Introduction to Web Mining

- **Mining text databases**
- Mining the Web
- Summary

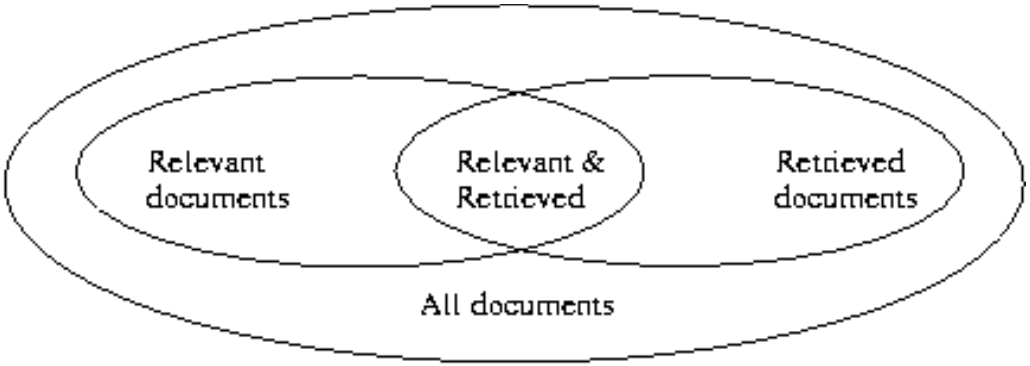
Text Databases and Information Retrieval

- Text databases (document databases)
  - Large collections of documents from various sources: news articles, research papers, books, digital libraries, e-mail messages, and Web pages, library database, etc.
  - Data stored is usually *semi-structured*
  - Traditional information retrieval techniques become inadequate for the increasingly vast amounts of text data
- Information retrieval
  - A field developed in parallel with database systems
  - Information is organized into (a large number of) documents
  - Information retrieval problem: locating relevant documents based on user input, such as keywords or example documents

Information Retrieval

- Typical IR systems
  - Online library catalogs
  - Online document management systems
- Information retrieval vs. database systems
  - Some DB problems are not present in IR, e.g., update, transaction management, complex objects
  - Some IR problems are not addressed well in DBMS, e.g., unstructured documents, approximate (in contrast to exact) search using keywords and relevance

Basic Measures for Text Retrieval



- Precision: the percentage of retrieved documents that are in fact relevant to the query (i.e., "correct" responses)

$$precision = \frac{|\{Relevant\} \cap \{Retrieved\}|}{|\{Retrieved\}|}$$

- Recall: the percentage of documents that are relevant to the query and were, in fact, retrieved

$$recall = \frac{|\{Relevant\} \cap \{Retrieved\}|}{|\{Relevant\}|}$$

Keyword-Based Retrieval

- A document is represented by a string, which can be identified by a set of keywords
- Queries may use expressions of keywords
  - E.g., car *and* repair shop, tea *or* coffee, DBMS *but not* Oracle
  - Queries and retrieval should consider synonyms, e.g., repair and maintenance
- Major difficulties of the model
  - Synonymy: A keyword *T* does not appear anywhere in the document, even though the document is closely related to *T*, e.g., data mining
  - Polysemy: The same keyword may mean different things in different contexts, e.g., mining in data mining vs. mining in archeology

Document Data

- Each document becomes a "term" vector,
  - each term is a component (attribute) of the vector,
  - the value of each component is the number of times the corresponding term occurs in the document.

	team	coach	play	ball	score	game	wi n	lost	timeout	season
Document 1	3	0	5	0	2	6	0	2	0	2
Document 2	0	7	0	2	1	0	0	3	0	0
Document 3	0	1	0	0	1	2	2	0	3	0

	Word Frequency								
Book Number	The	Big-Data	Analytics	Tree	newbie	book	for	Girl	honest
1	120	80	60	20	1	5	120	0	0
2	110	0	0	100	10	20	100	40	10
3	130	0	0	10	11	30	110	20	10
4	100	0	0	2	20	40	100	10	100
5	90	0	0	10	30	20	100	100	40

Similarity-Based Retrieval in Text Databases

- Finds similar documents based on a set of common keywords
- Answer should be based on the degree of relevance based on the *nearness of the keywords*, *relative frequency of the keywords*, etc.
- Basic techniques
  - Stop list
    - Set of words that are deemed "irrelevant", even though they may appear frequently
    - E.g., *a, the, of, for, with*, etc.
    - Stop lists may vary when document set varies

Similarity-Based Retrieval in Text Databases (cont.)

- Basic techniques (cont.)
  - Word stem
    - Several words are small syntactic variants of each other since they share a common word stem
    - E.g., *drug, drugs, drugged*
  - A term frequency table
    - Each entry *frequent_table(i, j)* = # of occurrences of the word t_i in document d_i
    - Usually, the *ratio* instead of the absolute number of occurrences is used
  - Similarity metrics: measure the closeness of a document to a query (a set of keywords)
    - Relative term occurrences
    - Cosine distance:

$$S(v_1, v_2) = \frac{v_1 \cdot v_2}{\|v_1\| \times \|v_2\|}$$

Cosine Similarity

- If d_1 and d_2 are two document vectors, then

$$\cos(d_1, d_2) = \frac{d_1 \cdot d_2}{\|d_1\| \times \|d_2\|}$$

where • indicates vector dot product and ||*d*|| denotes the length of vector *d*.

