CS4241: Lecture 1

Intro to MM Information Retrieval

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Topics

These are the topics that we will cover in the course:

- Introduction
- MM Retrieval-Framework
- Color-based Retrieval
- Texture-based Retrieval
- Shape-based Retrieval
- Audio Retrieval
- Video Retrieval
- Multi-attribute query and knowledge-based retrieval
- MM Info Systems Trends

MM Info Retrieval

Concerns with:

- Basic concepts and techniques in retrieving (unstructured) information
- Indexing and similarity-based retrieval of multimedia data

What is an information retrieval system?

- A system used to process, store, search, retrieve and disseminate information items
- Examples: DBMS, Free-text Systems, Hypermedia Systems etc.

Information Needs

- Volume of Information is growing at an exponential rate
  - By 1800, the amount of scientific information was doubling every 50 years
  - From 1800 to 1966, the no. of scientific journals has increased from 100 to over 10,000
- Large amount of data is available in the electronic form
  - Newspaper and picture archives, video & music catalogs, satellite images, financial data etc.
  - Latest web estimates: 1 billion pages, 20 terabytes of information: see

http://www.neci.nj.nec.com/homepages/lawrence/websize.html

We are inundated with information!

Info Retrieval Needs

- Aids are needed to retrieve information:
  - friends, library card system, references, reviews etc.
- Difficult since the data is unstructured
  - it differs from the DBMS structured record:

Name:<s>	Sex:<s>	Age:<I>	NRIC:<s>	···

- Information must be analyzed, indexed (either automatically or manually) for retrieval purposes.
- Examples:
  - text retrieval systems (LINC, Information Banks, AltaVista)
  - image systems (hospitals, police mugshot systems, TCS)
  - others: video, music information bases

Properties of MM Data

1: Media

2: Visual in nature?

3: Ease of data entry

4: Abstract concepts

5: Spatial Dimensions

6: Temporal Dimension

7: Does it have a well-defined interaction unit?

8: Does it have a well-defined semantic unit?

1	2	3	4	5	6	7	8
Text	Y	Easy	Y	1	N	Y	Y
Graphics	Y	Moderate	N	2-3	Y/N	Y	N
Image	Y	Difficult	N	2	N	N	N
Video	Y	Very Difficult	N	2	Y	N	N
Audio	N	Moderate	Y	1	Y	N	N

