CS6200/IS4200
Information Retrieval

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IR and Search Engines

Information Retrieval

Relevance

-Effective ranking

Evaluation

-Testing and measuring

Information needs

-User interaction

Search Engines

Performance

-Efficient search and indexing

Incorporating new data

-Coverage and freshness

Scalability

-Growing with data and users

Adaptability

-Tuning for applications

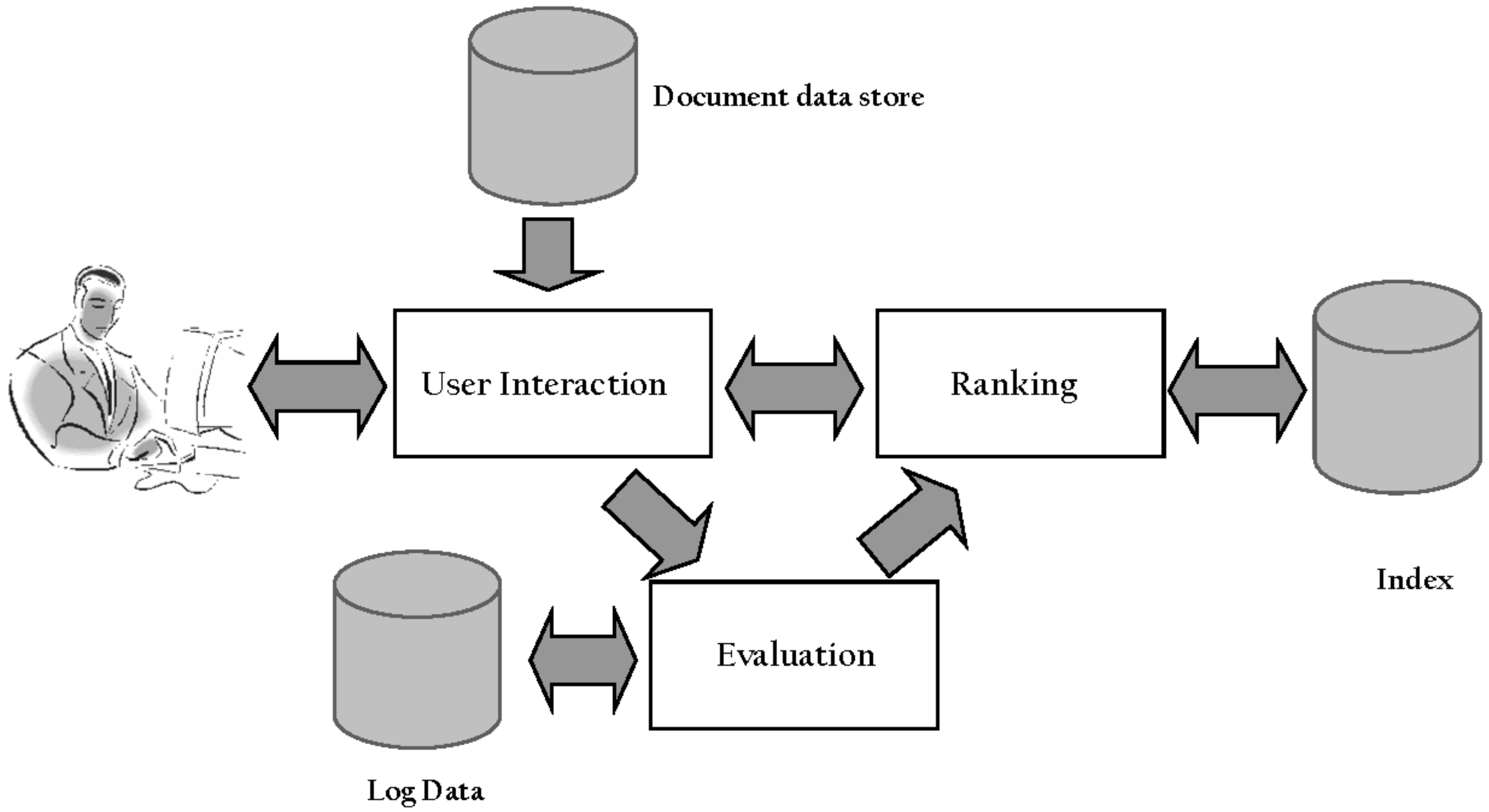
Specific problems

-e.g. Spam

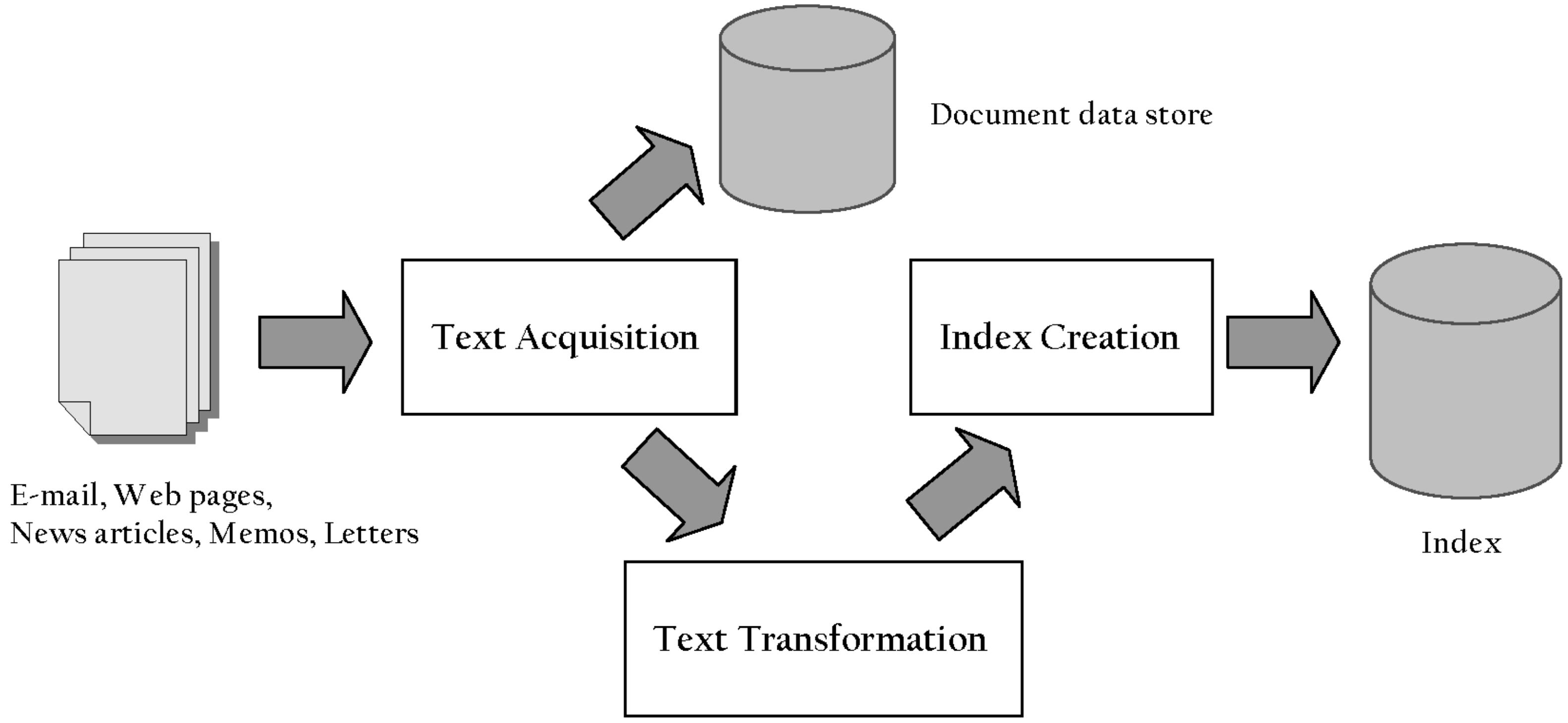
Search Engine Architecture

- 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 (response time and throughput)