- Example:

d_1 = **3 2 0 5 0 0 0 2 0 0**
d_2 = **1 0 0 0 0 0 0 1 0 2**

$d_1 \bullet d_2$ = 3*1 + 2*0 + 0*0 + 5*0 + 0*0 + 0*0 + 0*0 + 2*1 + 0*0 + 0*2 = 5

$||d_1||$ = (3*3+2*2+0*0+5*5+0*0+0*0+0*0+2*2+0*0+0*0)$^{0.5}$ = (42) $^{0.5}$ = 6.481

$||d_2||$ = (1*1+0*0+0*0+0*0+0*0+0*0+0*0+1*1+0*0+2*2) $^{0.5}$ = (6) $^{0.5}$ = 2.245

cos(d_1, d_2) = 0.3150

Types of Text Data Mining

- Keyword-based association analysis
- Document Clustering (text categorization)
- Similarity detection
  - Cluster documents by a common author
  - Cluster documents containing information from a common source
- Link analysis: unusual correlation between entities
- Sequence analysis: predicting a recurring event
- Anomaly detection: find information that violates usual patterns
- Hypertext analysis
  - Patterns in anchors/links
    - Anchor text correlations with linked objects

Keyword-based association analysis

- Collect sets of keywords or terms that occur frequently together and then find the association or correlation relationships among them
- First preprocess the text data by parsing, stemming, removing stop words, etc.
- Then evoke association mining algorithms
  - Consider each document as a transaction
  - View a set of keywords in the document as a set of items in the transaction
- Term level association mining
  - No need for human effort in tagging documents
  - The number of meaningless results and the execution time is greatly reduced

Document Clustering

- Automatically group related documents based on their contents
- Require no training sets or predetermined taxonomies, generate a taxonomy at runtime
- Major steps
  - Preprocessing
    - Remove stop words, stem, feature extraction, lexical analysis, …
  - Hierarchical clustering
    - Compute similarities applying clustering algorithms, …
  - Slicing
    - Fan out controls, flatten the tree to configurable number of levels, …

Web Mining

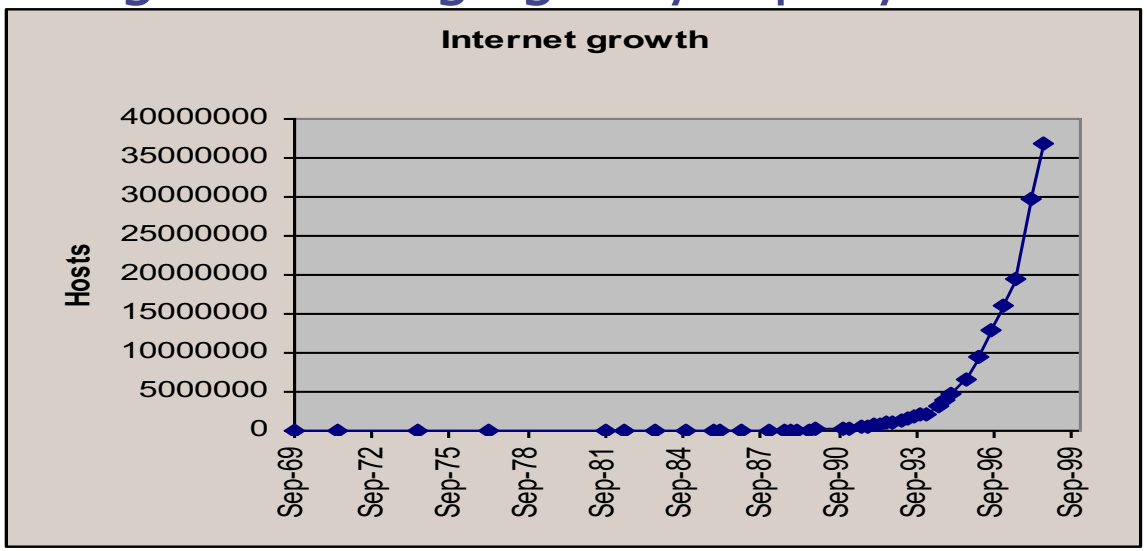
- Mining text databases
- **Mining the Web**
- Summary

Mining the World-Wide Web

- The WWW is huge, widely distributed, global information service center for
  - Information services: news, advertisements, consumer information, financial management, education, government, e-commerce, etc.
  - Hyper-link information
  - Access and usage information
- WWW provides rich sources for data mining
- Challenges
  - Too huge for effective data warehousing and data mining
  - Too complex and heterogeneous: no standards and structure

Mining the World-Wide Web (cont.)