Info Retrieval Process

1. Information Seeking Need

2. Formulation of Requirements (in terms of a Query)

3. Retrieve Information that meets the Requirements

4. Return (ranked) List of Relevant Information

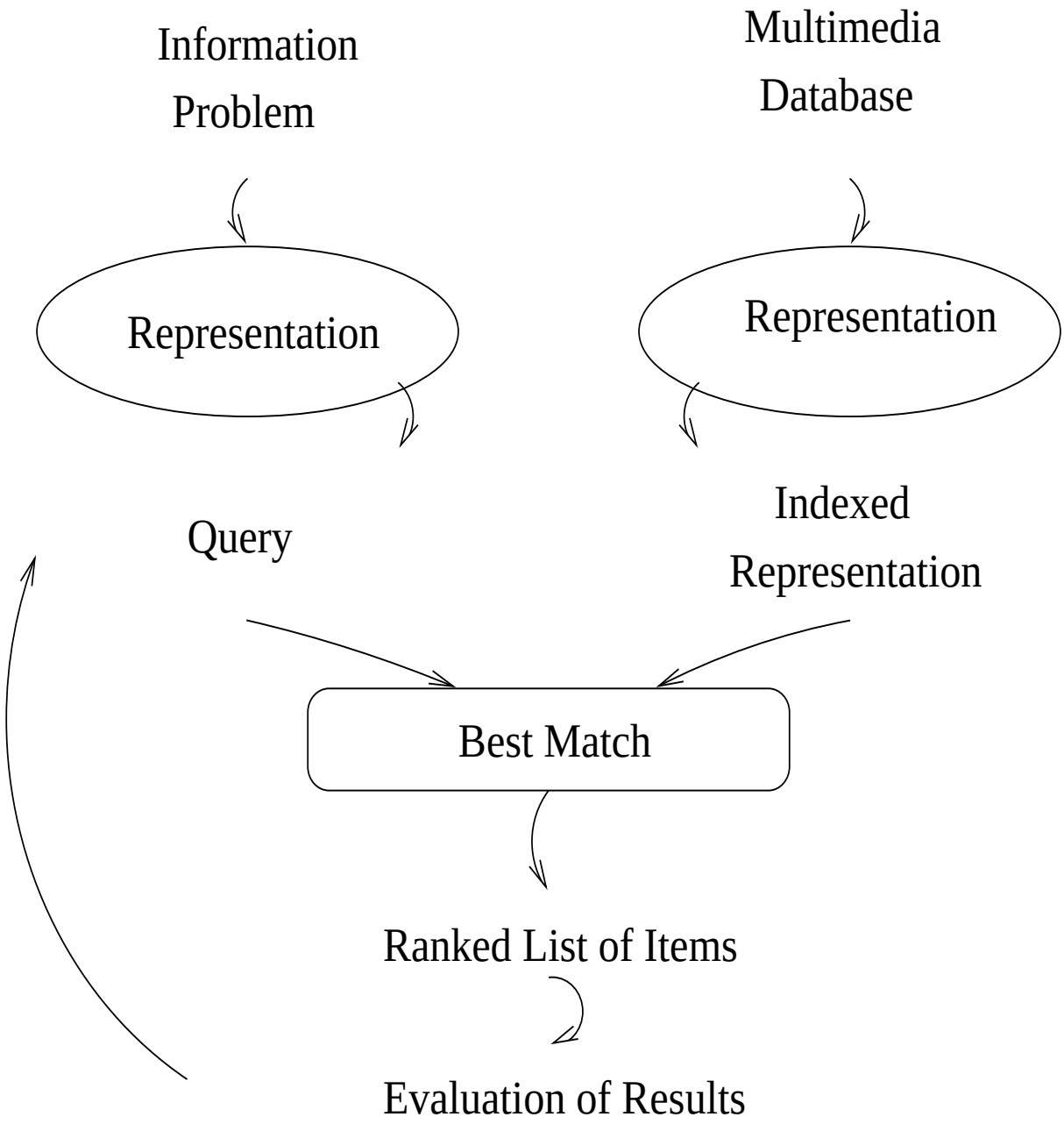
5. Go back to 2 if necessary

Note:

- The process can be repeated with new, improved formulation of information requirements

System Overview

Overview of a typical query-based IR system



Attributes Considered

These are some of the typical attributes considered for MM (Image, Audio & Video) data:

- No inherent structure
  - just an array of pixels with text captions
- Global features:
  - text description
  - color, texture
  - color with spatial information
  - heuristic measures for dominant shape
  - can be automatically extracted and indexed
- Local features:
  - shapes: need to perform image/frame segmentation
  - manual in nature

Query Processing

Query processing for visual data needs special attention:

- query formulation:
  - sample image
  - colors, textures, shapes etc.
- queries are ambiguous and often incomplete
- representation is also inexact
- relevance can be determined easily

Architecture

The architecture of the retrieval model has four layers:

Concept Layer
(names of objects and relationships)

Object Layer
(blocks of attributes)

Feature Layer
(colors, textures, extracted shapes)

Data Layer
(images, video, text documents)

Similarity Measures

Given two multimedia objects:

$$\begin{aligned} X &= (x_1, x_2, \ldots, x_n), \text{ where } x_i \, \epsilon \, \mathbf{R} \\ Y &= (y_1, y_2, \ldots, y_n), \text{ where } y_i \, \epsilon \, \mathbf{R} \end{aligned}$$

We need a measure to determine the closeness between these two objects.

There are three types of similarity measures:

- Distance Measures
- Correlation Coefficients
- Association Coefficients

Distance Measures

1. Mean Character Difference:

$$\frac{1}{n}\sum_{i=1}^{n}|x_i - y_i|$$

2. Minkowski Metric:

$$d(X,Y) = \left(\sum_{i=1}^{n}|x_i - y_i|^r\right)^{\frac{1}{r}}$$

   (a) Manhattan Distance (r = 1)

$$d(X,Y) = \sum_{i=1}^{n}|x_i - y_i|$$

   (b) Euclidean Distance (r = 2)

$$d(X,Y) = \left(\sum_{i=1}^{n}(x_i - y_i)^2\right)^{\frac{1}{2}}$$

   Intutive notion of distance!

   (c) Chebyshev Distance (r = ∞)

$$d(X,Y) = \max_{1\le i\le n}|x_i - y_i|$$

Correlation Coefficients

- Unnormalized Correlation Coefficient:

$$C = \sum_{i=1}^{n} x_i y_i$$

  Inner product of vectors!

