Building Topic Hierarchy of e-Documents using Text Mining Technology

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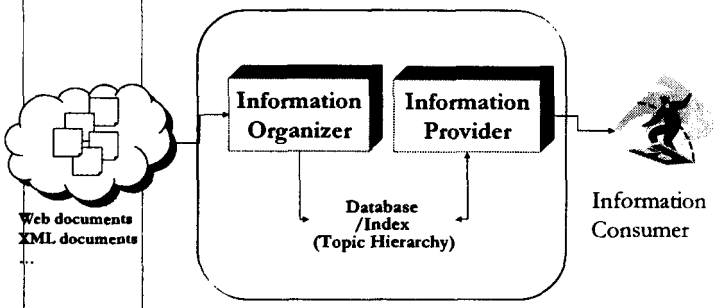
Information System



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Information Organization

- **Indexing**
  - **Key word-based**
    - **Polysemy/Synonymy problem**
  - **Topic-based**
    - **Topic hierarchy: Yahoo-style**

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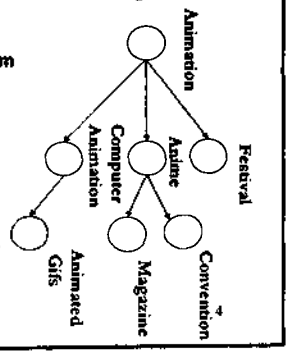
Introduction

- **Topic hierarchy paradigm**
  - **Summary view of a large amount of information**
- **Management of a large document collection**
  - **Topic hierarchy based Information System**
    - **Web search engine: Yahoo!, Lycos, Open Directory**
    - **Digital libraries: Library of Congress Catalog**
  - **Topic-oriented indexing**
  - **Browsing directories**
- **Maintenance of topic hierarchy**
  - **limitation of manual maintenance**



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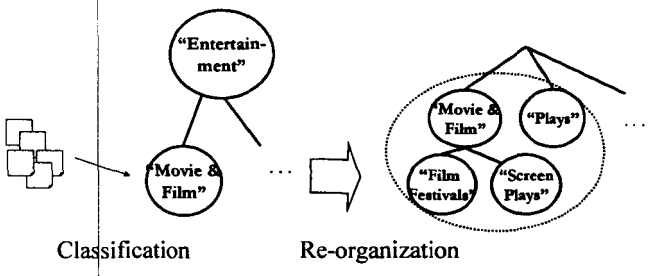
Information Organization: topic-based



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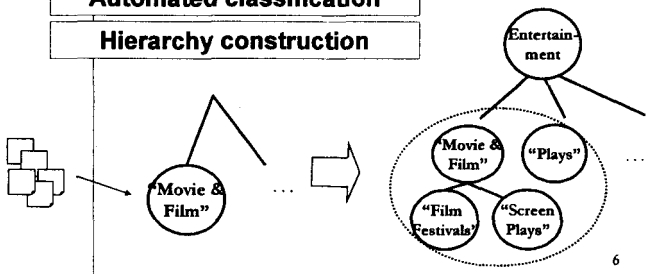
Information Organization

- **Issues : Text-Mining approach**
  - **Topic discovery (clustering)**
  - **Automated classification**
  - **Hierarchy construction**



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Clustering (Topic Discovery)

- **Document clustering**
  - **Grouping a set of documents into classes of similar documents**

Document Collection

Clustering

A *B* *C* *D* *E*

Clusters

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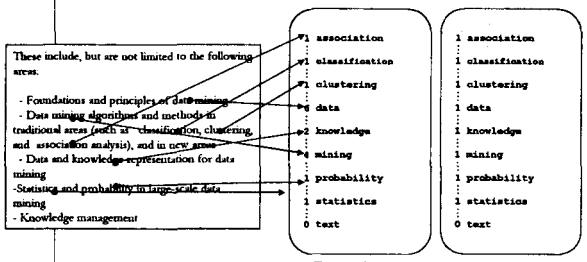
Preliminaries

- **Document representation**



Unstructured document

Bag-of-words representation

Boolean representation

Vector representation

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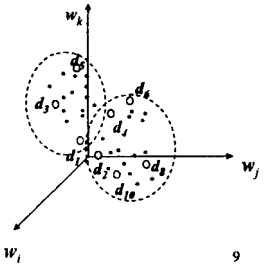
Clustering (Topic Discovery)

- **Conventional clustering methods**
  - **Hierarchical clustering methods**
  - **Depends on the standard Euclidean distance metric**
  - **Not suitable for topic discovery**
- **Goal**
  - **Generate user-specific clusters !**



Supervised Clustering (Topic Discovery)

Document Collection

Clustering

Human Knowledge

A' B' C' D' E'

