
Information Retrieval and Web Search

Introduction

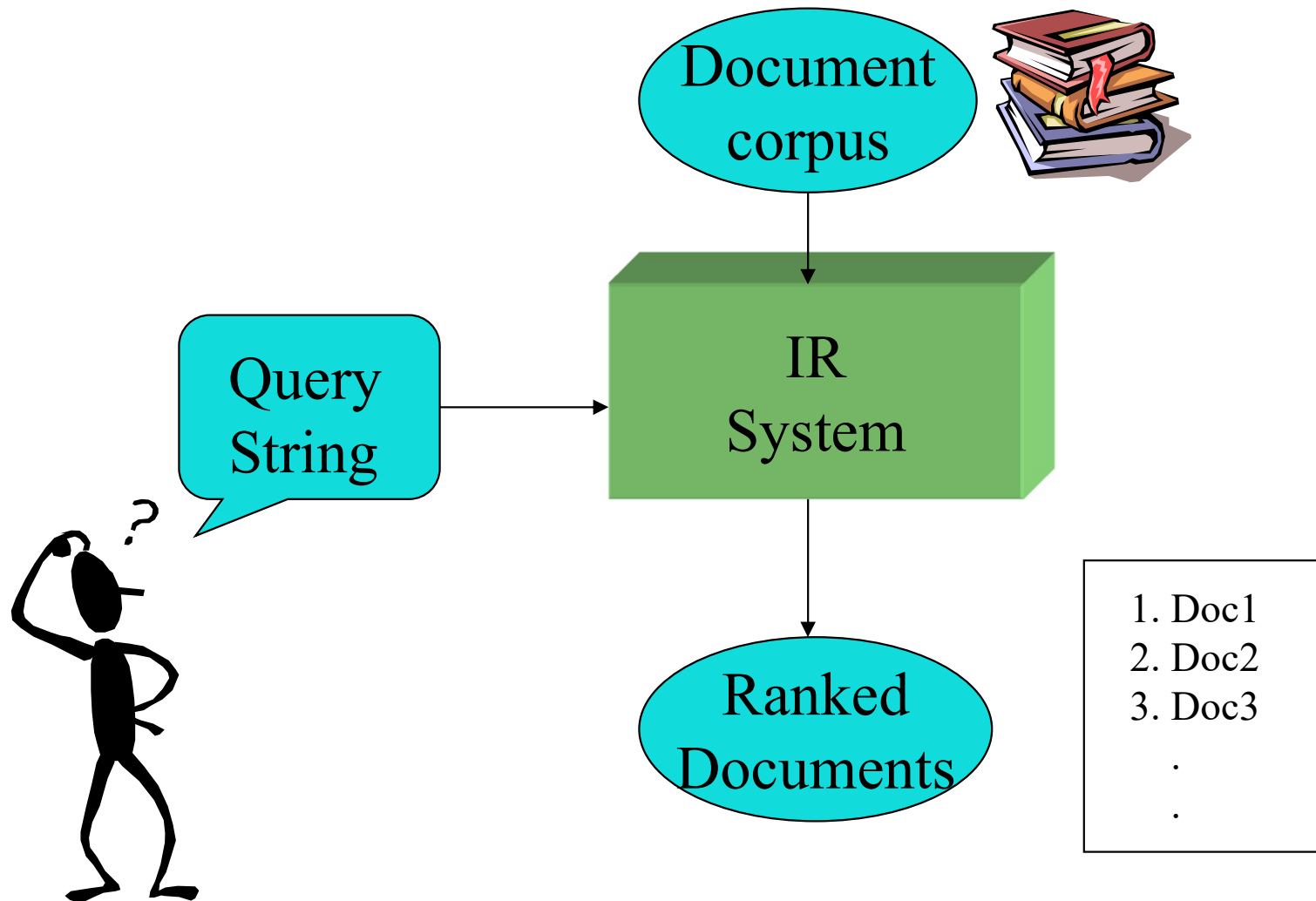
Information Retrieval (IR)

- The indexing and retrieval of textual documents.
- Searching for pages on the World Wide Web is the “killer app.”
- Concerned firstly with retrieving relevant documents to a query.
- Concerned secondly with retrieving from large sets of documents efficiently.

Typical IR Task

- **Given:**
 - A corpus of textual natural-language documents.
 - A user query in the form of a textual string.
- **Find:**
 - A ranked set of documents that are relevant to the query.

IR System



Relevance

- Relevance is a subjective judgment and may include:
 - Being on the proper subject.
 - Being timely (recent information).
 - Being authoritative (from a trusted source).
 - Satisfying the goals of the user and his/her intended use of the information (*information need*).

