Image Databases

- Indexing Content-based features
- Querying the exact vs Similar matches

Content Based Search and Retrieval

- Index multimedia data based on the *contents of the data,* not the description
- Contents may include, e.g. in images:
  - Structure of physical objects
  - Patterns of color intensities
  - Spatial relationship among objects
- Search indexed data archives using contents of the query.
- Retrieval based on *similarity* NOT exact match

Characteristics of Internet Data

- Documents consist of multiple media: audio, image, video
- Volume: huge
- Manipulation: requires diverse computational techniques, ranging from simple algebra to signal processing to artificial intelligence.

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Search and Retrieval in Today's Internet

- Keywords: okay for text documents
- Images, audio, and video: textually annotated
- Search based on textual descriptions

Difficulties of Annotation

- Perceptual differences
- Limited information can be attached to each picture
- Necessary information may not be covered
- Annotation time and effort

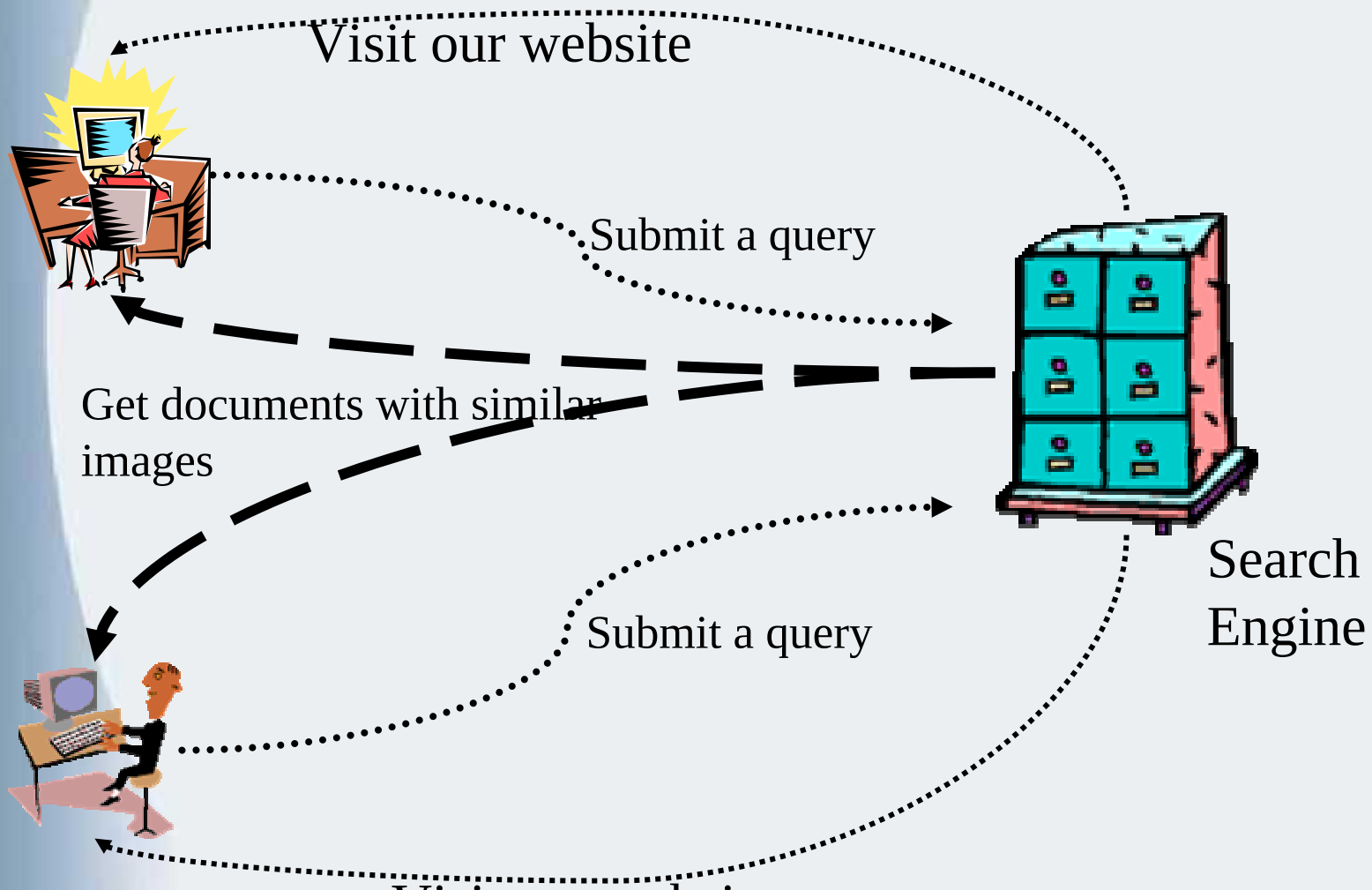
Challenges

- Similarity Criteria
  - closer to the human perception
  - difficult in the presence of multiple features
- Information Abstraction
  - indexing and retrieval of real time media requires abstractions at multiple levels
  - unbiased abstractions are difficult
- Query Modeling and Interface
  - expressing knowledge and concepts

Challenges

- Scalability
  - response time
    - response time should scale linearly only with the number of objects similar to the query NOT with the database size.
  - quality
    - robustness of the feature spaces should scale linearly with the database size.