Clusters ⇨ **Topics (categories)**

Distance Functions

- **Euclidean distance function**

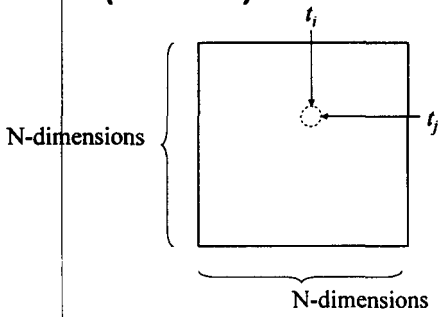
$$dist_{\mathbf{W}}(\vec{d}_x, \vec{d}_y) = \sqrt{(\vec{d}_x - \vec{d}_y)^T \cdot \square \cdot (\vec{d}_x - \vec{d}_y)}$$

- **Quadratic distance function**

$$dist_{\mathbf{W}}(\vec{d}_x, \vec{d}_y) = \sqrt{(\vec{d}_x - \vec{d}_y)^T \, \mathbf{W} \, (\vec{d}_x - \vec{d}_y)}$$

Weight Matrix

- **Representing the inter-correlation of terms (features)**



Quadratic Distance Function

- **Examples**
  - Vocabulay = {'*digital*', '*image*', '*picture*'}
  - "*e-book with digital images*"
    - $d_1 = (1, 1, 0)$
  - "*picture book*"
    - $d_2 = (0, 0, 1)$
  - **Weight Matrix**
  - **Distance values**

$$W_{novelist} = \begin{array}{c} \begin{matrix} d & i & p \end{matrix} \\ \begin{pmatrix} 1.0 & 0.0 & 0.0 \\ 0.0 & 1.0 & 0.8 \\ 0.0 & 0.8 & 1.0 \end{pmatrix} \end{array} \begin{matrix} d \\ i \\ p \end{matrix}$$

$$W_{scientist} = \begin{pmatrix} 1.0 & 0.5 & 0.0 \\ 0.5 & 1.0 & 0.0 \\ 0.0 & 0.0 & 1.0 \end{pmatrix} \begin{matrix} d \\ i \\ p \end{matrix}$$

$$dist_{standard}(d_1, d_2) = \sqrt{3}$$

$$dist_{novelist}(d_1, d_2) = \sqrt{1.2}$$

$$dist_{scientist}(d_1, d_2) = \sqrt{3.5}$$

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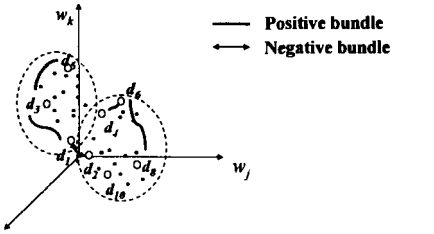
Human Knowledge

- **Document bundles (or bundles)**
  - **Positive/Negative bundles**



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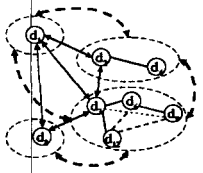
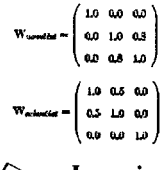
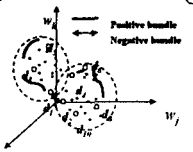
Supervised Clustering: overview



Bundle Knowledge



Learning weight matrix



Clustering

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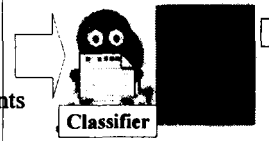
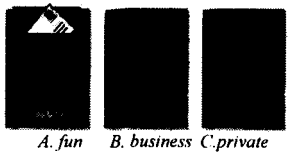
Automated Classification

Training e-Documents





Unknown e-Documents

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Automated Classification

Factors to Consider	Manual	Automated
Cost (per document)	High	Low
Speed	Slow	Fast
Consistency	Variable	High
Quality	Variable	Variable

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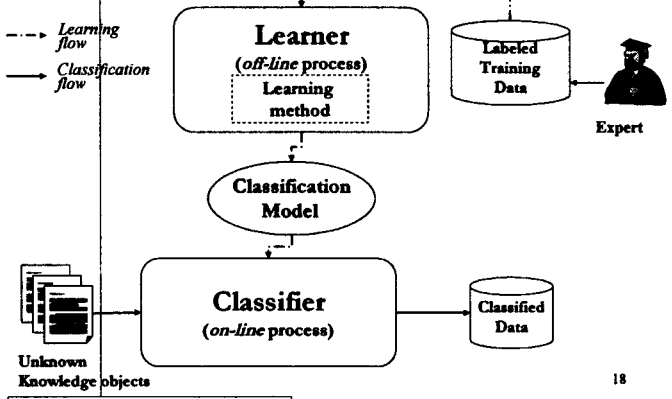
Machine Learning based approach (Basic architecture)