- Growing and changing very rapidly



- Broad diversity of user communities
- Only a small portion of the information on the Web is truly relevant or useful
  - 99% of the Web information is useless to 99% of Web users
  - How can we find high-quality Web pages on a specified topic?

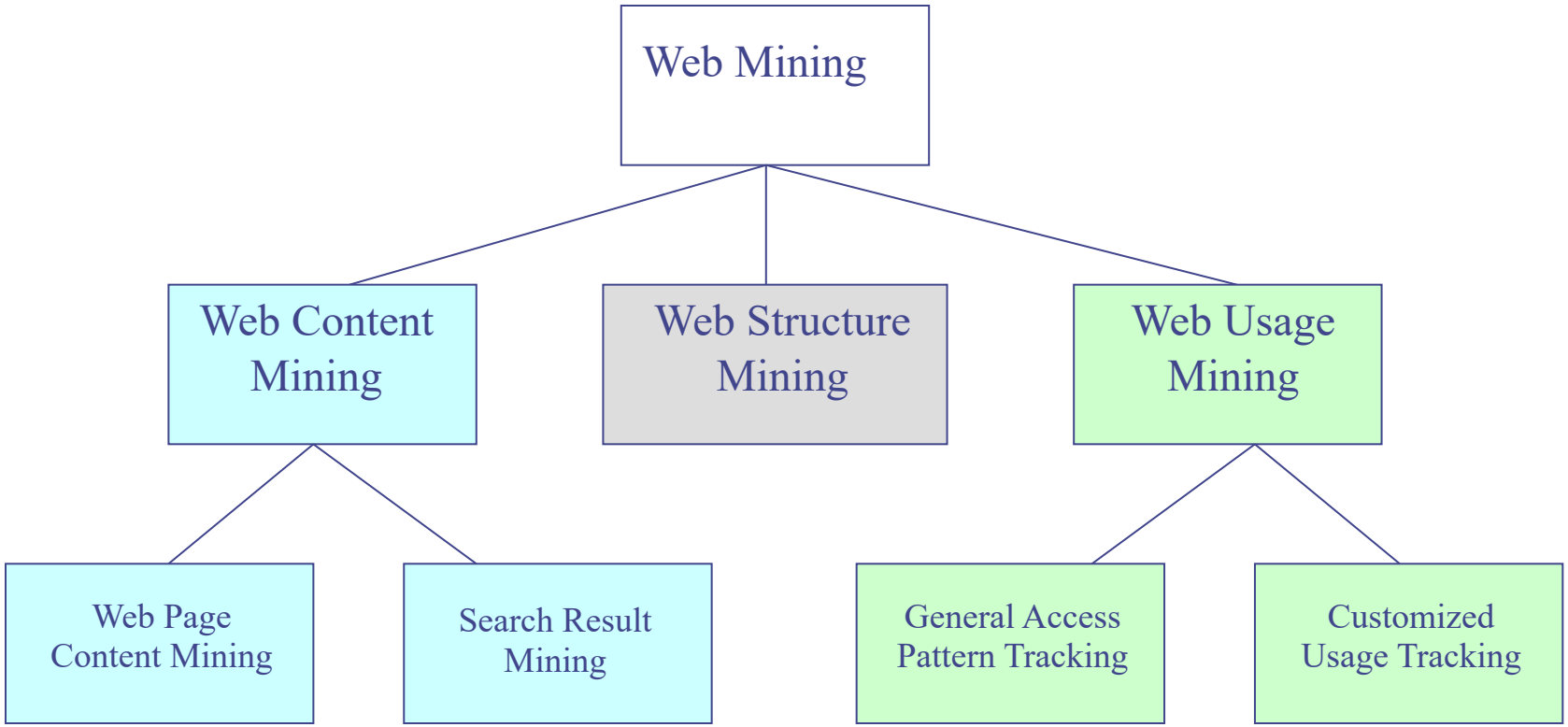
Web search engines

- Index-based: search the Web, index Web pages, and build and store huge keyword-based indices
- Help locate sets of Web pages containing certain keywords
- Deficiencies
  - A topic of any breadth may easily contain hundreds of thousands of documents
  - Many documents that are highly relevant to a topic may not contain keywords defining them (polysemy)

