Information Retrieval
INFO 4300 / CS 4300

- Last class (short class)
  - Issues for IR systems
    - Relevance
    - Evaluation
    - Users

Topics for Today

- Precision/recall exercise
- Search engine architecture
  - The indexing process
  - The querying process

In-Class Exercise

- Precision/Recall

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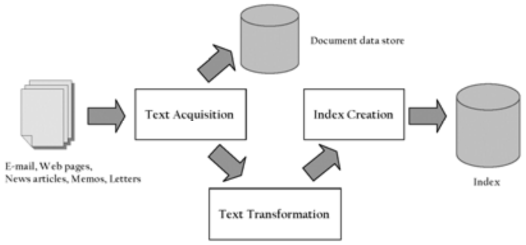
Search Engine Architecture

- A **software architecture** consists of software components, the interfaces provided by those components, and the relationships between them
  - describes a system at a particular level of abstraction
- Architecture of a search engine determined by two requirements
  - effectiveness (quality of results) and efficiency (speed: response time and throughput)

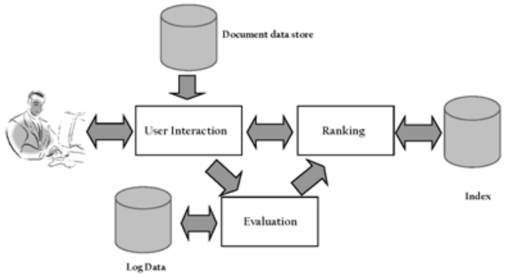
Indexing Process



Indexing Process

- Text acquisition
  - identifies and stores documents for indexing
- Text transformation
  - transforms documents into *index terms* or *features*
- Index creation
  - takes index terms and creates data structures (*indexes*) to support fast searching

Query Process



Query Process

- User interaction
  - supports creation and refinement of query, display of results
- Ranking
  - uses query and indexes to generate ranked list of documents
- Evaluation
  - monitors and measures effectiveness and efficiency (primarily offline)

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Details: Text Acquisition

- Crawler
  - Identifies and acquires documents for search engine
  - Many types – web, enterprise, desktop
  - Web crawlers follow *links* to find documents
  - *Document* crawlers for enterprise and desktop search
    - Follow links and scan directories

Details: Text Acquisition

- Crawler
  - Identifies and acquires documents for search engine
  - Many types – web, enterprise, desktop
  - Web crawlers follow *links* to find documents
    - Must efficiently find huge numbers of web pages (*coverage*) and keep them up-to-date (*freshness*)
    - Single site crawlers for *site search*
    - *Topical* or *focused* crawlers for vertical search
  - *Document* crawlers for enterprise and desktop search
    - Follow links and scan directories

Text Acquisition

- Feeds
  - – Real-time streams of documents
    - » e.g., web feeds for news, blogs, video, radio, tv
  - – RSS is common standard
    - » RSS “reader” can provide new XML documents to search engine
- Conversion
  - – Convert variety of documents into a consistent **text plus metadata** format
    - » e.g. HTML, XML, Word, PDF, etc. → XML
  - – Convert text encoding for different languages
    - » Using a Unicode standard like UTF-8

Text Acquisition

- Document data store
  - – Stores text, metadata, and other related content for documents
    - » Metadata is information about document such as type and creation date
    - » Other content includes links, anchor text
  - – Provides fast access to document contents for search engine components
    - » e.g. result list generation
  - – Could use relational database system
    - » More typically, a simpler, more efficient storage system is used due to huge numbers of documents

Text Transformation

- Parser
  - – Processing the sequence of text ***tokens*** in the document to recognize structural elements
    - » e.g., titles, links, headings, etc.
  - – *Tokenizer* recognizes “words” in the text
    - » must consider issues like capitalization, hyphens, apostrophes, non-alpha characters, separators
  - – *Markup languages* such as HTML, XML often used to specify structure
    - » *Tags* used to specify document *elements*
      - u E.g., <h2> Overview </h2>
    - » Document parser uses *syntax* of markup language (or other formatting) to identify structure

Text Transformation

- Stopping
  - – Remove common words
    - » e.g., “and”, “or”, “the”, “in”
  - – Some impact on efficiency and effectiveness
  - – Can be a problem for some queries
- Stemming
  - – Group words derived from a common *stem*
    - » e.g., “computer”, “computers”, “computing”, “compute”
  - – Usually effective, but not for all queries
  - – Benefits vary for different languages

Text Transformation

- Link Analysis
  - – Makes use of ***links*** and ***anchor text*** in web pages
  - – Link analysis identifies *popularity* and *community* information
    - » e.g., PageRank, Hubs & Authorities
  - – Anchor text can significantly enhance the representation of pages pointed to by links
  - – Significant impact on web search
    - » Less importance in other applications