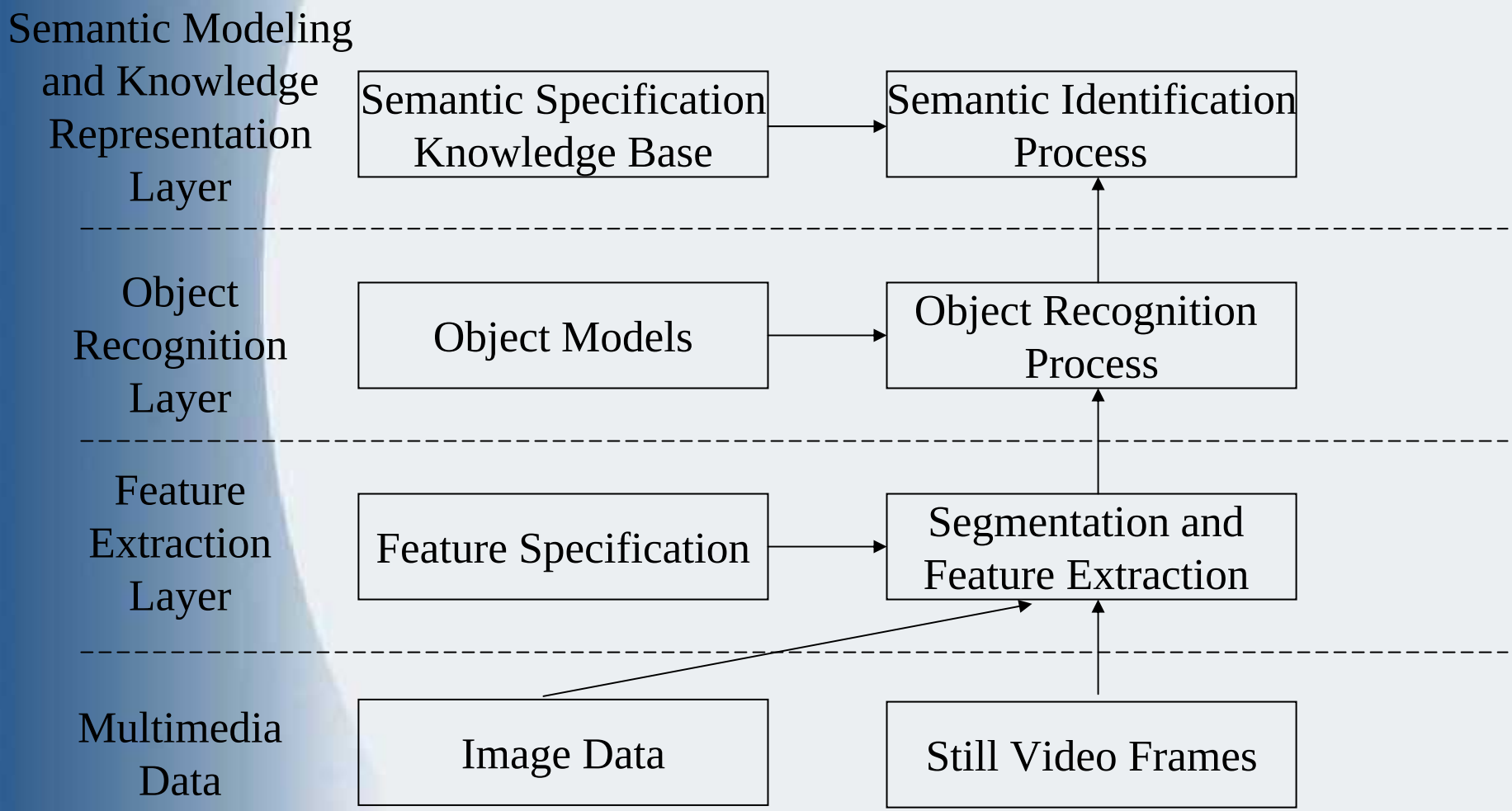
Search Engine



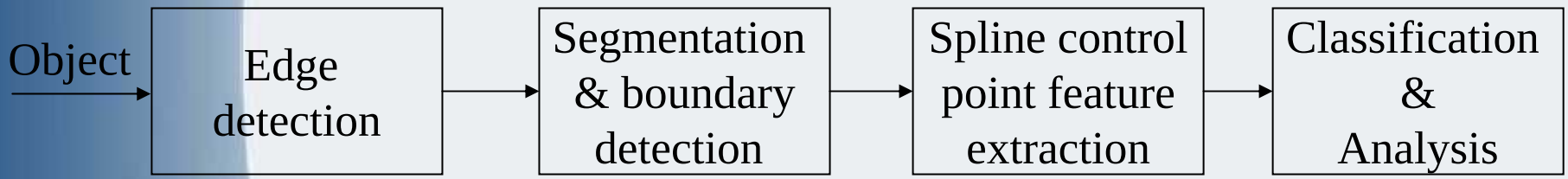
Issues Involved

- Multiplicity of users
  - (250,000 unique users/day for Hotbot)
- Database size !
  - Hotbot (110 million documents)
- Multiple Databases

Semantic Modeling and Knowledge Representation in Image Databases



Steps in Image Processing



Feature Extraction Layer

- Image Features: colors, Textures, Shapes, Edges, ..etc.
- Features are mapped into a multidimensional feature space allowing similarity-based retrieval.

- Features can be classified into two types: Global and local.

- Global features generally emphasize “coarse-grained” pattern matching techniques.
  - Transform the whole image into a functional representation.
