent upwards and forwards respectively and the object is centered on the origin.

Normalization: Given these considerations, normalization proceeds by uniformly scaling the object to fit within a unit cube, thereby preserving the aspect ratio and orientation.

Voxelization: This is accomplished using a three-dimensional generalization of the standard polygon scan conversion algorithm.

Wavelet Decomposition: The non-standard Haar wavelet basis [2] is applied in each dimension to decompose the voxel array into a set of wavelet coefficients. The Haar basis was selected because of its simplicity and consequent efficiency. The inclusion and comparison of other wavelet basis functions is left as an area for future research.

Signature Extraction: In keeping with Jacobs *et al*. [1], a compact signature is then extracted by truncating and quantizing the coefficient array. Only the sign of the larger coefficients is retained. One exception is the average intensity, which is stored without quantization.

The Signature File: Two operations are permitted on a signature: incorporation into and comparison against the signature file. Since adding signatures is not time critical and can be executed offline, the signature file is optimized for comparison operations by using Jacobs *et al*. [1] inverted structure.

Performance: The signature extraction process executes in less than a second for an object with 8000 polygons. Since query models are likely to have low polygon counts, this is not a time-critical component of the system. The table below lists the execution times of a signature query for different database sizes (numbers of models). Timings were taken on a Pentium II 300 MHz with 96Mb RAM.

Database Size	10000	20000	30000	50000
Query Times	0.001s	0.01s	1.0s	2.5s

Conclusions: This technical sketch has demonstrated the feasibility and benefits of extending the work on wavelet-based image querying [1] to three-dimensional polygon mesh objects.

References:

[1] Jacobs, C., Finkelstein, A., and Salesin, D. (1995) Fast Multiresolution Image Querying. Computer Graphics (SIGGRAPH '95 Proceedings), pp. 277-286.

[2] Stollnitz, E., De Rose, T., and Salesin, D. (1996) Wavelets for Computer Graphics: Theory and Applications. Morgan Kaufmann, San Francisco.

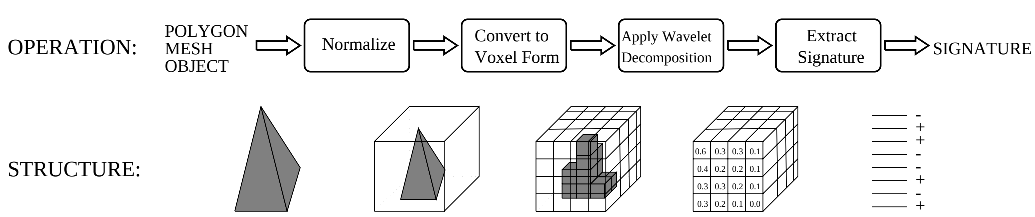

FIGURE 1: The operations and data structures involved in deriving a wavelet signature from a polygon mesh object.