Keyword Search

- Simplest notion of relevance is that the query string appears verbatim in the document.
- Slightly less strict notion is that the words in the query appear frequently in the document, in any order (*bag of words*).

Problems with Keywords

- May not retrieve relevant documents that include synonymous terms.
 - “restaurant” vs. “café”
 - “PRC” vs. “China”
- May retrieve irrelevant documents that include ambiguous terms.
 - “bat” (baseball vs. mammal)
 - “Apple” (company vs. fruit)
 - “bit” (unit of data vs. act of eating)

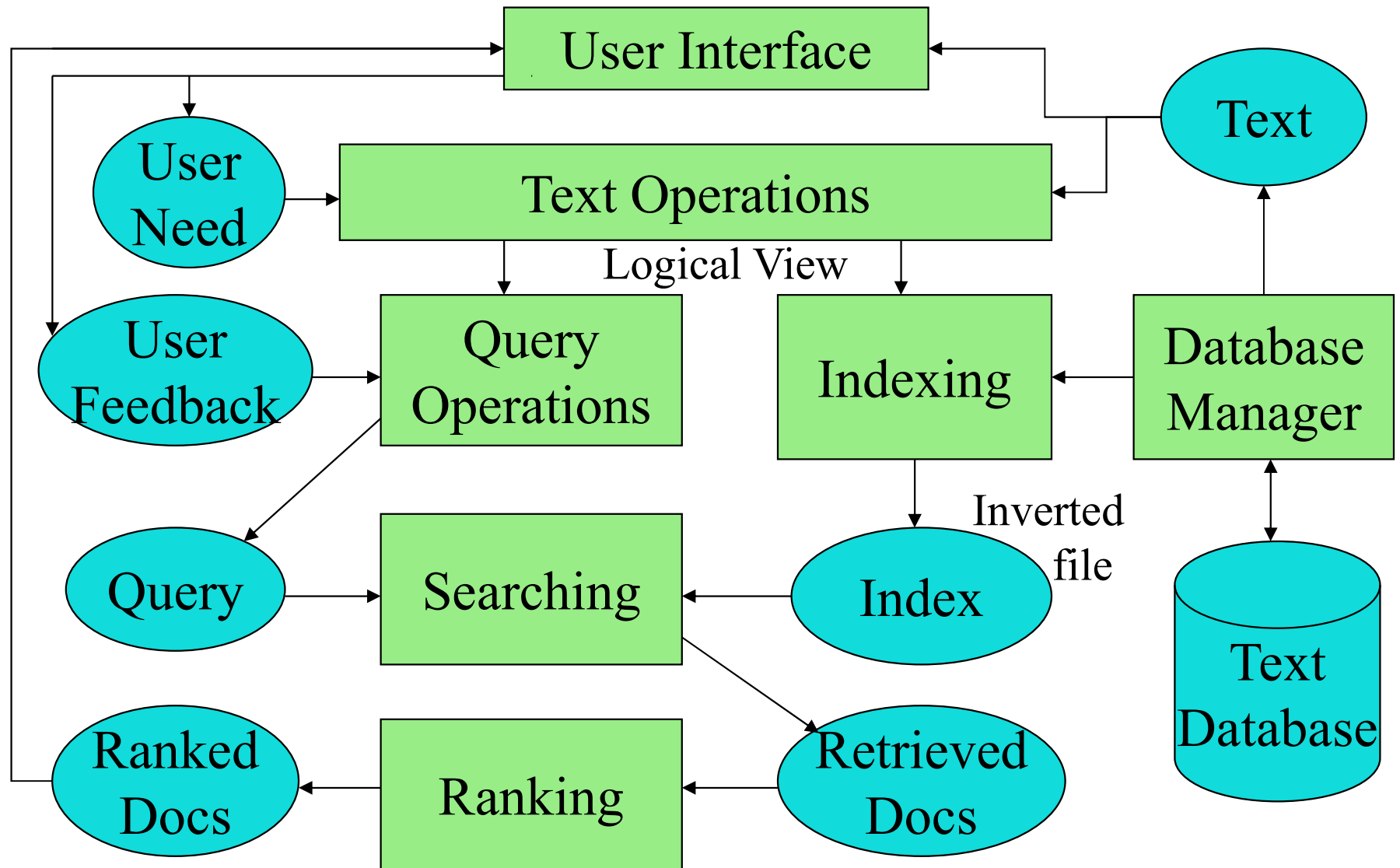
Beyond Keywords

- We will cover the basics of keyword-based IR, but...
- We will focus on extensions and recent developments that go beyond keywords.
- We will cover the basics of building an *efficient* IR system, but...
- We will focus on basic capabilities and algorithms rather than systems issues that allow scaling to industrial size databases.