  - Finer details within individual parts of the image are ignored.
  - Color histograms, Fast Fourier Transform, Hough Transform, and Eigen values are well known functional techniques.

Images Databases

- Requirements:
  - Image Processing Capability
  - Image understanding Capability (knowledge-based)
- Image Representation
  - Local Features:
    - Pixels
    - Edges
    - Shape
    - Texture
    - Colors
  - Global Features:
    - Histograms
    - FFT
    - Hough Transform
    - Eigenvalues

Different features are useful for different types of queries.

Global Features

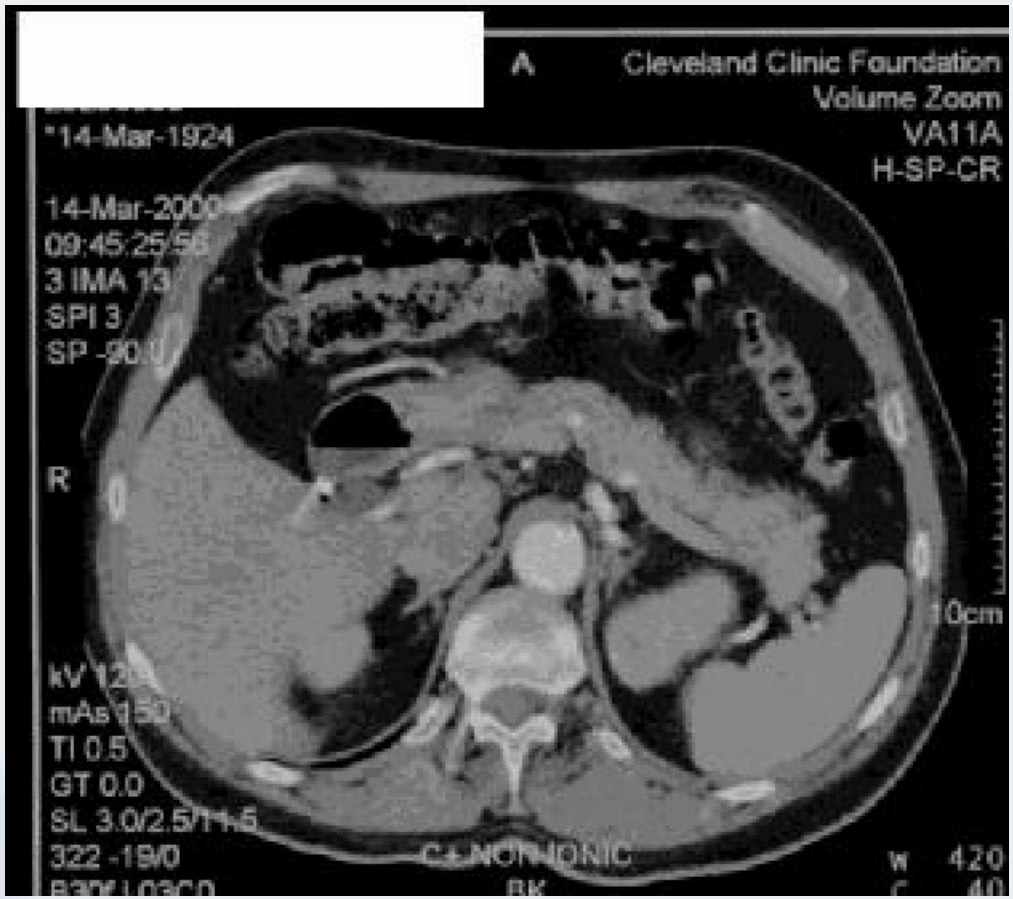
- Advantages
  - Simple
  - Low computational complexity
- Disadvantage
  - Low accuracy