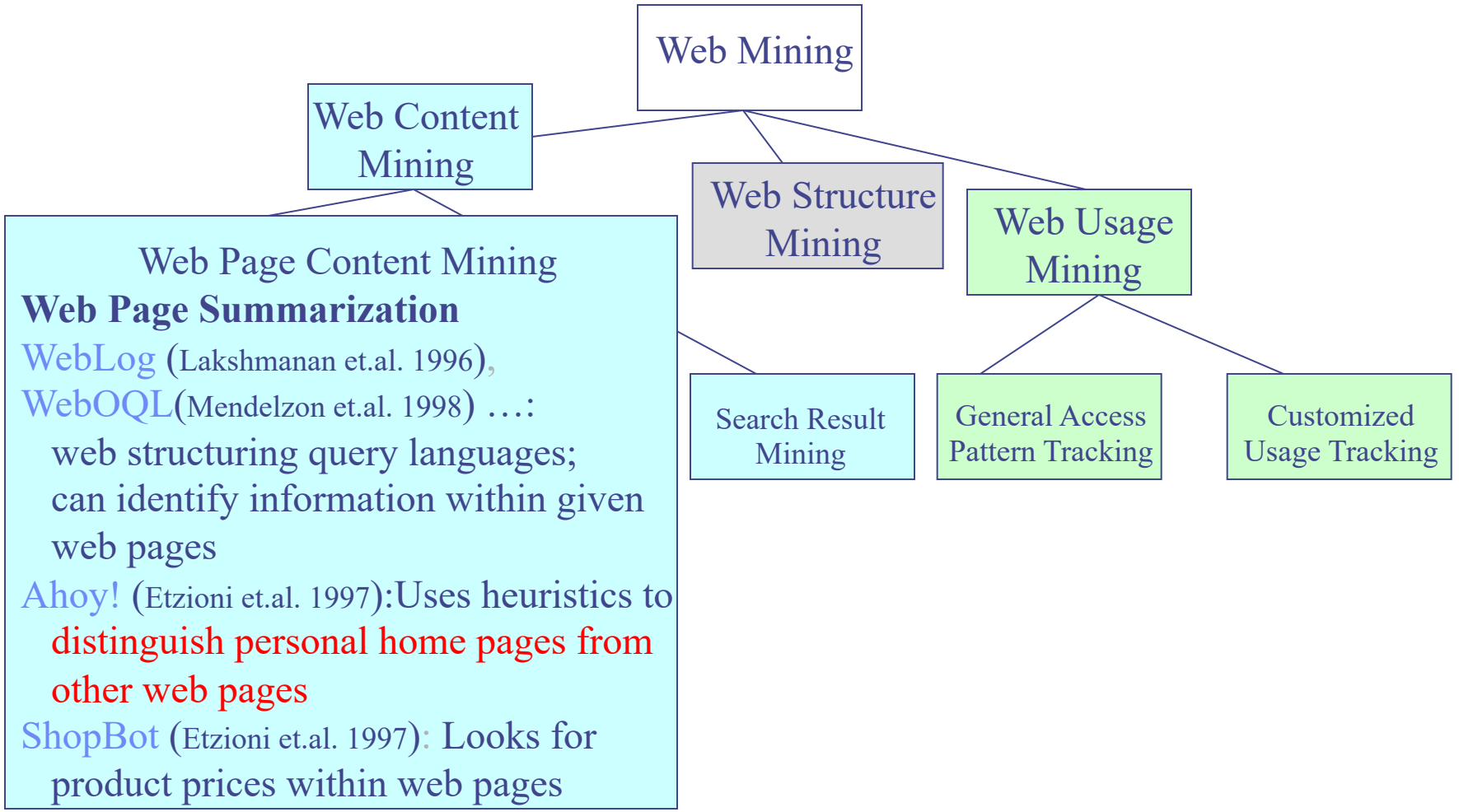
Web Mining: A more challenging task

- Searches for
  - Web access patterns
  - Web structures
  - Regularity and dynamics of Web contents
- Problems
  - The "abundance" problem
  - Limited coverage of the Web: hidden Web sources, majority of data in DBMS
  - Limited query interface based on keyword-oriented search
  - Limited customization to individual users⇒Personalization Issue

Web Mining Taxonomy



Web Mining Taxonomy (cont.)



