Image Retrieval Using Kernel Methods

Mini Proposal Defense

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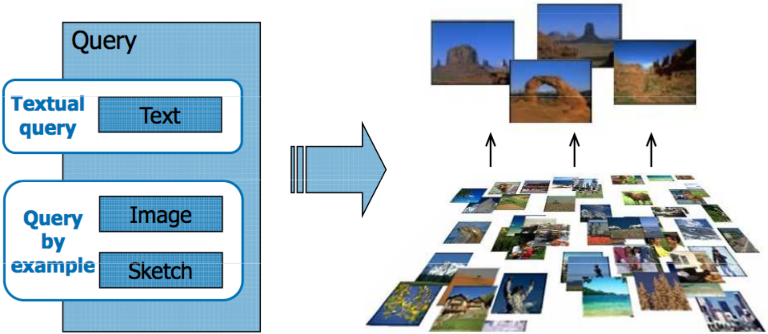
Overview

- What is Content-based Image Retrieval?
- What is Kernel Methods?
- Why is it a good idea to use Kernel Methods?

What is Image Retrieval

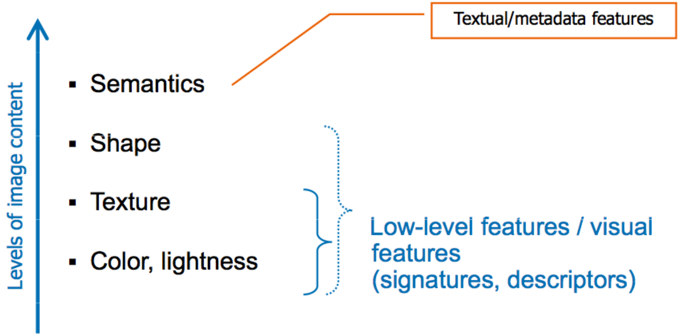


Courtesy of Natalia Vassilieva, Russian Summer School in Information Retrieval 2009

Content-based vs. Description-based

	DBIR	CBIR
+	▪ Fulltext search algorithms are applicable ▪ Search results corresponds to image semantics	▪ Automatic index construction ▪ Index is objective
–	▪ Manual annotating is hardly feasible ▪ Manual annotations are subjective	▪ Semantic gap ▪ Querying by example is not convenient for a user

Features


Levels of image content
Semantics
Shape
Texture
Color, lightness
Textual/metadata features
Low-level features / visual features
(signatures, descriptors)

Similarity

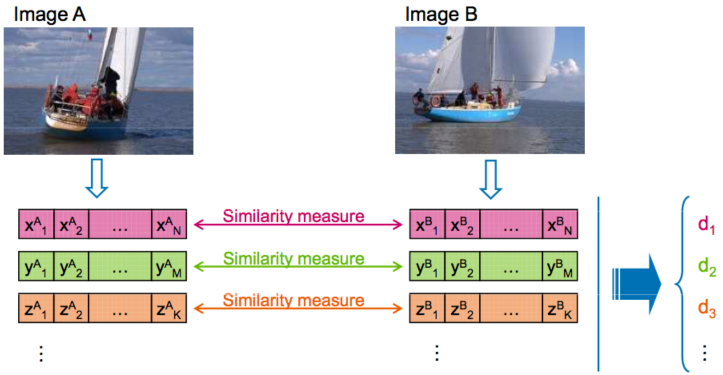
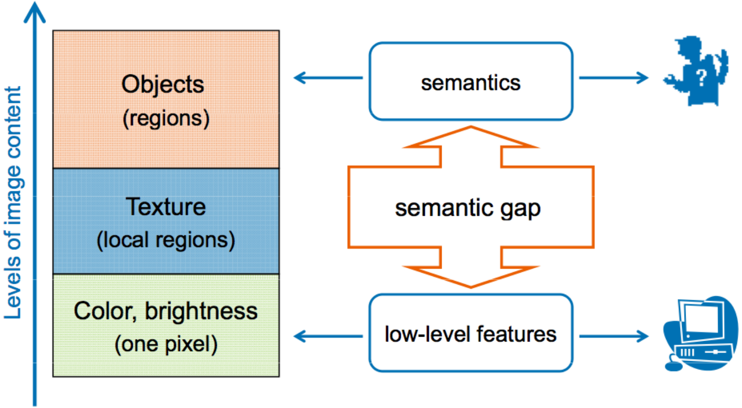