Local Feature

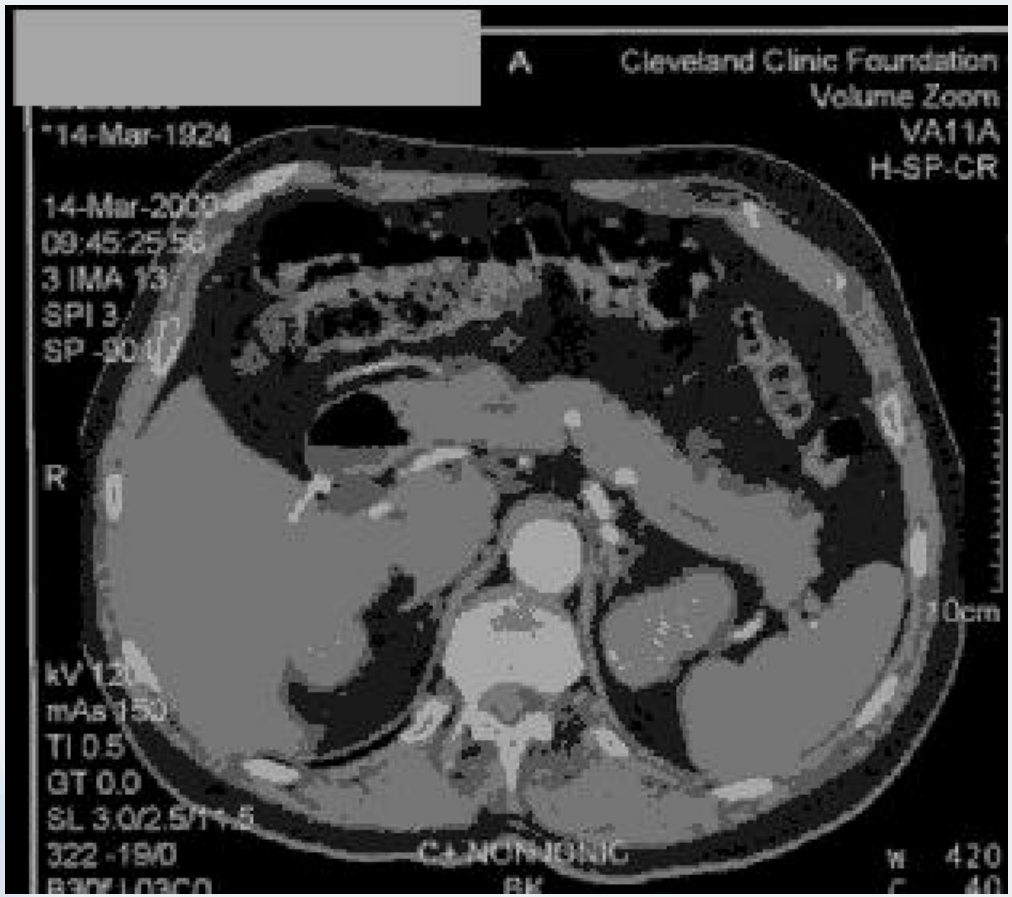
- Images are segmented into a collection of smaller regions, with each region representing a potential object of interest (fine grained)
  - An object of interest may represent a simple semantic object (e.g. a round object)
  - Choice of features is domain specific.
    - X-ray imaging, GIS, ..etc require spatial features (e.g. shapes and dimensions).
    - Paintings, MMR imaging, ..etc may use color features.