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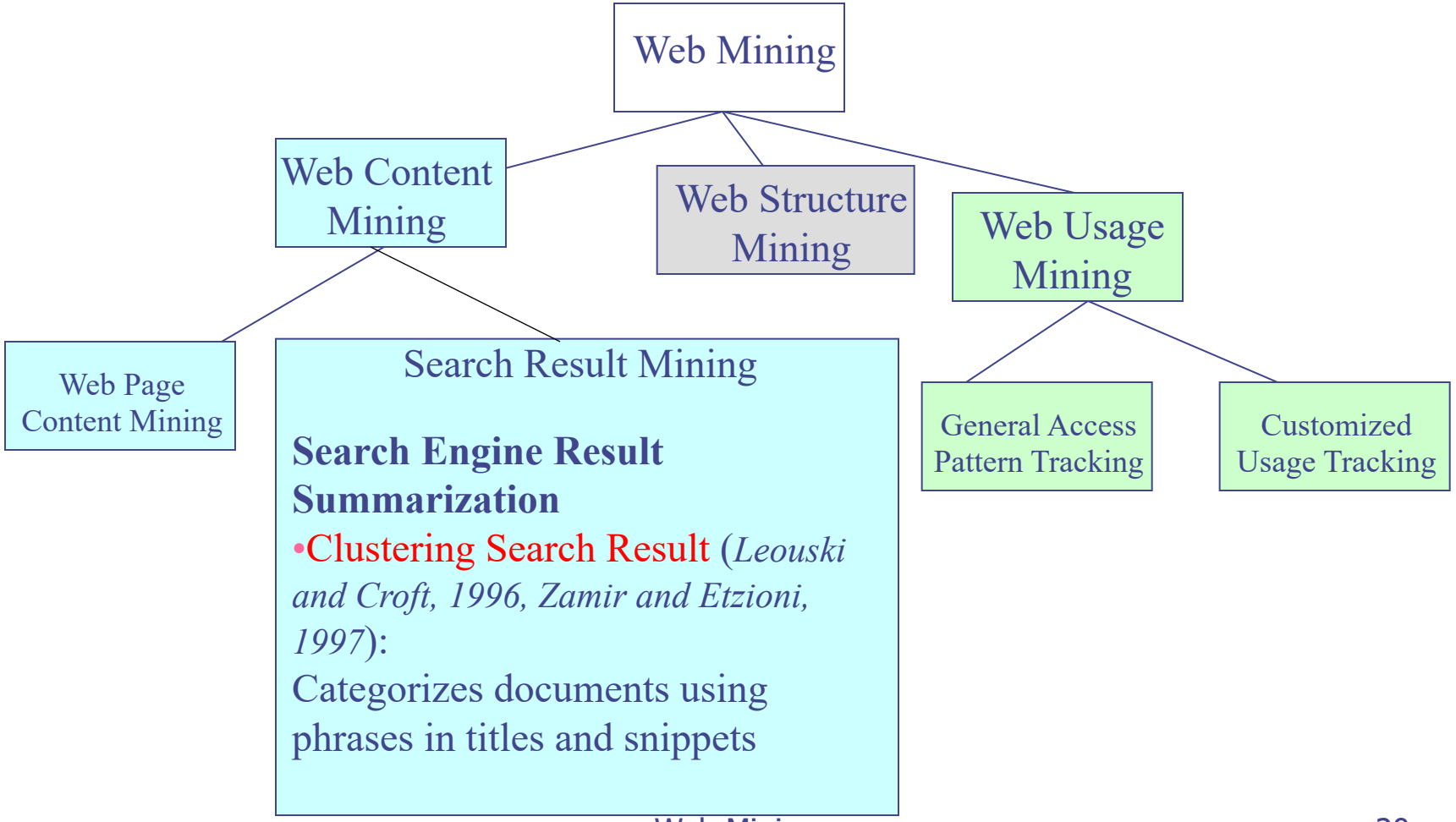

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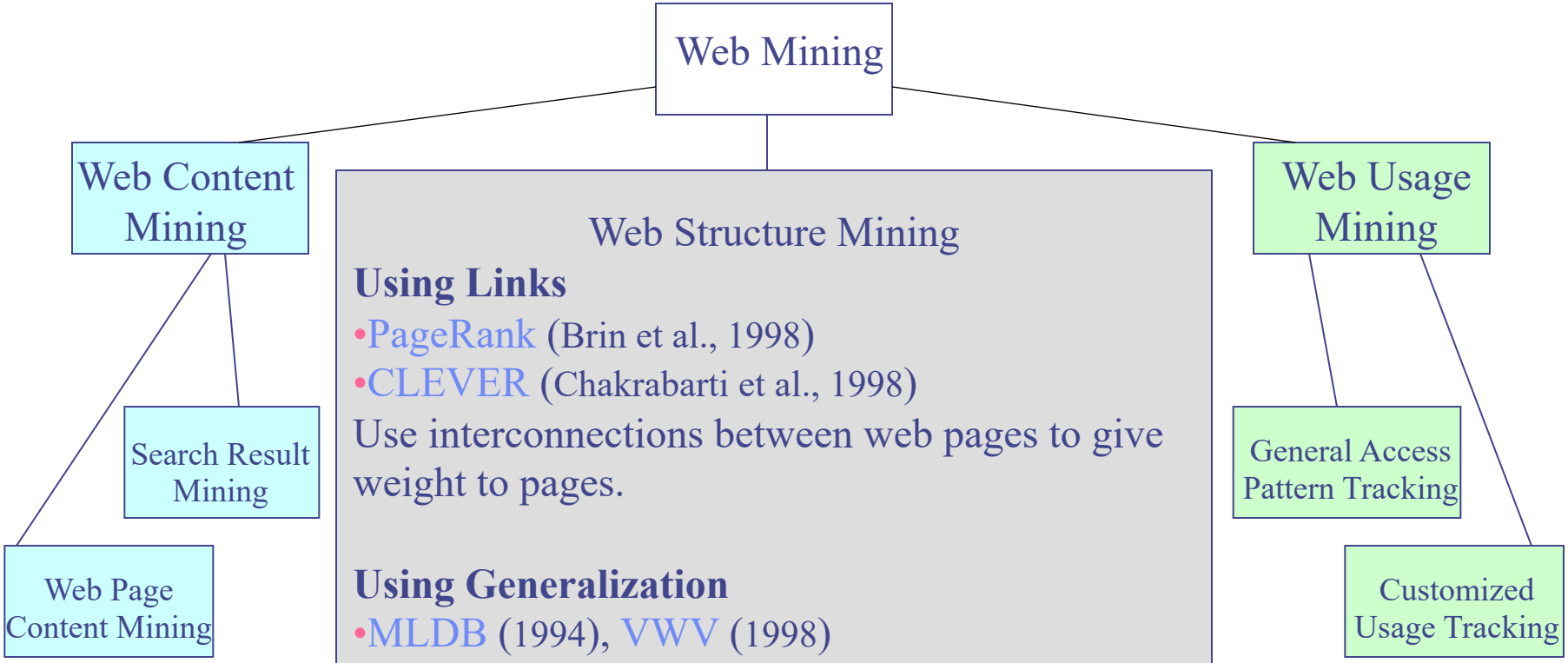

