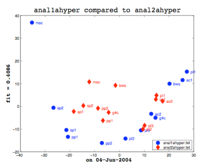
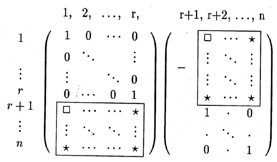
Data Mining and Information retrieval





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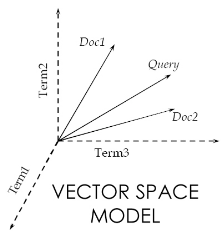

VECTOR SPACE MODEL

27 February 2008

Overview, Lecture I

Data Mining

- What's Data?
  - Record data, numerical data, data matrix, document data, graph data, chemical data, etc.
- What's Data Mining?
- Why Data Mining?
  - Commercial viewpoint
  - Scientific viewpoint

Overview, Lecture I

- Mining Data sets
  - Association Rules
  - Classification
  - Clustering
  - Forecasting
- Challenges of Data Mining
- References

Information Retrieval, Lecture II

- What's Information Retrieval
- Information Retrieval and Business Intelligence
- Data preparation - Parsing
  - Tokenisation
  - Stop words removal
  - Stemming
  - Entity detection
  - Part of speech
- Data storage - Indexing
  - Index construction
- Exploitation - Querying
  - Exploiting data repositories
- Questions

Lecture II

Information Retrieval

27 February 2008

What's Information Retrieval

In the science of searching for information in heterogeneous data sources such as:

- Documents
- Images
- Audio
- Video

What I.R. systems do?

- Take documents in any format
  - Break into words
- Create an index
- Search it very quickly
- Update index when collection changes

Information Retrieval and B.I.

Business Intelligence transforms data into valuable information that can be accessed to help decision makers develop strategic, tactical and operational planning initiatives.

Business Intelligences deals with data integration from structured and unstructured data sources.

Enterprise Search

Enterprise search characteristics:

- Diversity of content sources and formats, and not necessarily HTTP based
- Secure access
- Combined structured and unstructured search
- Dedicated search (e.g. email search)
- Intranet search
- Ranking and categorisation problem
- Social forces behind the creation of Internet and Intranet content are quite different
- Deployment environments for these domains also differs

Enterprise Search comparison with Web search

<u>Similarities</u>

- Crawling
- Indexing and ranking
- User interface

<u>Differences</u>

- Diverse repositories
- Fewer documents
- Access control
- Diverse doc type
- Different user needs
- Less filtering

Data preparation and data source

Different document types requiered different access methods. PDF, MS Word, HTML, Open formats, email, etc.

Good Formatted file

docno="lists-046-11826843"
name="Ron Whitney"
email="RFW@math.ams.org"
sent="Sat, 20 Apr 1996 17:44:20 -0400 (EDT)"
inreplyto="199604201303.6479@uvea.wolfram.com"
* Mail-System-Version:
id="830036660.25042.RFW@MATH.AMS.ORG"
subject="Re: conference call Mon 22 April"
To: w3c-math-erb@w3.org

I was unable to attend last week, but am available this Monday. If the group plans to meet, I'll attend, but I have no specificitems for the agenda now.

-Ron

Bad formatted file

name=""
email="mail137@163.com"
sent="Wed, 8 May 2002 14:39:51 -0400"
subject="øÏÀŸÕΔπ„ƒ˙µƒÕ¯’æ°∞≤˙Δ∑"
To: web-access@w3.org

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µƒ≤˙Δ∑∑¢≤°µΩÕ¯…œ»•°£œ÷‘⁄£¨Œ“√«Õ®π˝“ª–©◊®“µµƒ»Ì°¸
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Parsing, tokenisation

Tokenisation is the process of splitting a stream of words into units or "tokens". Normally this process does not included the following symbols:

- period (.)
- comma (,)
- semicolon (;)
- quotation marks (")
- colon (:)
- brackets [ ]
- braces { }
- parentheses ( )
- mathematical operators + - / * = < >
- special characters | & ~
- the at sign @
- underscores and other rare characters

e.g

The "brown" fox jumps, quickly over the lazy dog*.

