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

- Query String
  - Document corpus
    - IR System
      - Ranked Documents
        - 1. Doc1
        - 2. Doc2
        - 3. Doc3
        - ...
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

User Need → Query Need

User Feedback

Query Operations

Indexing

Index

Text

Retrieved Docs

Inverted file

Text Database

User Interface

Logical View

Text Operations

Ranking

Ranked Docs

Searching

User Interface

Database Manager
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

Web

Spider

Document corpus

Query String

IR System

Ranked Documents

1. Page1
2. Page2
3. Page3
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
Recent IR History

• 2010’s
  – Intelligent Personal Assistants
    • Siri
    • Cortana
    • Google Now
    • Alexa
  – Complex Question Answering
    • IBM Watson
  – Distributional Semantics
  – Deep Learning
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