Query Process



Indexing Process



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

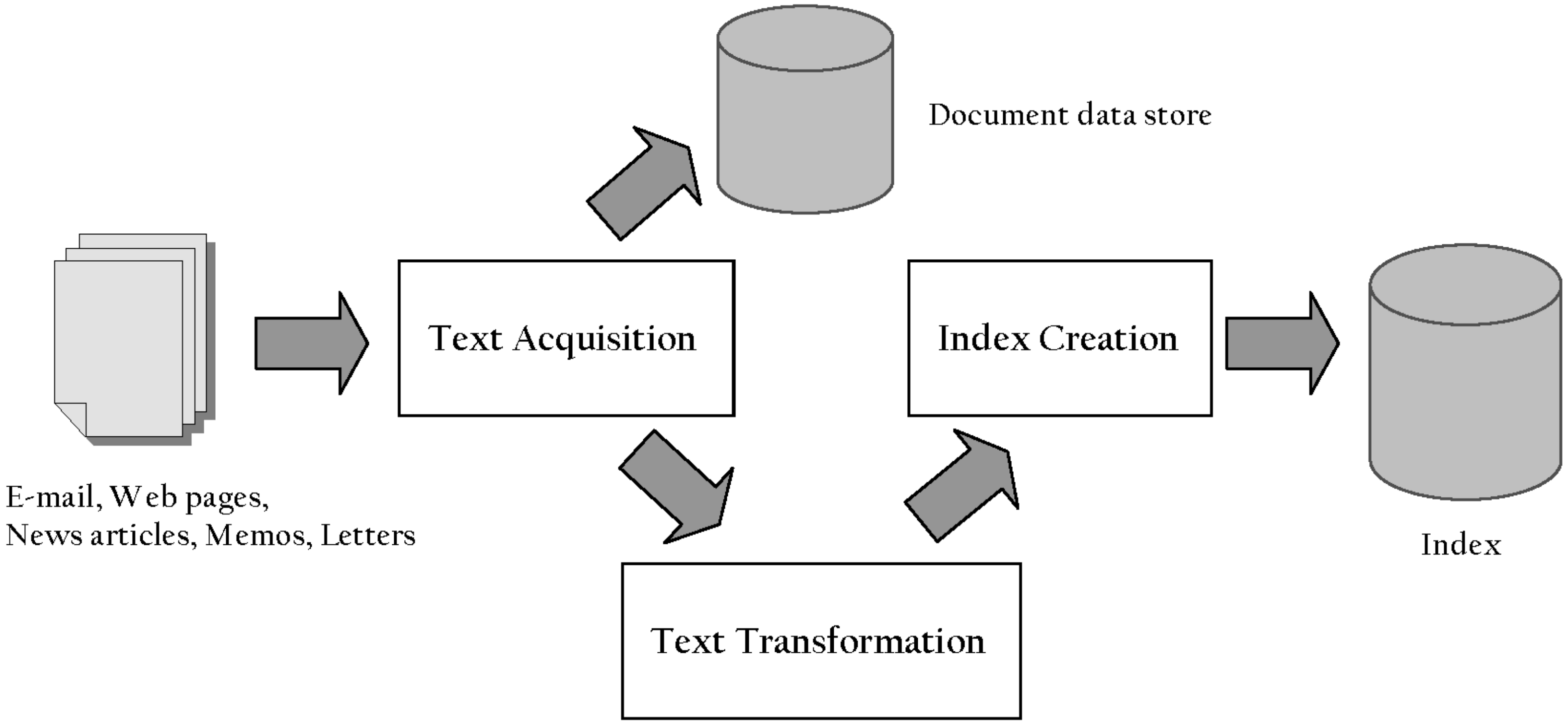
Text Acquisition

- Feeds and APIs
  - Real-time streams of documents
    - e.g., web feeds for news, blogs, video, radio, TV
  - RSS is an example 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
  - Use a relational database system? A file system?
    - More typically, a simpler, more efficient storage system is used due to huge numbers of documents

Indexing Process



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
    - hard-coded or learned from data (e.g, WordPiece)
  - *Markup languages* such as HTML, XML used to specify structure (& JSON, CSV, PDF, closed captions, …)
    - *Tags* used to specify document *elements*
      - 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”
- 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
- Embedding
  - Mapping sequences of words to vectors, usually trained to optimize some predictive task
  - Like other transformations, *dimensionality reduction*