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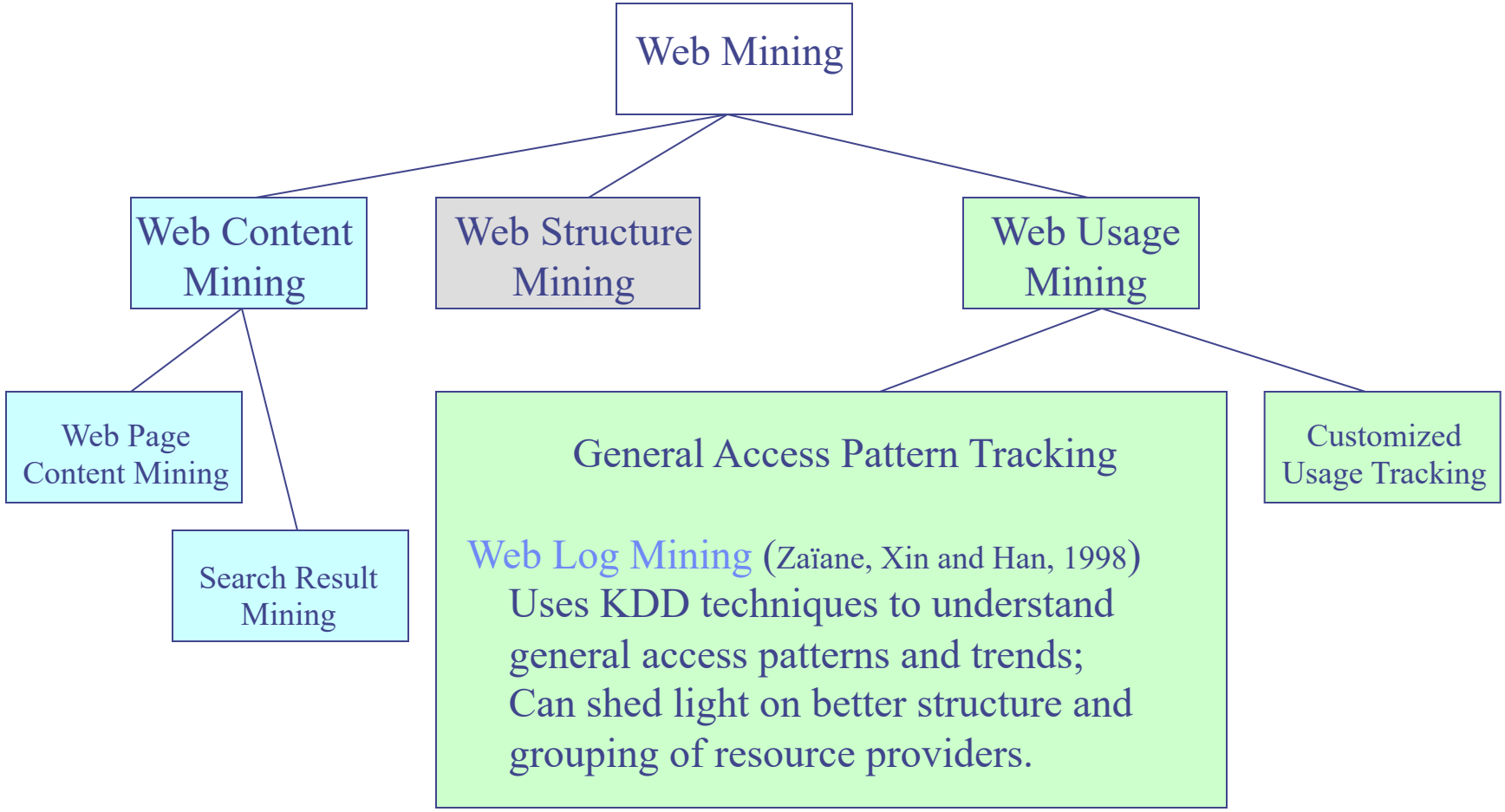