<u>The</u> <u>brown</u> <u>fox</u> <u>jumps</u> <u>quickly</u> <u>over</u> <u>the</u> <u>lazy</u> <u>dog</u>

Parsing, stop words removal

Stop Word is the name given to a word that will be filtered and is not consider relevant by an information retrieval system. Some of the more frequently used stop words for English include: *"a", "of ", "the", "I", "it", "you", and "and"*. These are generally regarded as functional words that do not carry meaning for the system.

Stop List is the list or set of *stop words*, there are as many *stop lists* as there are languages. I.e. if a system processes text that includes English, French, German and Spanish it also should be a *stop list* for each of these languages.

Parsing, Stemming

Stemming is the process to obtain a word's root (also called normalisation) through eliminating suffixes.

running	→	run
ran		ran
laughing		laugh
laughs		laugh
laughed		laugh
languished		languish
seals		seal

connection
connections
connective → connect
connected
connecting

Benefits of Stemming

- Takes care of morphological variants
- Reduces index size

Known Limitations

- Impact on advanced syntax and exact match
- Accented characters are not supported
- Short words are not stemmed

more info see: the porter stemming algorithm, http://tartarus.org/~martin/PorterStemmer, http://snowball.tartarus.org/

Parsing, entity detection

The problem here is to find various structured data within unstructured documents, e.g.

- people's names
- project's names
- places
- amounts

Algorithms for entity detection normally are either rule or statistical based.

see: Special Interest Group on Natural Language Learning on the Association for Computational Linguistics (CoNLL). http://cnts.uia.ac.be/signll/conll.html

Parsing, part of speech

Part of speech is a categorisation process that take in consideration phrase function. Each part of speech explains not what the word is, but how the word is used. POS is very useful when dealing with Natural Language Processing in IR.

Parts of speech: the *verb*, the *noun*, the *pronoun*, the *adjective*, the *adverb*, the *preposition*, the *conjunction*, and the *article*.

e.g.

can	I think I can do it.	verb
can	Don't open that can of beans.	noun
only	This is my only pen.	adjective
only	He was only joking.	adverb
his	That book is his.	pronoun
his	That is his book.	adjective
English	Can you speak English?	noun
English	I am reading an English novel.	adjective

Data storage: indexing

After parsing

- Tokenisation
- Stop words removal
- Stemming
- Entity detection
- Part of speech

we can start the indexation process, which consist in storing the tokens in a DB, usually in a vector space fashion

Index design factors

- Merge factors
- Storage techniques
- Index size (compression)
- Lookup speed
- Maintenance
- Fault tolerance
- Scalability

Index construction, inverted index

T1: bab(y, ies, y's)
T2: child(ren's)
T3: guide
T4: health
T5: home
T6: infant
T7: safety
T8: toddler

D1: Infant & Toddler First Aid
D2: Babies & Children's Rooms (For Your Home)
D3: Child Safety at Home
D4: Your Baby's Health and Safety: From Infant to Toddler
D5: Baby Proofing Basics
D6: Your Guide to Easy Rust Proofing
D7: Beanie Babies Collector's Guide

$$
A = \begin{bmatrix}
0 & 1 & 0 & 1 & 1 & 0 & 1 \\
0 & 1 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 1 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 1 & 1 & 0 & 0 & 0 & 0 \\
1 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 1 & 1 & 0 & 0 & 0 \\
1 & 0 & 0 & 1 & 0 & 0 & 0
\end{bmatrix}
$$

Vector Space Model (VSM)

$$\mathbf{t}_i^T = \begin{bmatrix} x_{i,1} & \dots & x_{i,n} \end{bmatrix} \qquad \mathbf{d}_j = \begin{bmatrix} x_{1,j} \\ \vdots \\ x_{m,j} \end{bmatrix}$$

$$\begin{array}{cc} & \mathbf{d}_j \\ & \downarrow \\ \mathbf{t}_i^T \rightarrow & \begin{bmatrix} x_{1,1} & \dots & x_{1,n} \\ \vdots & \ddots & \vdots \\ x_{m,1} & \dots & x_{m,n} \end{bmatrix} \end{array}$$

Binary	$\chi(f_{ij})$
Logarithmic	$log(1 + f_{ij})$
Normal	$1/\sqrt{\sum_j f_{ij}^2}$
Inverse Document Frequency	$log(n/\sum_j \chi(f_{ij})$
etc.	....