Intelligent IR

- Taking into account the *meaning* of the words used.
- Taking into account the *order* of words in the query.
- Adapting to the user based on direct or indirect feedback.
- Taking into account the *authority* of the source.

IR System Architecture



IR System Components

- **Text Operations** forms index words (tokens).
 - Stopword removal
 - Stemming
- **Indexing** constructs an *inverted index* of word to document pointers.
- **Searching** retrieves documents that contain a given query token from the inverted index.
- **Ranking** scores all retrieved documents according to a relevance metric.

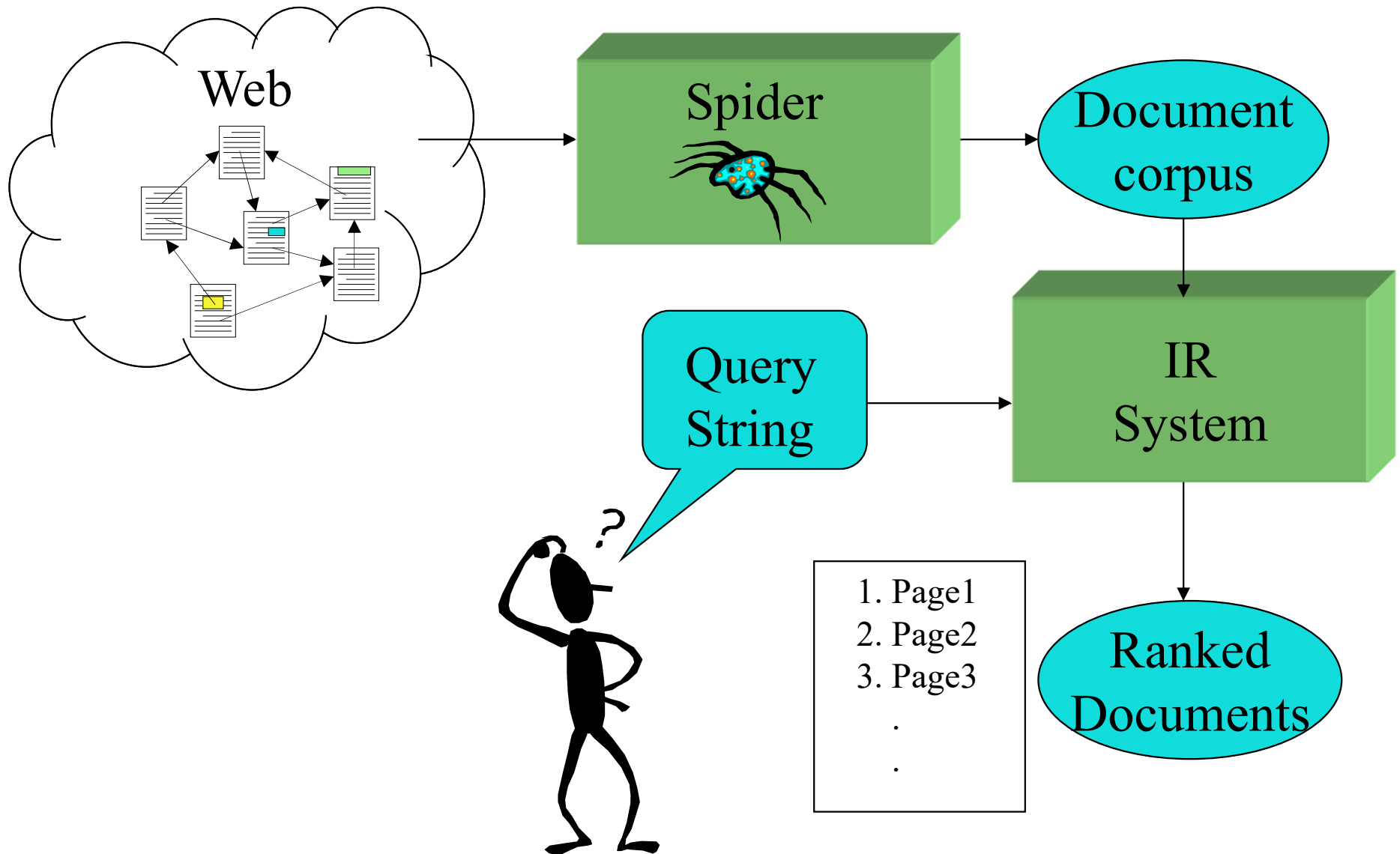
IR System Components (continued)

- **User Interface** manages interaction with the user:
 - Query input and document output.
 - Relevance feedback.
 - Visualization of results.
- **Query Operations** transform the query to improve retrieval:
 - Query expansion using a thesaurus.
 - Query transformation using relevance feedback.