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Automated Classification

- **Related algorithms**
  - Decision trees
  - Neural networks
  - Support vector machines
  - Bayesian statistics
  - etc

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Automated Classification

- **Critical Issue**
  - Difficulty in obtaining good quality training data
  - Related researches
    - Active learning
      - Actively selecting the best training data out of unclassified ones
    - EM algorithms
      - Augment of labeled (training) documents with classifying unlabeled documents

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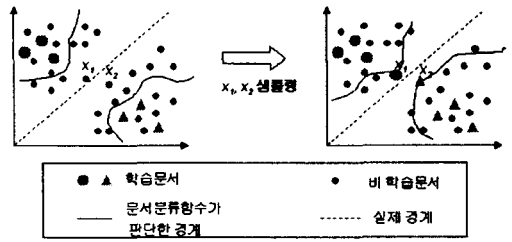
Active Learning

- **Uncertainty-based sampling**



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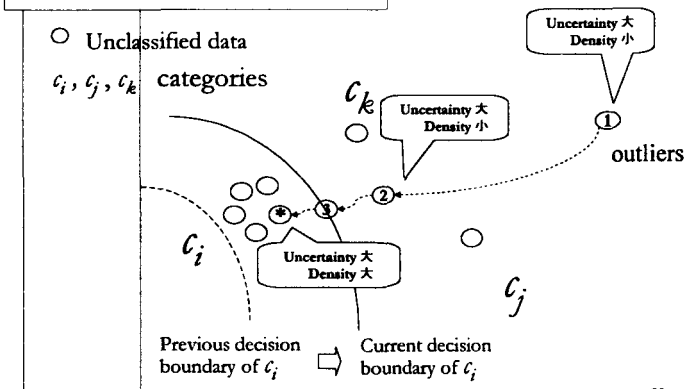
Uncertainty/Density-based Selective Sampling



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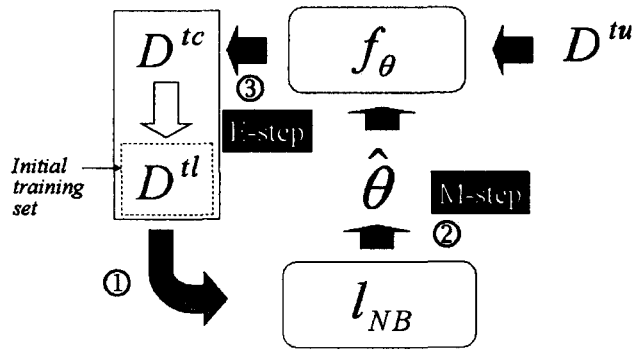
EM (Expectation Maximization) algorithm



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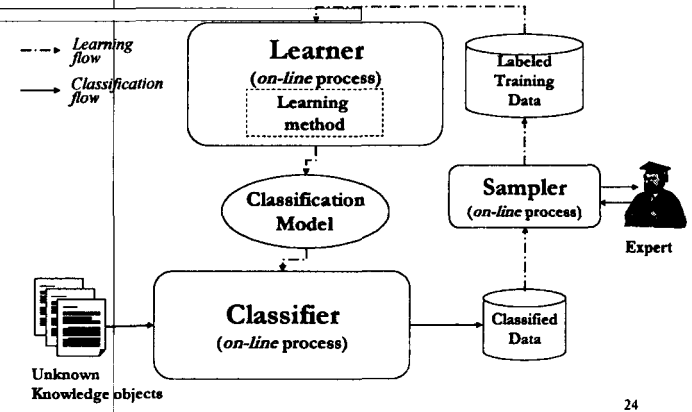
Machine Learning based approach (The proposed architecture)



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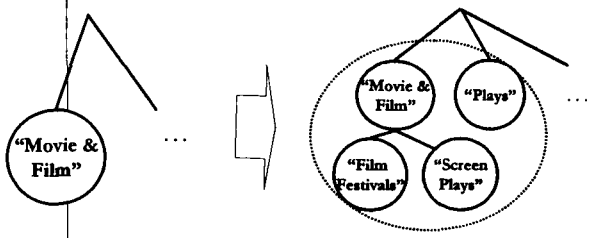
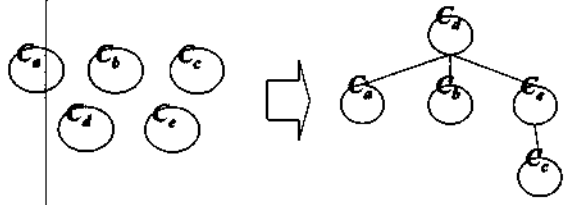
Topic Hierarchy Construction