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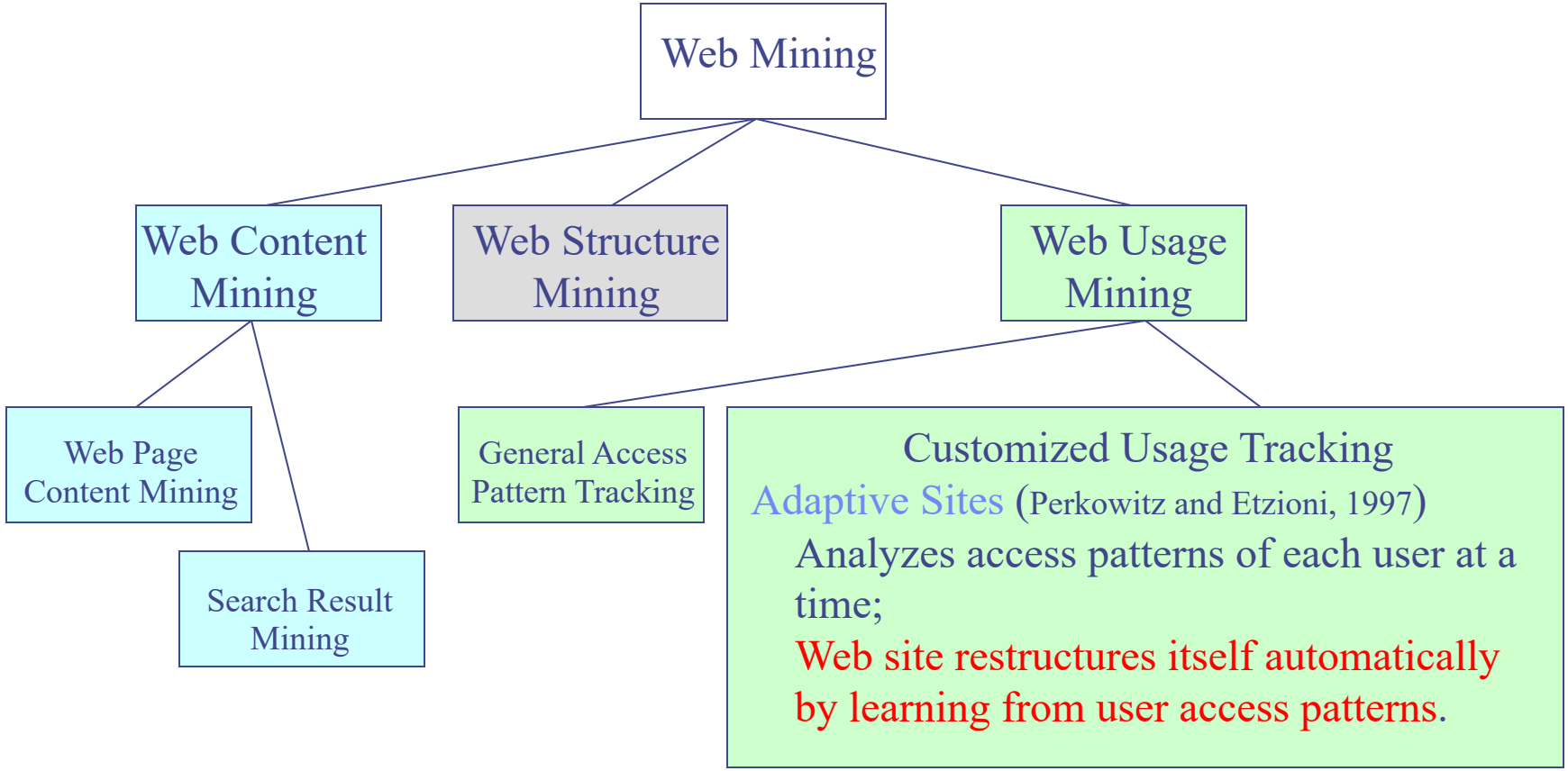


Web Content Mining:
Automatic Classification of Web Documents

- Assign a class label to each document from a set of predefined topic categories
- Based on a set of examples of preclassified documents
- Example
  - Use Yahoo!'s taxonomy and its associated documents as training and test sets
  - Derive a Web document classification scheme
  - Use the scheme classify new Web documents by assigning categories from the same taxonomy
- Keyword-based document classification methods
- Statistical models, Classification models, etc.