Web Search

- Application of IR to HTML documents on the World Wide Web.
- Differences:
 - Must assemble document corpus by spidering the web.
 - Can exploit the structural layout information in HTML (XML).
 - Documents change uncontrollably.
 - Can exploit the link structure of the web.

Web Search System



Other IR-Related Tasks

- Automated document categorization
- Information filtering (spam filtering)
- Information routing
- Automated document clustering
- Recommending information or products
- Information extraction
- Information integration
- Question answering

History of IR

- 1960-70's:
 - Initial exploration of text retrieval systems for “small” corpora of scientific abstracts, and law and business documents.
 - Development of the basic Boolean and vector-space models of retrieval.
 - Prof. Salton and his students at Cornell University are the leading researchers in the area.

IR History Continued

- 1980's:
 - Large document database systems, many run by companies:
 - Lexis-Nexis
 - Dialog
 - MEDLINE

IR History Continued

- 1990's:
 - Searching FTPable documents on the Internet
 - Archie
 - WAIS
 - Searching the World Wide Web
 - Lycos
 - Yahoo
 - Altavista

IR History Continued

- 1990's continued:
 - Organized Competitions
 - NIST TREC
 - Recommender Systems
 - Ringo
 - Amazon
 - NetPerceptions
 - Automated Text Categorization & Clustering

IR History Continued

- 2000's
 - Link analysis for Web Search
 - Google
 - Automated Information Extraction
 - Parallel Processing
 - Map/Reduce
 - Question Answering
 - TREC Q/A track

IR History Continued

- 2000's continued:
 - Multimedia IR
 - Image
 - Video
 - Audio and music
 - Cross-Language IR
 - DARPA Tides
 - Document Summarization
 - Learning to Rank

IR History Continued

- 2010's
 - Intelligent Personal Assistants
 - Siri
 - Cortana
 - Google Now
 - Alexa
 - Complex Question Answering
 - IBM Watson
 - Distributional Semantics
 - Deep Learning

Recent IR History

- 2020's
 - Large Language Models (LLM's)
 - ELMO
 - BERT
 - GPT 1, 2, 3
 - ChatBots
 - ChatGPT, GPT 4
 - Reinforcement Learning from Human Feedback (RLHF)

Related Areas

- Database Management
- Library and Information Science
- Artificial Intelligence
- Natural Language Processing
- Machine Learning

Database Management

- Focused on *structured* data stored in relational tables rather than free-form text.
- Focused on efficient processing of well-defined queries in a formal language (SQL).
- Clearer semantics for both data and queries.
- Recent move towards *semi-structured* data (XML) brings it closer to IR.

Library and Information Science

- Focused on the human user aspects of information retrieval (human-computer interaction, user interface, visualization).
- Concerned with effective categorization of human knowledge.
- Concerned with citation analysis and *bibliometrics* (structure of information).
- Recent work on *digital libraries* brings it closer to CS & IR.

Artificial Intelligence

- Focused on the representation of knowledge, reasoning, and intelligent action.
- Formalisms for representing knowledge and queries:
 - First-order Predicate Logic
 - Bayesian Networks
- Recent work on web ontologies and intelligent information agents brings it closer to IR.

Natural Language Processing

- Focused on the syntactic, semantic, and pragmatic analysis of natural language text and discourse.
- Ability to analyze syntax (phrase structure) and semantics could allow retrieval based on *meaning* rather than keywords.

Natural Language Processing: IR Directions

- Methods for determining the sense of an ambiguous word based on context (*word sense disambiguation*).
- Methods for identifying specific pieces of information in a document (*information extraction*).
- Methods for answering specific NL questions from document corpora or structured data like FreeBase or Google's Knowledge Graph.

Machine Learning

- Focused on the development of computational systems that improve their performance with experience.
- Automated classification of examples based on learning concepts from labeled training examples (*supervised learning*).
- Automated methods for clustering unlabeled examples into meaningful groups (*unsupervised learning*).

Machine Learning: IR Directions

- Text Categorization
 - Automatic hierarchical classification (Yahoo).
 - Adaptive filtering/routing/recommending.
 - Automated spam filtering.
- Text Clustering
 - Clustering of IR query results.
 - Automatic formation of hierarchies (Yahoo).
- Learning for Information Extraction
- Text Mining
- Learning to Rank