Segmentation and feature extraction (example)

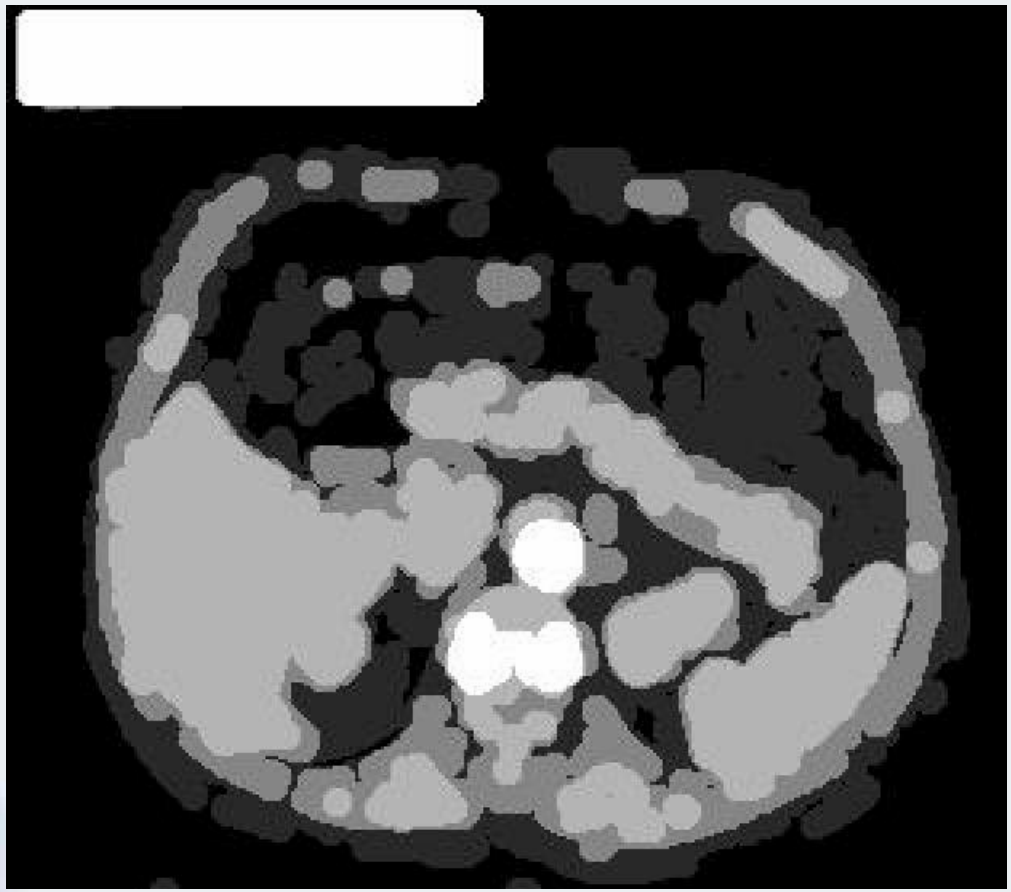
Original Image



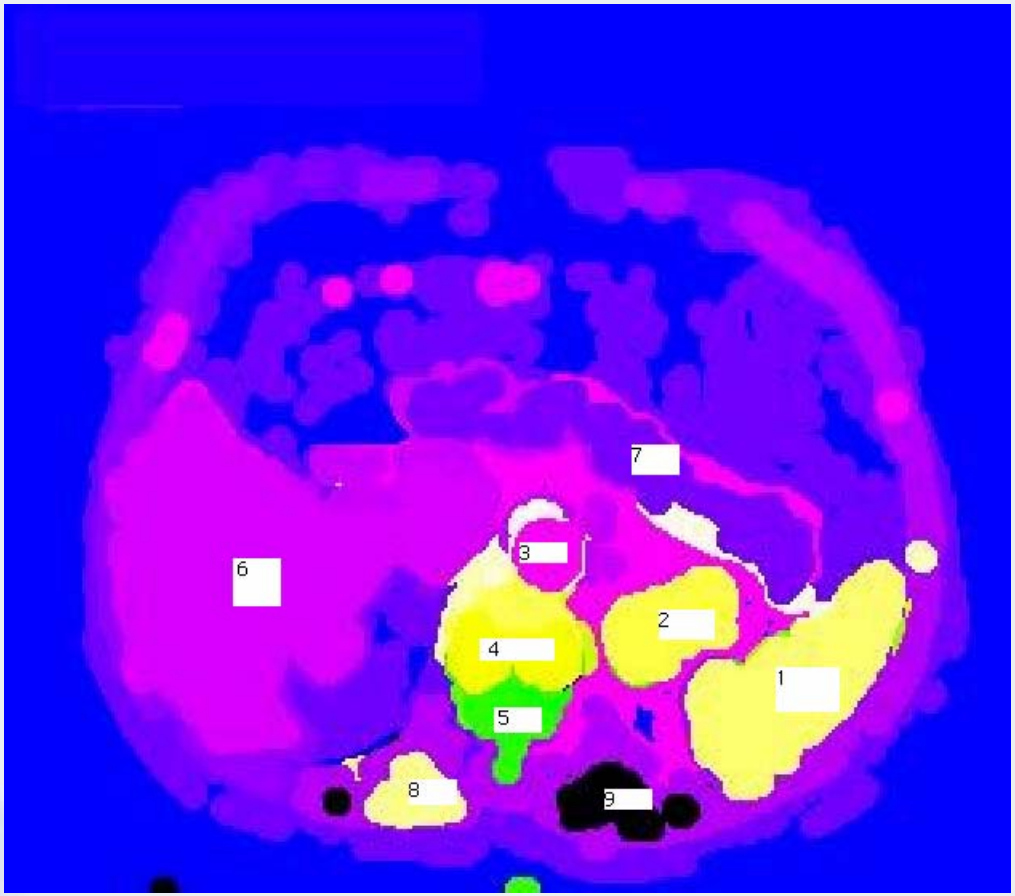
Segmented Image



After Morphological Filtering



Labeled Image



Binary Object Features

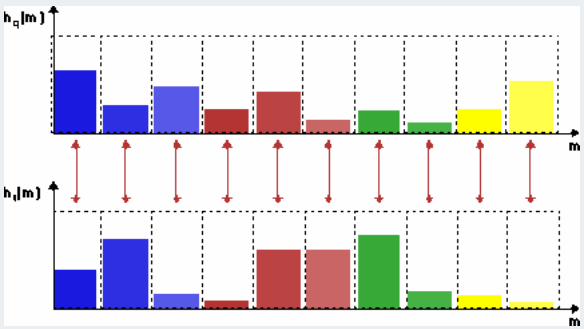
Object	Area	X_c	Y_c	Orientation	Perimeter	Euler No.	Aspect Ratioo
1	2588	213	247	-0.703	200	202	0.932
2	855	194	207	-0.752	100	190	1.114
3	406	172	170	0.780	63	170	0.957
4	787	203	159	0.663	114	202	1.615
5	468	225	157	0.554	145	231	0.892
6	7449	177	79	0.393	413	182	1.061
7	2554	144	193	-0.625	343	134	1.730
8	521	247	128	0.393	78	243	1.333
9	693	250	193	0.625	115	249	1.800
10	4338	16	77	0.000	338	19	4.833
11	16496	142	168	-0.687	1615	94	1.199

Similarity Based Retrieval

- Minkowsky Distance

$$d(Hq,Ht) = \left\{ \sum_{i=1}^{n} |h_q(i) - h_t(i)|^p \right\}^{1/p}$$

  - h_q and h_t are the histograms of query and target images.
  - 'n' is the total number of bins.
  - $h_x(i)$ is the average height of the ith bin.



Similarity Based Retrieval

- Histogram intersection

$$d = 1 - \frac{\sum_{i=1}^{n} \min(h_q[i] - h_t[i])}{\min(|q|, |t|)}$$

  - used to find known objects within images using color histogram
  - The object (q) size is less than the image (t) size.