Web Usage Mining

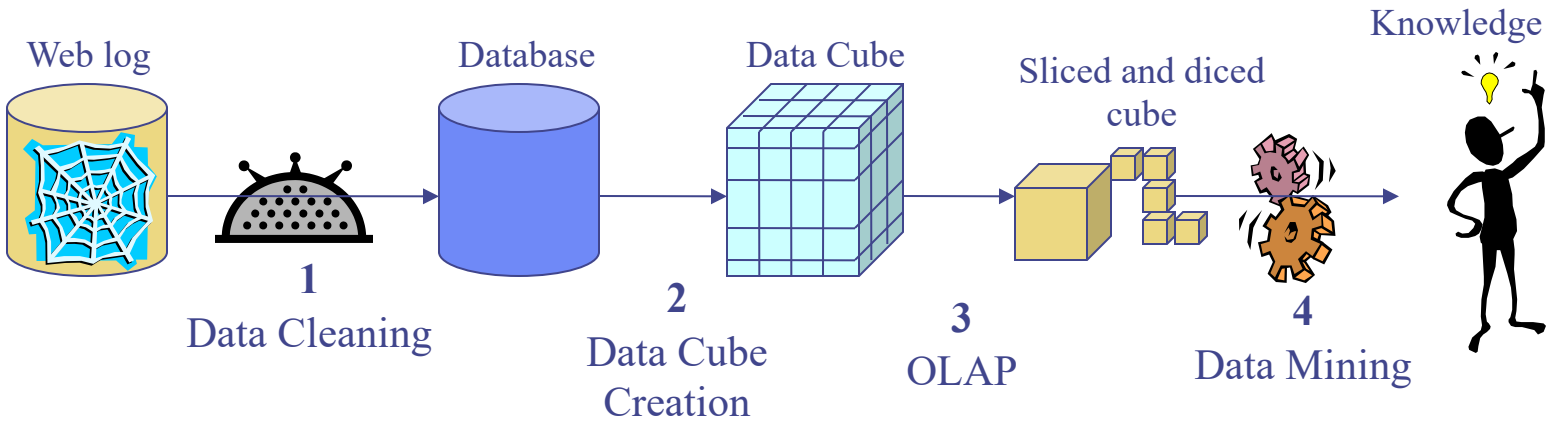
- Mining Web log records to discover user access patterns of Web pages
- Applications
  - Target potential customers for electronic commerce
  - Enhance the quality and delivery of Internet information services to the end user
  - Improve Web server system performance
  - Identify potential prime advertisement locations
- Web logs provide rich information about Web dynamics
  - Typical Web log entry includes the URL requested, the IP address from which the request originated, and a timestamp

Techniques for Web Usage Mining

- Perform data mining on Weblog records
  - Find association patterns, sequential patterns, and trends of Web accessing
  - May need additional information,e.g., user browsing sequences of the Web pages in the Web server buffer
  - Treat the URL information as items
  - Treat the IP address as customer
- Conduct studies to
  - Analyze system performance, improve system design by Web caching, Web page prefetching, and Web page swapping
- Construct multidimensional view on the Weblog database
  - Perform multidimensional OLAP analysis to find the top *N* users, top *N* accessed Web pages, most frequently accessed time periods, etc.

Techniques for Web Usage Mining (Cont.)

- Design of a Web Log Miner
  - Web log is filtered to generate a relational database
  - A data cube is generated form database
  - OLAP is used to drill-down and roll-up in the cube
  - OLAM is used for mining interesting knowledge



Web Structure Mining: Mining the Web's Link Structures

- Finding authoritative Web pages
  - Retrieving pages that are not only relevant, but also of high quality, or authoritative on the topic
- Hyperlinks can infer the notion of authority
  - The Web consists not only of pages, but also of hyperlinks pointing from one page to another
  - These hyperlinks contain an enormous amount of latent human annotation
  - These called upon web link analysis models

Web Link Analysis Model: PageRank

- The year 1998 was an eventful year for Web link analysis models. Both the PageRank and HITS algorithms were reported in that year.
- The connections between PageRank and HITS are quite striking.
- Since that eventful year, PageRank has emerged as the dominant link analysis model,
  - due to its query-independence,
  - its ability to combat spamming, and
  - Google's huge business success.

PageRank: The Intuitive Idea

- PageRank relies on the democratic nature of the Web by using its vast link structure as an indicator of an individual page's value or quality.
- PageRank interprets a hyperlink from page *x* to page *y* as a vote, by page *x*, for page *y*.
- However, PageRank looks at more than the sheer number of votes; it also analyzes the page that casts the vote.
  - Votes casted by “important” pages weigh more heavily and help to make other pages more "important."
- This is exactly the idea of **rank prestige** in social network.

More specifically (PageRank)

- A hyperlink from a page to another page is an implicit conveyance of authority to the target page.
  - The more in-links that a page *i* receives, the more prestige the page *i* has.
- Pages that point to page *i* also have their own prestige scores.
  - A page of a higher prestige pointing to *i* is more important than a page of a lower prestige pointing to *i*.
  - In other words, a page is important if it is pointed to by other important pages.

Mining the Web's Link Structures

- Problems with the Web linkage structure
  - Not every hyperlink represents an endorsement
    - Other purposes are for navigation or for paid advertisements
    - If the majority of hyperlinks are for endorsement, the collective opinion will still dominate
  - One authority will seldom have its Web page point to its rival authorities in the same field
  - Authoritative pages are seldom particularly descriptive
- Hub
  - Set of Web pages that provides collections of links to authorities

Summary

- Text mining goes beyond keyword-based and similarity-based information retrieval and discovers knowledge from semi-structured data using methods like keyword-based association and document classification
- Web mining includes mining Web link structures to identify authoritative Web pages (Web structure mining), the automatic classification of Web documents (Web content mining), and Weblog mining (Web usage mining)