Where:

f_{ij} : number of times term *i* in document *j*

Similarity

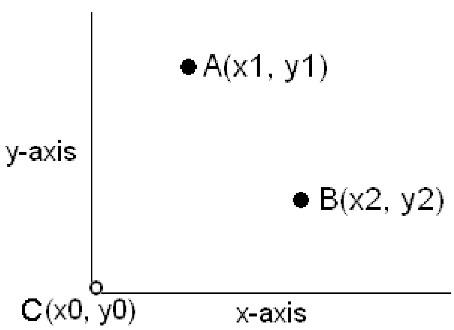
Similarity help to identifying the closeness between different vectors or in our case documents (or between a query and documents).

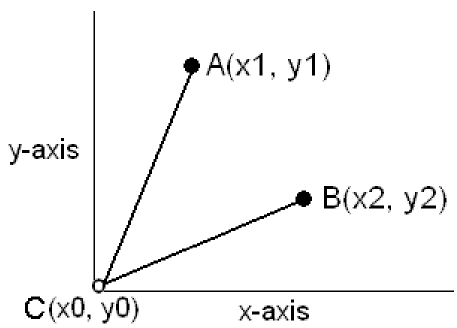
Similarity is based in a metric that defines distance

Euclidean distances in the classical example

Similarity

Vector Space geometrically explained (2 dimensions)





Dot product

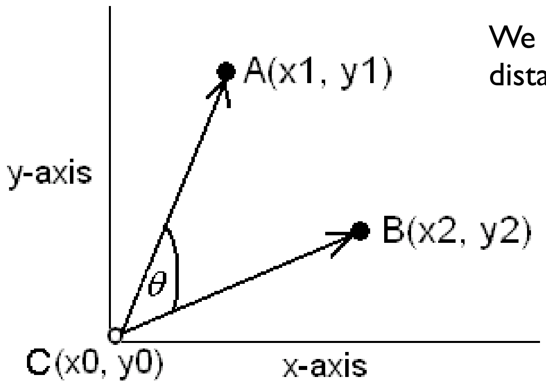
A•B = x1*x2 + y1*y2

Pythagorean theorem

$a^2 + b^2 = c^2 \qquad c = \sqrt{a^2 + b^2}.$

Euclidean distance a, b = $d_{ab} = ((x1 - x0)^2 + (y1 - y0)^2)^{1/2} = (x12 + y12)^{1/2}$

Similarity, how far is A from B?



We normalise the dot product by the Euclidean distance. This ratio defines the cosine.

Dot product

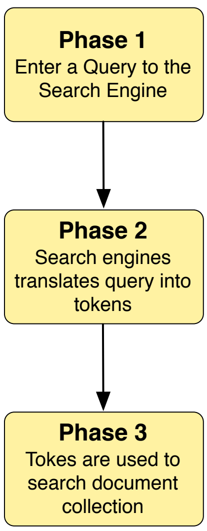
$$\mathrm{Sim}(A, B) = \text{cosine } \theta = \frac{A \bullet B}{|A||B|} = \frac{x1 * x2 + y1 * y2}{(x1^2 + y1^2)^{1/2} \; (x2^2 + y2^2)^{1/2}}$$

Distance

Similarity between a query and a document

$$\mathrm{Sim}(Q, D_i) = \frac{\sum_i w_{Q,j} w_{i,j}}{\sqrt{\sum_j w_{Q,j}^2} \sqrt{\sum_i w_{i,j}^2}}$$