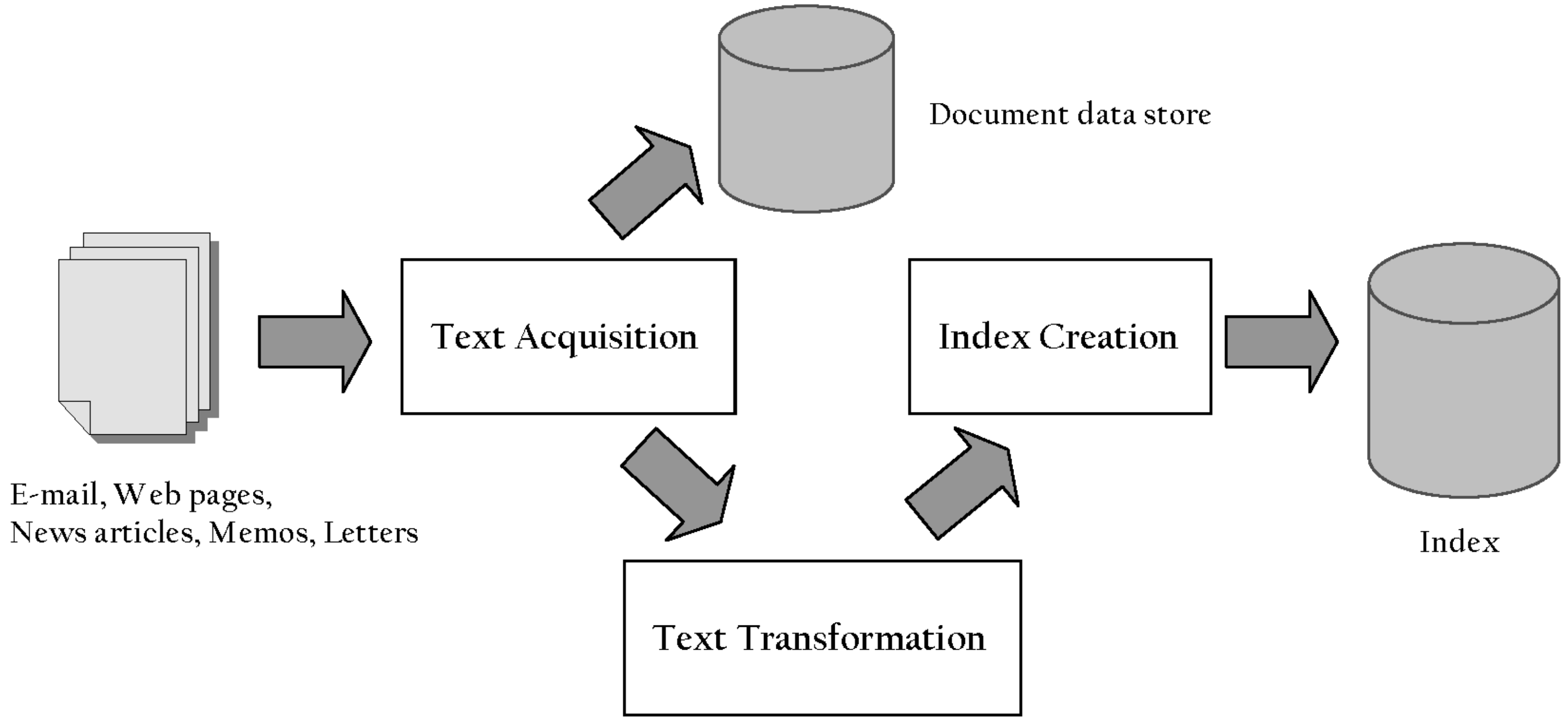
Text Transformation

- Link Analysis
  - Makes use of *links* and *anchor text* in web pages
  - Link analysis identifies *popularity* and *community* information
    - e.g., PageRank
  - 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
  - *Named entity recognizers* identify classes such as *people*, *locations*, *companies*, *dates,* etc.
  - Other parsers for business addresses, event information, job postings, 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

Indexing Process



Index Creation

- Document Statistics
  - Gathers counts and positions of words and other features
  - Used in ranking algorithm
- 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