Image A
Image B
x^A_1 x^A_2 ... x^A_N
Similarity measure
x^B_1 x^B_2 ... x^B_N
y^A_1 y^A_2 ... y^A_M
Similarity measure
y^B_1 y^B_2 ... y^B_M
z^A_1 z^A_2 ... z^A_K
Similarity measure
z^B_1 z^B_2 ... z^B_K
d_1
d_2
d_3

Semantic Gap



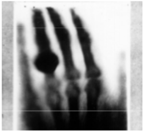
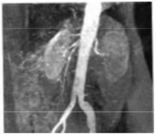
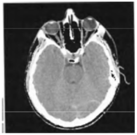
Application: Image Archives





- personal photo collection
- art gallery
- search for uncle John's photos
- search for Monet's painting

Application: Medical Images

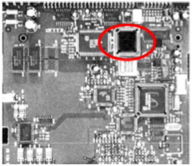
   

- x-ray
- MRI
- pathological vs healthy

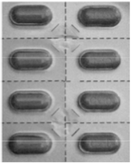
Application: Security

- suspicious items
- face recognition

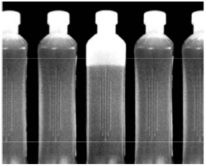
Application: Industry



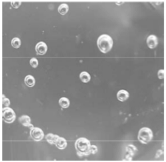
(a) CD-ROM controller



(b) Pack of pills

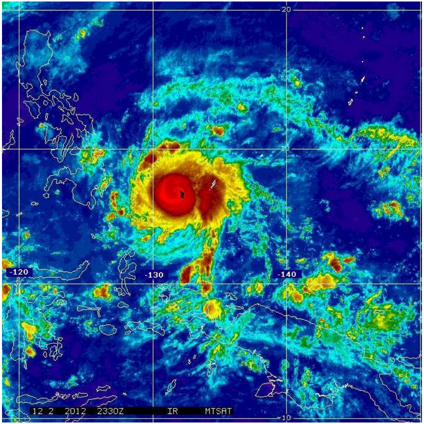


(c) Level of liquid



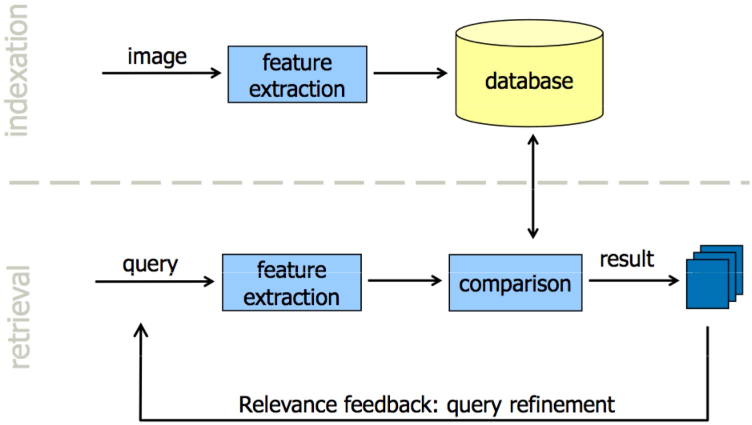
(d) Air-bladders in plastic

Application: Satellite Images

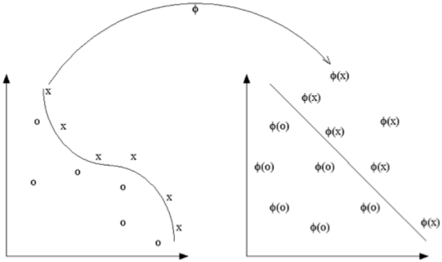


- weather monitoring
- military

Main Components



Courtesy of Natalia Vassilieva, Russian Summer School in Information Retrieval 2009



$$\phi : X \mapsto H$$

Kernel Methods (2)

- no explicit representation, only kernel function
- implicitly calculate in higher dimensional space
- higher dimension $\Rightarrow$ higher capacity
- separation of data representation and algorithm

Kernel Methods (3)

Definition

A positive definite kernel $k(x, x')$ is a function from X^2 to real number such that:

$$\sum_{i,j} a_i a_j k(x_i, x_j) > 0$$

Theorem (Aronszajn theorem)

k is a positive definite kernel if and only if there exist a Hilbert Space H and a mapping $\phi : X \mapsto H$ such that $k(x, x') = \phi(x)^T \phi(x')$ for all $(x, x') \in X^2$

Kernel Methods (4)

Definition (Kernel Trick)

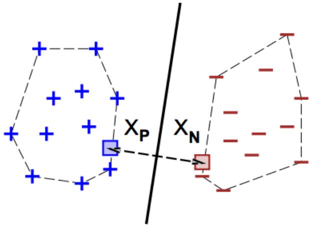
any algorithm for finite-dimensional vectors that only uses pairwise dot-products can be applied in the feature space.