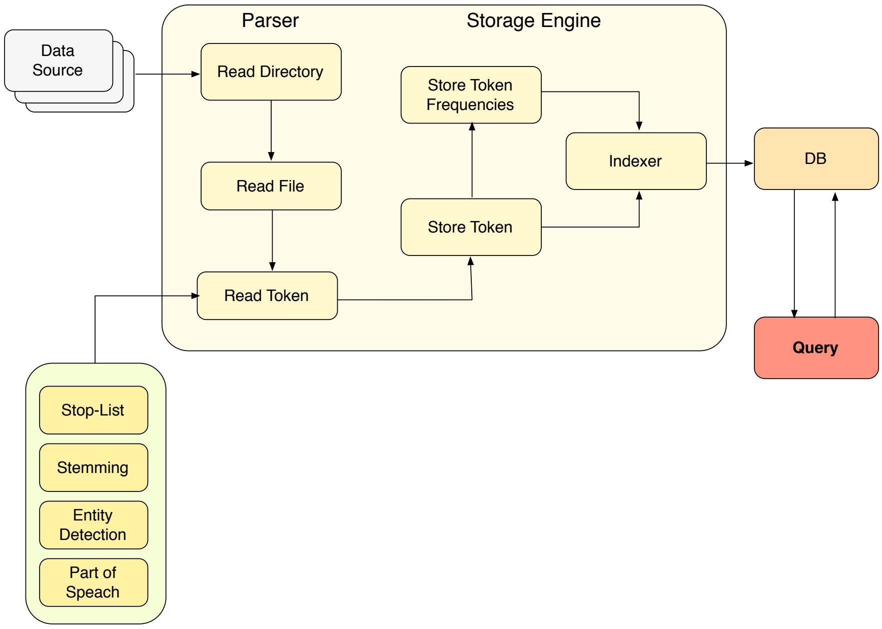
System exploitation, querying



Types of Queries

- **Boolean**: *AND, OR, NOT*
- **Natural Language Queries**: query is formulated as a question or a statement
- **Thesaurus Queries**: the user select the term from a previous term-set provided by the IR system
- **Fuzzy Queries**: threshold of relevance is expanded to include additional documents
- **Term Searches:** based in a few words or phrases provided by the user
- **Probabilistic Queries**: IR systems based in a computed probability to retrieve documents

An IR system overview



Sorting the query's result

To present a query's result to the user the output should be sorted in a meaningful way.

For example we can use the cosine similarity measure to rank result.

Also we can use clustering!

Ranking

For ranking we can use different mathematical functions based in word frequencies to determine the importance of a query's result.

Then we can sort this result in ascent order.

Clustering

Given a set of data points, each having a set of attributes, and a similarity measure among them, find clusters such that:

– Data points in one cluster are more similar to one another
– Data points in separate clusters are less similar to one another

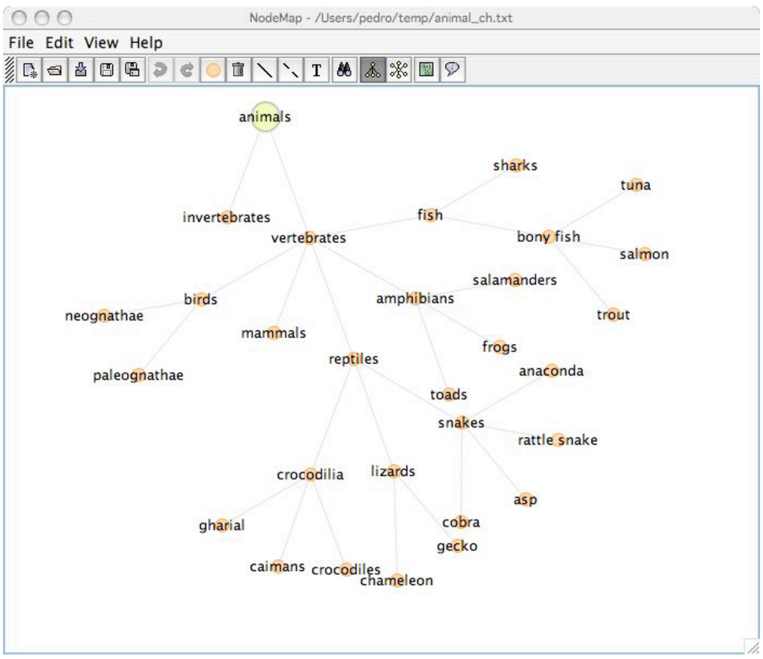
Unlike the classification problem here we do not know the labels or data categories, for this reason this is also called unsupervised learning.