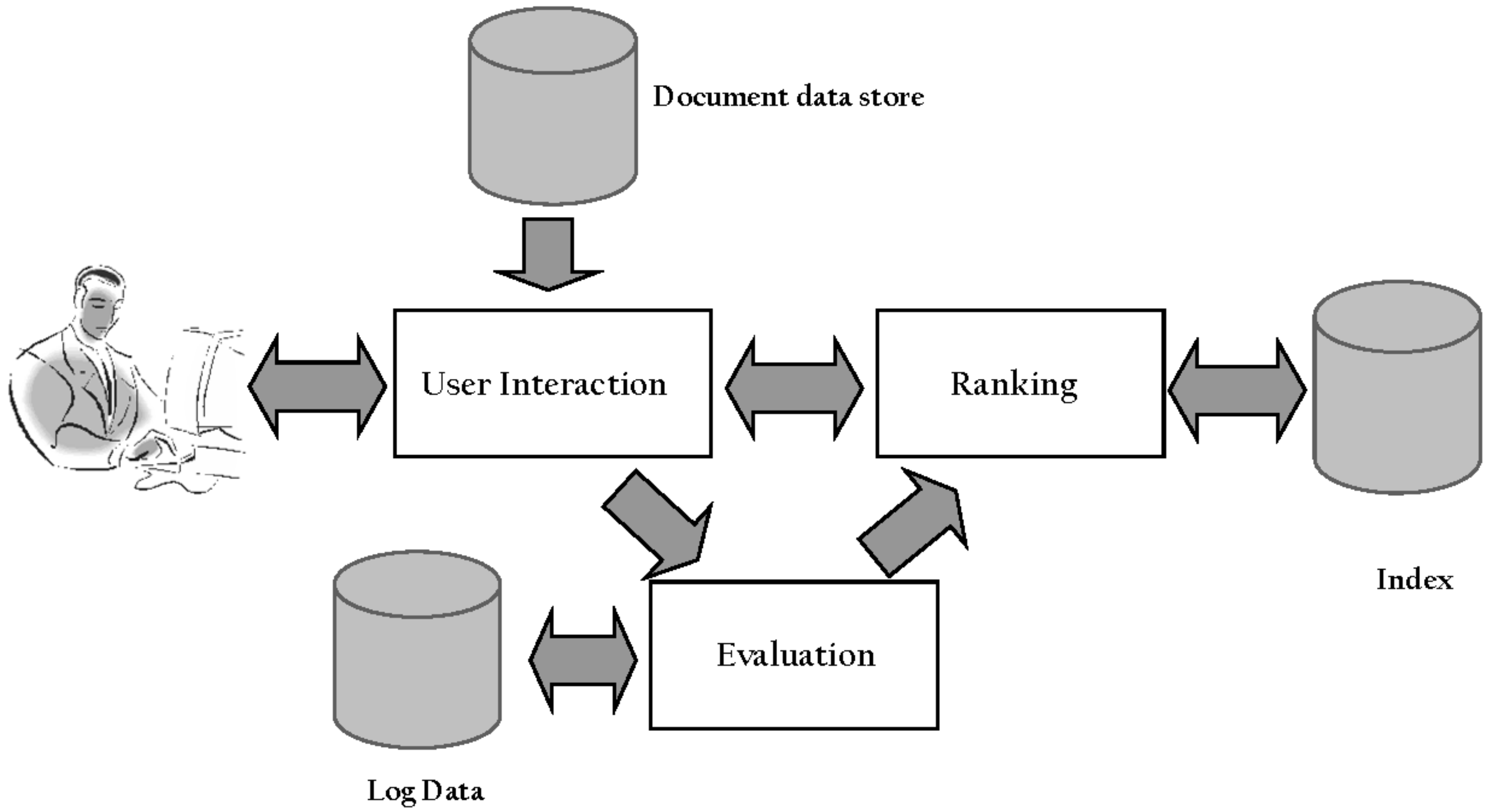
Index Creation

- Inversion
  - Efficient data structure for sparse representations
  - 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
- Dense embeddings
  - Search in Euclidean, probability etc. vector spaces

Index Creation

- Index Distribution
  - Distributes indexes across multiple computers and/or multiple sites
  - Essential for fast query processing with large numbers of documents
  - Many variations
    - Document distribution, term distribution, replication
  - *Federated* and *distributed IR* involve search across multiple sites
    - *For efficiency or for data encapsulation/hiding*

Query Process



User Interaction

- Query input
  - Provides interface and parser for *query language*
  - Most web queries are very simple, 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