- **Goal : find category subsumption relations**
  - **Solution: generate fuzzy partial ordering**

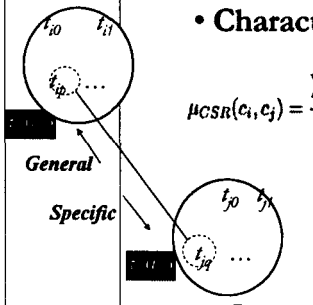
Topic Hierarchy Construction

- **Goal : find category subsumption relation**



Category Subsumption Relation

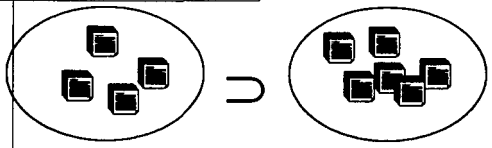
Category A



- **Characteristic function**

$$\mu_{CSR}(c_i, c_j) = \frac{\sum_{t_i \in V_{c_i}, t_j \in V_{c_j}} \tau_{c_i}(t_i) \cdot \tau_{c_j}(t_j) \cdot Pr(D_{t_j} \subset D_{t_i})}{\sum_{t_i \in V_{c_i}, t_j \in V_{c_j}} \tau_{c_i}(t_i) \cdot \tau_{c_j}(t_j)}$$

Term Subsumption Relation

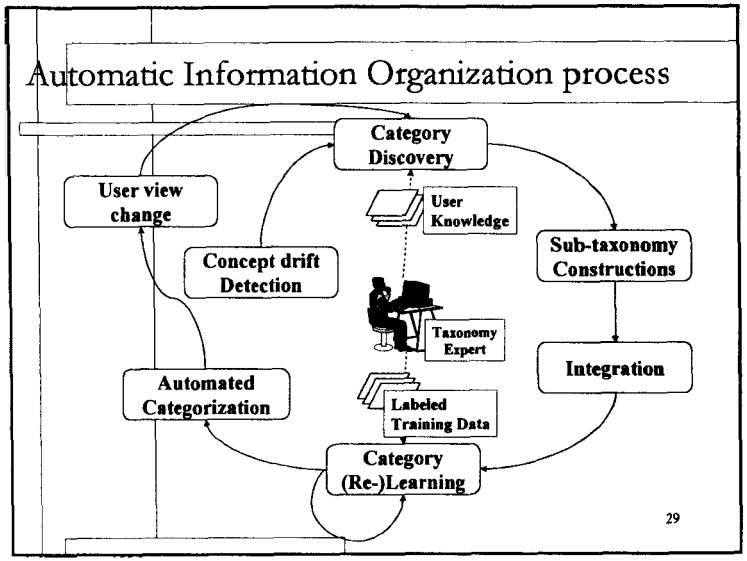


D_{t_i} D_{t_j}

t_i : more general

/

t_j



Summary

- **Text-mining approach to e-documents organization based on topic hierarchy**
  - **Machine-Learning & information Theory-based**
    - ***'Category (topic) discovery' problem***
      - → document bundle-based user-constraint document clustering
    - ***'Automatic categorization' problem***
      - → Accelerated EM with CU-based active learning
    - ***'Hierarchy Construction' problem***
      - → Unsupervised learning of category subsumption relation

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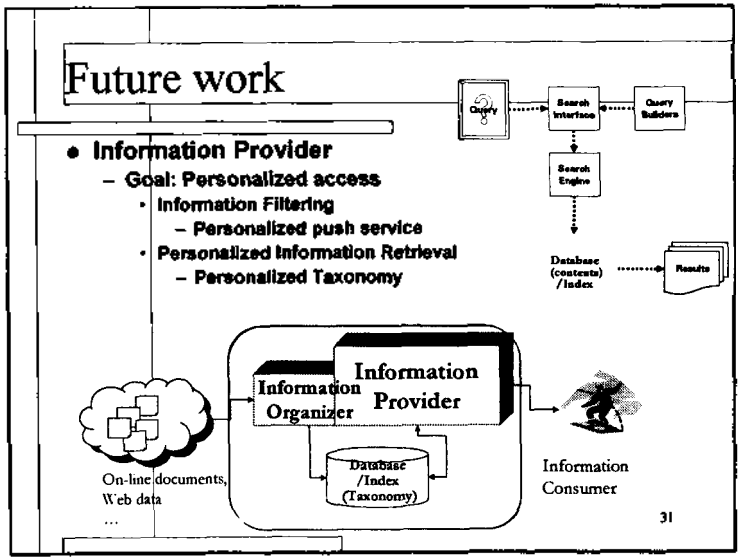

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Thank you

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