Evaluation of I.R. systems

$$\text{Recall} = \frac{\text{No. of relevant docs retrieved}}{\text{Total relevant in the collection}}$$

$$\text{Precision} = \frac{\text{No. of relevant docs retrieved}}{\text{Total retrieved in the collection}}$$

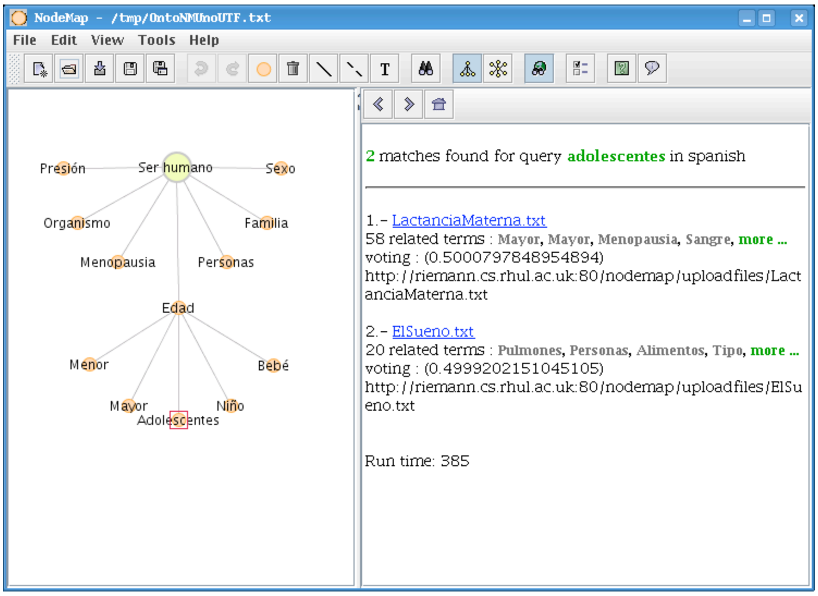
Demo 1: text classification



Here we have an ontology and we would like to assign or classify documents on a given category