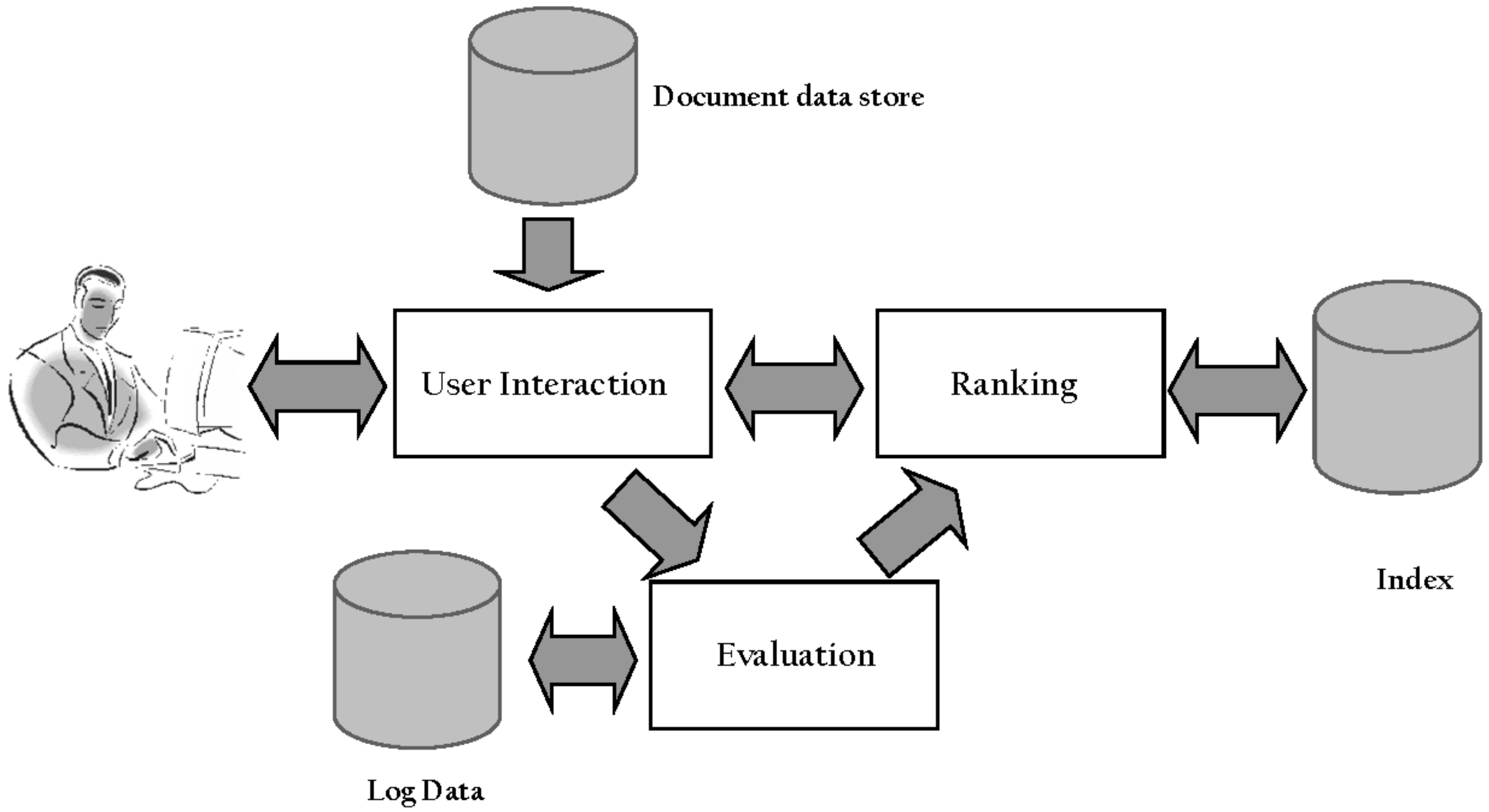
User Interaction

- Query transformation
  - Improves initial query, both before and after initial search
  - Includes text transformation techniques used for documents
  - *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