- Cosine Measure:

$$\cos\theta = \frac{\sum_{i=1}^{n} x_i y_i}{\sqrt{\sum_{i=1}^{n} {x_i}^2}\sqrt{\sum_{i=1}^{n} {x_i}^2}}$$

- Pearson Product Moment Measure:

$$r_{XY} = \frac{\sum_{i=1}^{n}(x_i - \overline{x}_i)(y_i - \overline{y}_i)}{\sqrt{\sum_{i=1}^{n}(x_i - \overline{x}_i)^2 \sum_{i=1}^{n}(y_i - \overline{y}_i)^2}}$$

  - measures moments around mean
  - similar to cosine measure

Association Coefficients I

- For binary or multi-state features
- Measures the amount of agreement

Assume: 2 binary valued feature vectors:

$$X = (x_1, x_2, \ldots, x_n) \quad Y = (y_1, y_2, \ldots, y_n)$$

For the two objects X and Y, let

α = number of features which are 1 for both

β = number of features which is 1 for X and 0 for Y

γ = number of features which is 0 for X and 1 for Y

δ = number of features which are 0 for both

Association Coeffs II

Then we have the following measures:

$$\text{[Russel \& Rao]}\ d(X,Y) = \frac{\alpha}{\alpha + \beta + \gamma + \delta}$$

$$\text{[Jaccard \& Needham]}\ d(X,Y) = \frac{\alpha}{\alpha + \beta + \gamma}$$

$$\text{[Kulzinski]}\ d(X,Y) = \frac{\alpha}{\beta + \gamma}$$

$$\text{[Sokal \& Mitchener]}\ d(X,Y) = \frac{\alpha + \delta}{\alpha + \beta + \gamma + \delta}$$

$$\text{[Rogers \& Tanimoto]}\ d(X,Y) = \frac{\alpha + \delta}{\alpha + \delta + 2(\beta + \gamma)}$$

$$\text{[Yule]}\ d(X,Y) = \frac{\alpha\delta - \beta\gamma}{\alpha\delta + \beta\gamma}$$

Gower's general similarity coefficient, S_G,

$$S_G = \frac{\sum_{i=1}^{n} \omega_i s_i}{\sum_{i=1}^{n} \omega_i}$$

where $s_i = 1$ if x_i matches y_i and $s_i = 0$ if x_i mismatches y_i. $\omega_i = 1$ if the comparison is valid and is 0 if comparison is not valid or if the state is unknown.

Complex Sim. Measures

- Multiple Features:
  - like color, texture and shape for images

  If each feature i has measure σ_i
  then the overall similarity measure is:

$$\sigma = \sum_{i=1}^{k} \lambda_i \sigma_i$$

  The weights λ_i are usually chosen empirically.

- Compound Retrieval:
  - mix of continuous & binary features
  - k features with similarity measure σ_i
  - j binary features

  Then the overall similarity measure is:

$$\sigma = \prod_{j} \rho_j(X, Y) \sum_{k} \lambda_k \sigma_k(X, Y).$$

Data Considerations I

Normalization

1. *Ranging:*

$$x'_i \;=\; \frac{x_i \;-\; x_{\min}}{x_{\max} \;-\; x_{\min}}$$

   Features now range from 0 to 1

   No lopsided effect of any feature!

2. *Zero Mean:* Assume N objects:

$$m_i \;=\; \frac{1}{N}\sum_N x_i$$

   Then the normalization can be done in this manner:

$$x'_i \;=\; x_i \;-\; m_i$$

3. *Zero Mean and Unit Variance*:

$$s_i \;=\; \frac{1}{N}\sum_N (x_i \;-\; m_i)^2$$

   and the normalization can be applied as:

$$x'_i \;=\; \frac{x_i \;-\; m_i}{s_i}.$$

Data Considerations II

Missing Data

Suppose a feature is missing from the query object or a database object
Then how to compute the distance?
Let

$$d_i = \begin{cases} 0 & \text{if } x_i \text{ or } y_i \text{ is missing} \\ x_i - y_i & \text{otherwise} \end{cases}$$

Then the distance between X and Y is defined as:

$$d(X,Y) = \frac{n}{n - n_0}\sqrt{\sum_i {d_i}^2}$$

where n_0 is the number of features missing in X or Y or both.

Summary

- There is an information explosion
- Need to process, store and retrieve this data effectively (by content) and efficiently (using indexes)
- We will focus on unstructured text, image and video data
- These data have local and global attributes
- Features are extracted for these attributes which uniquely capture the attributes
- Data objects are retrieved by *feature similarity*
- Various types of similarity measures are employed:
  - Distance Measures
  - Correlation Coefficients
  - Association Coefficients