http://thames.cs.rhul.ac.uk/wstalk

Demo 1: text classification



http://thames.cs.rhul.ac.uk/wstalk/prototype.html

Demo 2: email search

file:<keyword>

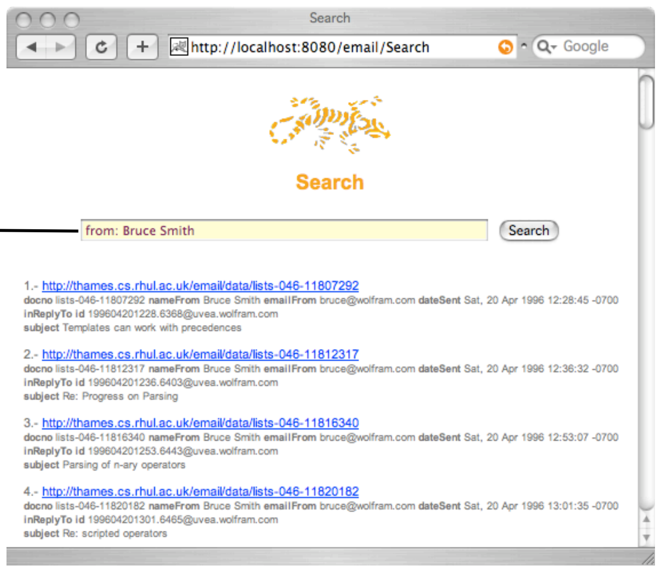
from: <name>

to: <email to>

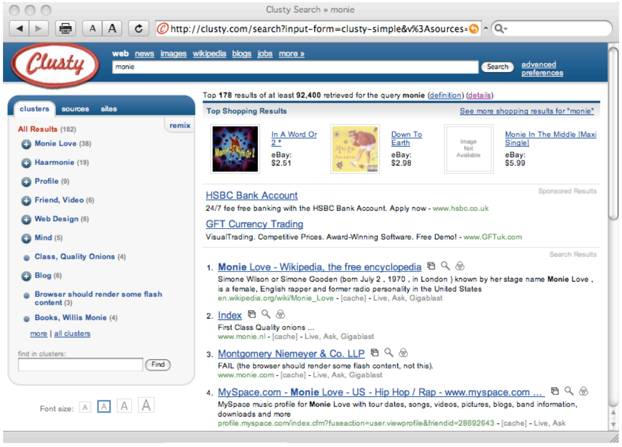
cc: <email cc>

subject: <subject>

<keyword>



Search engines



Commercial

Google · YAHOO! · Ask · alltheweb find it all

HOTBOT · WebCrawler® The Web's Top Search Engines Spun Together · Live Search · altavista · ....

Open source

Lucene · Terrier · Xapian · a personal full-text search system Estraier · and so on...

The web needs a lot of servers

Enterprise search

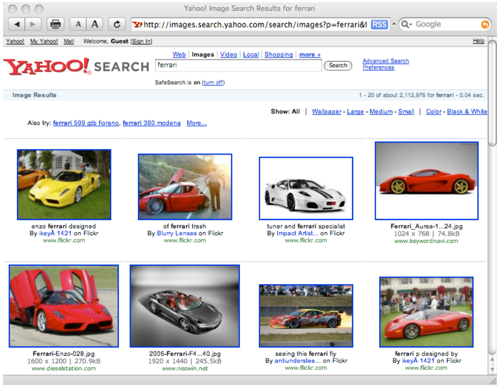
Not just docs. Multimedia I.R.

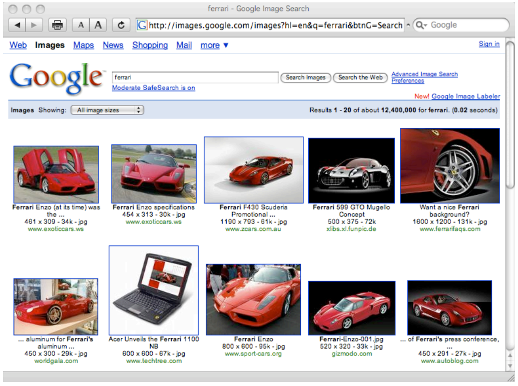
Content is not just text-based, there is more than text, i.e.

- Images
- Video
- Audio

But there again there isn’t a perfect technique... let’s see some examples

Text based image retrieval

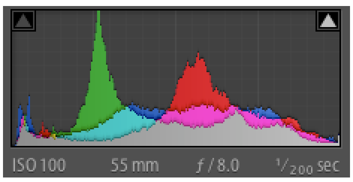


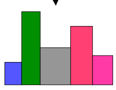


e.g. Using information from the web site to annotate images

- Neighbouring text
- Same paragraph text
- Tittle
- Heading
- etc.