Query Process



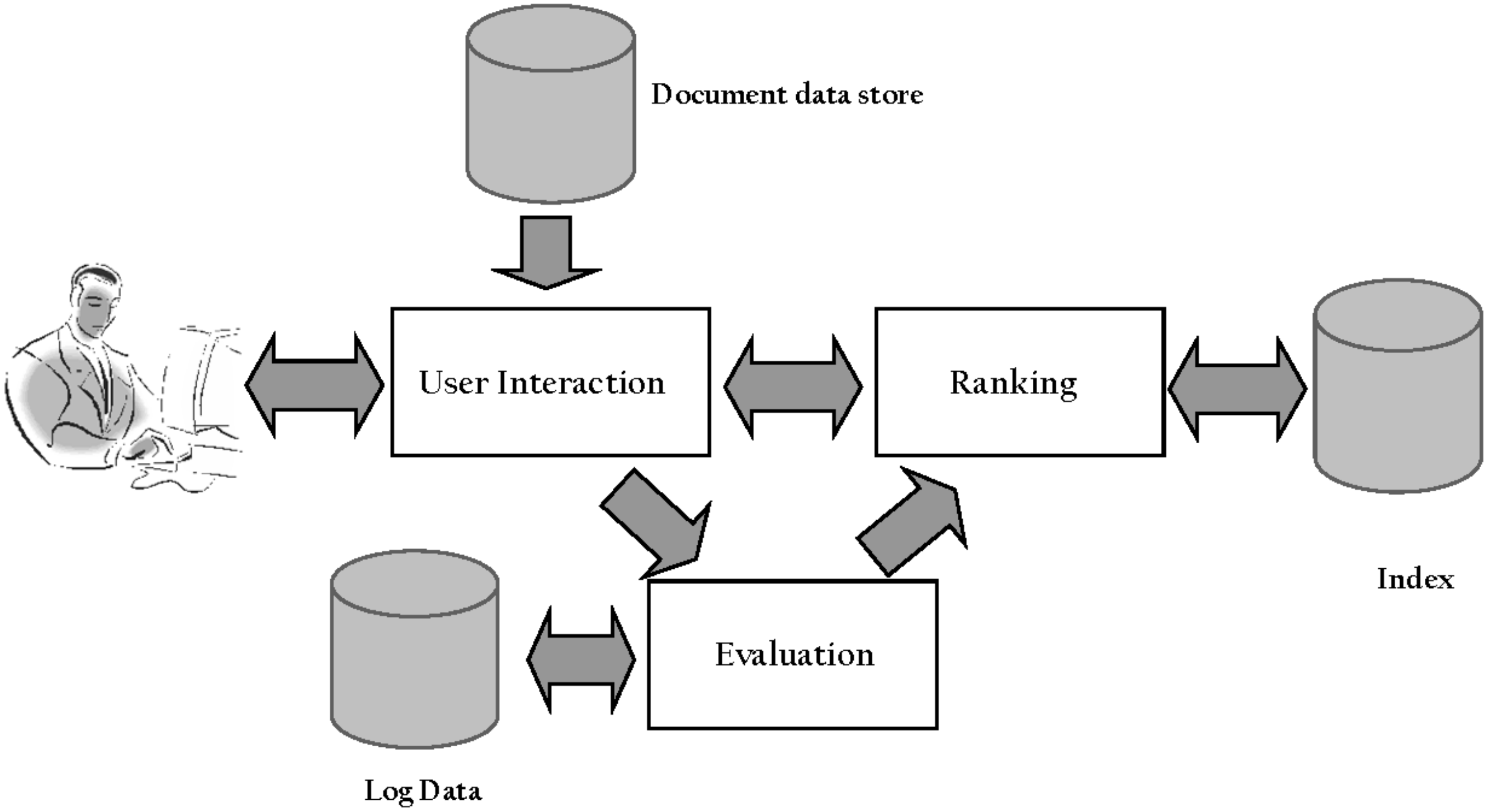
Ranking

- Scoring
  - Calculates scores for documents using a ranking algorithm
  - Core component of search engine
  - Basic form of score is $\sum q_i d_i$
    - q_i and d_i are query and document weights for feature *I*, e.g., words, other terms, embeddings, etc.
  - 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

Query Process



Evaluation

- Logging
  - Logging user queries and interaction is crucial for improving search effectiveness and efficiency
  - *Query logs* and *clickthrough data* 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
  - Follow up references in text for alternatives

Topics

- *Overview*
- Architecture of a search engine
- **Data acquisition**
- Text representation
- Indexing
- Query processing
- Ranking
- Evaluation
- Classification and clustering
- Embeddings and vector search
- Conversational interfaces

Topics

- For background read:
  - *Search Engines* chapter 3, or
  - *Intro to IR*, chapters 19 and 20

Exercise

- Write down 2 queries for a web search engine, each between 2 and 5 words.
- **Before** you run the queries, write down what you expect to find.
- Run these queries on 2 search engines and compare the top 10 results.
- How are the search engines different?
- What criteria did you use to evaluate results?

TREC Topic Example

```
<top>
<num> Number: 794

<title> pet therapy

<desc> Description:
How are pets or animals used in therapy for humans and what are the
benefits?

<narr> Narrative:
Relevant documents must include details of how pet- or animal-assisted
therapy is or has been used.  Relevant details include information
about pet therapy programs, descriptions of the circumstances in which
pet therapy is used, the benefits of this type of therapy, the degree
of success of this therapy, and any laws or regulations governing it.

</top>
```