Text Transformation

- Information Extraction
  - – Identify classes of index terms that are important for some applications
  - – e.g., *named entity recognizers* identify classes such as *people*, *locations*, *companies*, *dates,* etc.
- Classifier
  - – Identifies class-related metadata for documents
    - » i.e., assigns labels to documents
    - » e.g., topics, reading levels, sentiment, genre
  - – Use depends on application

Index Creation

- Document Statistics
  - – Gathers counts and positions of words and other features
  - – Ranking algorithm uses to compute doc scores
- Weighting
  - – Computes weights for index terms
  - – Used in ranking algorithm
  - – e.g., ***tf.idf*** weight
    - » Combination of ***term frequency*** in document and ***inverse document frequency*** in the collection

Index Creation

- Inversion
  - – Core of indexing process
  - – Converts document-term information to term-document for indexing
    - » Difficult for very large numbers of documents
  - – Format of inverted file is designed for fast query processing
    - » Must also handle updates
    - » Compression used for efficiency

Index Creation

- Index Distribution
  - Distributes indexes across multiple computers and/or multiple sites on a network
  - Essential for fast query processing with large numbers of documents
  - Many variations
    - » **Document distribution**, **term distribution**, **replication**
  - *P2P* and *distributed IR* involve search across multiple sites

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User Interaction

- Query input
  - Provides interface and parser for ***query language***
  - Most web queries are very simple (few **operators**), other applications may use forms
  - Query language used to describe more complex queries and results of query transformation
    - » e.g., Boolean queries, Indri and Galago query languages
    - » similar to SQL language used in database applications
    - » IR query languages also allow content and structure specifications, but focus on content

User Interaction

- Query transformation
  - Improves initial query, both before and after initial search
  - Includes text transformation techniques used for documents (e.g. tokenization, stopping)
  - ***Spell checking*** and ***query suggestion*** provide alternatives to original query
  - ***Query expansion*** and ***relevance feedback*** modify the original query with additional terms

User Interaction

- Results output
  - Constructs the display of ranked documents for a query
  - Generates ***snippets*** to show how queries match documents
  - ***Highlights*** important words and passages
  - Retrieves appropriate ***advertising*** in many applications
  - May provide ***clustering*** and other visualization tools

Ranking

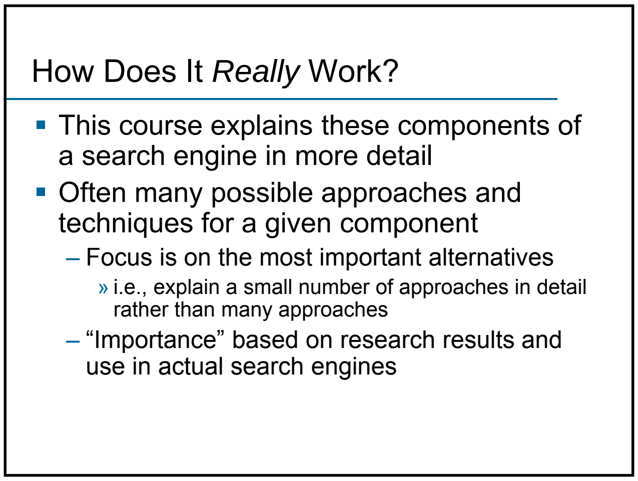
- Scoring
  - Calculates scores for documents using a ranking algorithm
  - Core component of search engine
  - Basic form of score is $\sum_t q_i d_i$
    - q_i and d_i are query and document term weights for term i
  - Many variations of ranking algorithms and retrieval models

Ranking

- Performance optimization
  - Designing ranking algorithms **for efficient processing**
    - *Term-at-a time* vs. *document-at-a-time* processing
    - *Safe* vs. *unsafe* optimizations
- Distribution
  - Processing queries in a distributed environment
  - *Query broker* distributes queries and assembles results
  - *Caching* is a form of distributed searching

Evaluation

- Logging
  - Logging user queries and interaction is crucial for improving search effectiveness and efficiency
  - *Query logs* and *clickthrough data* or *dwell time* used for query suggestion, spell checking, query caching, ranking, advertising search, and other components
- Ranking analysis
  - Measuring and tuning ranking effectiveness
- Performance analysis
  - Measuring and tuning system efficiency



How Does It *Really* Work?

- This course explains these components of a search engine in more detail
- Often many possible approaches and techniques for a given component
  - Focus is on the most important alternatives
    - i.e., explain a small number of approaches in detail rather than many approaches
  - “Importance” based on research results and use in actual search engines