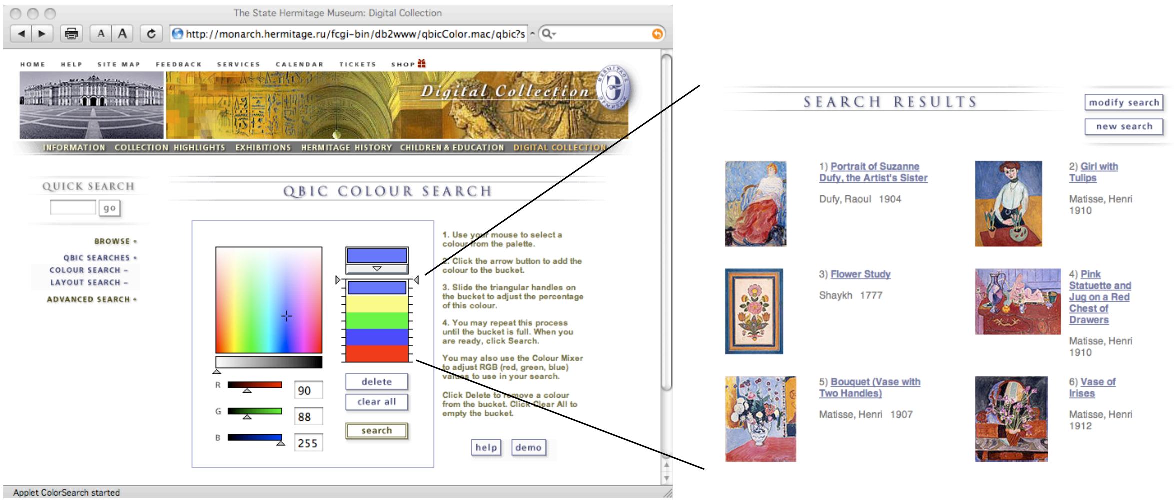
Colour histogram based image retrieval





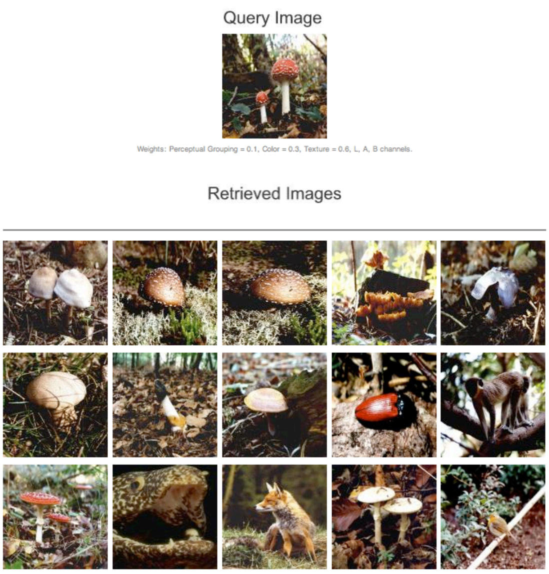
Take an image, convert to histogram and used to query image index

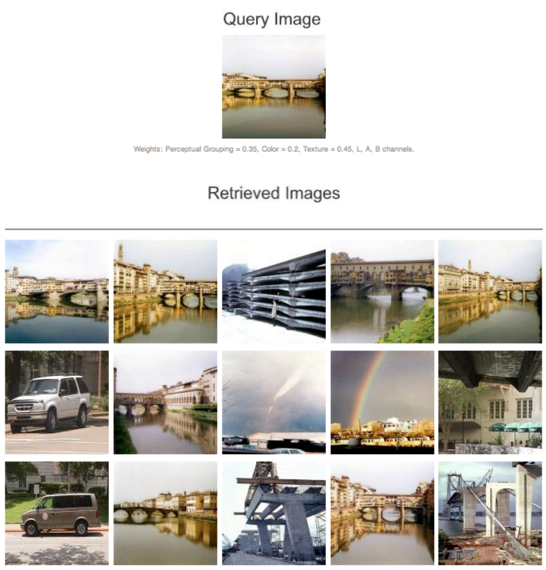
Colour based image retrieval



http://www.hermitagemuseum.org/

Features based image retrieval





http://amazon.ece.utexas.edu/~qasim/cires.htm

Questions

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