The algorithm and data are separated, hence *Modularity*

Kernel Methods (5) - Examples

- linear kernel, $k_L(x, x') = x^T x'$ and
- polynomial kernel, $k_P(x, x') = (x^T x')^d$
- Gaussian RBF kernel, $k_G(x, x') = exp(-\frac{|x-x'|^2}{2\sigma^2})$

Support Vector Machine

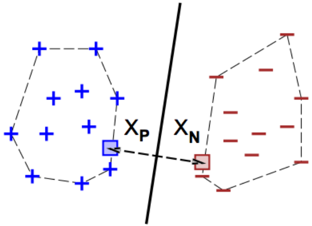


The points X_p and X_n can be parametrized as:

$$X_P = \sum_{i \in P} a_i x_i, \sum a_i = 1$$

$$X_N = \sum_{j \in N} a_j x_j, \sum a_j = 1$$

Support Vector Machine



The solution can be found by optimizing:

$$max||X_P - X_N||^2$$

Online SVM

UPDATE(k):

- Compute $\boldsymbol{X}_P \boldsymbol{x}_k$, $\boldsymbol{X}_N \boldsymbol{x}_k$, and $\boldsymbol{x}_k \boldsymbol{x}_k$.
- Compute λ_u using equations (4) or (5).
- Compute λ using equation (6)
- $\alpha_i \leftarrow (1 - \lambda)\alpha_i$ for all i such that $y_i = y_k$.
- $\alpha_k \leftarrow \alpha_k + \lambda$.
- Update $\boldsymbol{X}_P \boldsymbol{X}_P$, $\boldsymbol{X}_N \boldsymbol{X}_P$ and $\boldsymbol{X}_N \boldsymbol{X}_N$ using equation (7) or (8).

HULLER:

- Initialize $\boldsymbol{X}_P$ and $\boldsymbol{X}_N$ by averaging a few points.
  Compute initial $\boldsymbol{X}_P \boldsymbol{X}_P$, $\boldsymbol{X}_N \boldsymbol{X}_P$, and $\boldsymbol{X}_N \boldsymbol{X}_N$.
- Iterate:
  - Pick a random p such that $\alpha_p = 0$
  - **UPDATE**(p)
  - Pick a random r such that $\alpha_r \neq 0$
  - **UPDATE**(r)

The Huller: a simple and efficient online SVM, Antoine Bordes and Leon Bottou

Future Work - Rigorous Formulation of Problem

- only empirical justification
- hard to compare result
- hidden assumption
  - fixed distribution
  - independent sampling

Future Work - Clustering with SVD

Suppose that our database contains images $I_1, I_2, ..., I_k$, and the image I_j is represented by $[O^j_1, O^j_2, ..., O^j_n]$ then we can construct the matrix below:

$$O = \begin{pmatrix} O^1_1 & O^2_1 & \cdots & O^k_1 \\ O^1_2 & O^2_2 & \cdots & O^k_2 \\ \vdots & \vdots & \ldots & \vdots \\ O^1_n & O^2_n & \cdots & O^k_n \end{pmatrix}$$

Future Work - Clustering with SVD

$$O = U\Sigma V^*$$

where U is an $n \times n$ unitary matrix, Σ is a $n \times k$ diagonal matrix, and V is a $k \times k$ unitary matrix. The core of this method is that we truncate the matrix Σ down to a rank r matrix Σ_r, and U, V to U_r, V_r by keeping only their first r columns.

- SVM is a kind of supervised learning - need label
- similar to PCA

Future Work - Improvement on Algorithm

- multi-classes
- soft margin

Future Work - Kernel Design

- Fisher Kernel is a general framework to design kernel for for probabilistic distribution.
- Pyramid Match Kernel is a kernel used for unordered features sets with variable length

Questions ?