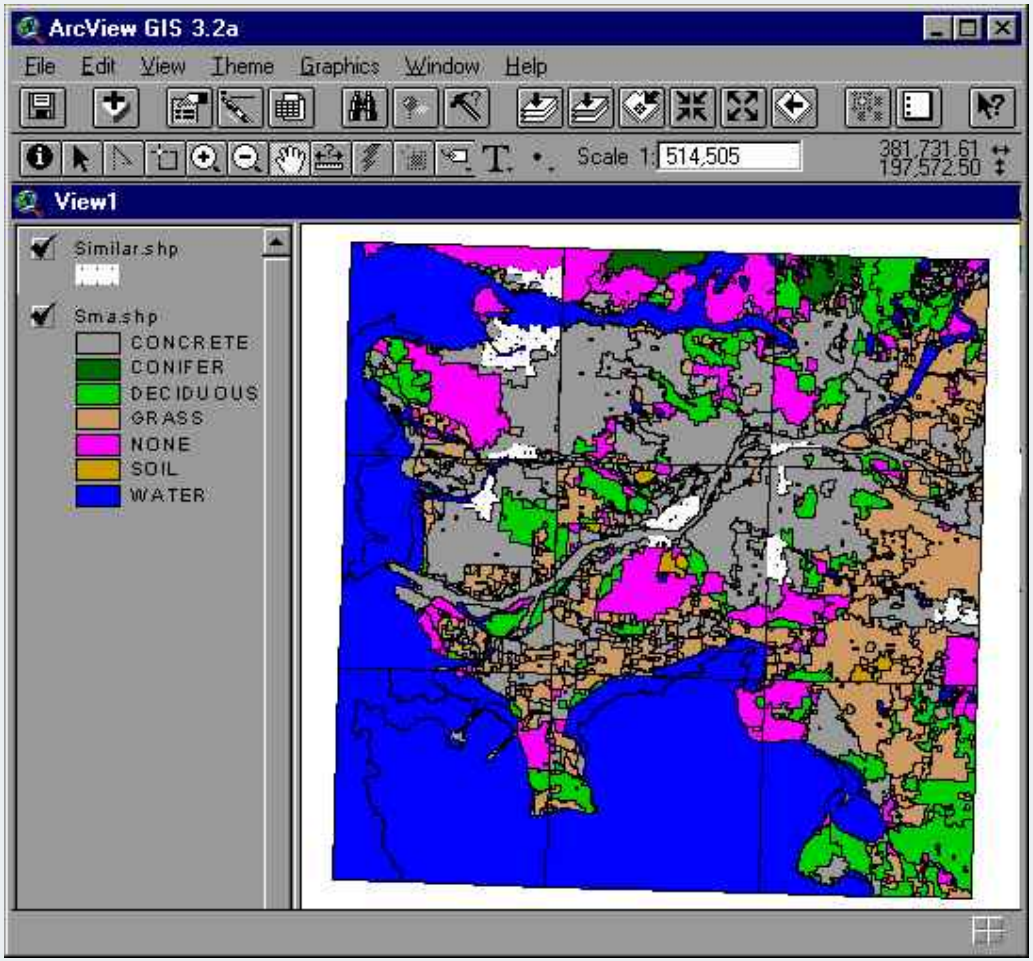
Similarity Based Retrieval

- Histogram Euclidean Distance

$$d = (h_q - h_t)^T (h_q - h_t) = \sum_{i=1}^{n} \left(h_q(i) - h_t(i) \right)^2$$

  - h_q and h_t are the histograms of the query and target images respectively.

Information Retrieval from Satellite Imagery and GIS Data



Segmented Image

Ref: http://gis.esri.com/library/userconf/proc01/professional/papers/pap271/p271.htm

Querying GIS Data (Example)

Query: Find the satellite Images of all downtowns that are similar t (Seattle Downtown)

Similarity is based on level of concrete, vegetation, terrain etc.

Result

Vancouver Downtown

South Seattle Downtown

North Seattle Downtown

Victoria Downtown

Ref: http://gis.esri.com/library/userconf/proc01/professional/papers/pap271/p271.htm

Existing Systems

- Query by Image Content (QBIC) (IBM)
- VisualSEEK (EE, Columbia Univ)
- Blobworld (CS, UC-Berkeley)
- WBIIS (CS, Stanford Univ)
- Multiresolution Wavelets (CS, Univ of Washington)
- Virage (CS, UC-San Diego)
- Chabot
  - Uses color and textual annotation.
  - Improved performance due to textual annotation (concept Query).
- KMeD
  - Uses shapes and contours features.
  - Features are extracted automatically in some cases and manually in other cases.