Voxels And Stuff

[Fast Multiresolution Image Querying, Charles Jacobs, Adam Finkelstein, David Salesin]

Multiresolutional Analysis

- Describe the multiresolution approach for images
- Generalize this approach to three dimensional voxel grids
- Discuss
**Multiresolution analysis for Images**

- Generation of image signature
- Defining the image querying metric
- Specifying a data-structure for queries

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**Image Signature 1**

- Given an $nxn$ image, generate an $nxn$ array of the wavelet coefficients for the standard Haar basis functions. (Very fast to compute)

[http://www.cl.cam.ac.uk/~jeg24/PUBLICATIONS/ONS/SKETCHES/WAVELET/sld001.htm]
Image Signature 2

- **Truncate**: Find the $m$ largest coefficients and set all others equal to zero
- **Quantize**: Set the non-zero coefficients to $+1$ or $-1$ depending on their sign

Jackie Chan Example

Original Image (256x256)
Truncated And Quantized to 5000

Truncated And Quantized to 1000
Querying Metric 1

The query metric is defined by:

$$\|Q, T\| = \sum_{i,j} w_{i,j} |Q[i, j] - T[i, j]|$$

where $Q[i, j]$ and $T[i, j]$ are the truncated and quantized coefficients and $w_{i,j}$ are weights, fine tuned to the database.

Querying Metric 2

It can be simplified to:

$$\|Q, T\| = \sum_{i,j: Q[i, j] \neq 0} w_{bin(i, j)} (Q[i, j] \neq T[i, j])$$

where $bin(i, j)$ is a simple bucketing function dependent on the scale of the wavelet function to which they correspond.
Data Structure 1

Preprocessing:
- The images in the database are truncated and quantized.
- Two 2-D arrays, $D^+$ and $D^-$ are generated, with $D^+[i,j]$, respectively $D^- [i,j]$ indexing the list of images with high positive, respectively negative, wavelet coefficients.

Data Structure 2

Given a query image:
- The image is truncated and quantized giving a 2-D array $Q$ with $(-1,0,1)$ as entries
- A scoring array indexing all database elements is generated.
- For each indexing pair $(i,j)$ with $Q[i,j]>0$, the elements in $D^+$ are used to update the scoring array (same for $Q[i,j]<0$)
Data Structure 3

The n best scoring database images are selected.

3D Generalization

The generalization of this method to a voxel grid is immediate. The big trick is establishing a good choice of weights.

[http://www.cl.cam.ac.uk/~jeg24/PUBLICATIONS/SKETCHES/WAVELET/sld001.htm]
The Magnificent Torus

Torus Truncated to 5000
Torus Truncated to 1000

Torus Truncated to 500
Torus Truncated to 100

Torus Truncated to 50
Discussion 1

+ Very Fast: (Works in a fraction of a second on databases of 20,000 images)
+ The use of a Haar basis makes obtaining the signature very fast
+ Invariant under small amounts of noise and perturbations

Discussion 2

- The query method is not hierarchical (i.e. $O(n)$) and hence is not satisfactory for large image/voxel databases (e.g. the web)
- It does not allow for affine transformations
- The Haar basis is anistropic
Discussion 3

- Even with a guarantee that it finds roughly the true target within 1% of the database, this becomes ineffective for large databases.
- The weights for the “metric” are determined after coefficients are discarded.