Information Retrieval
CS 6900

Lecture 01

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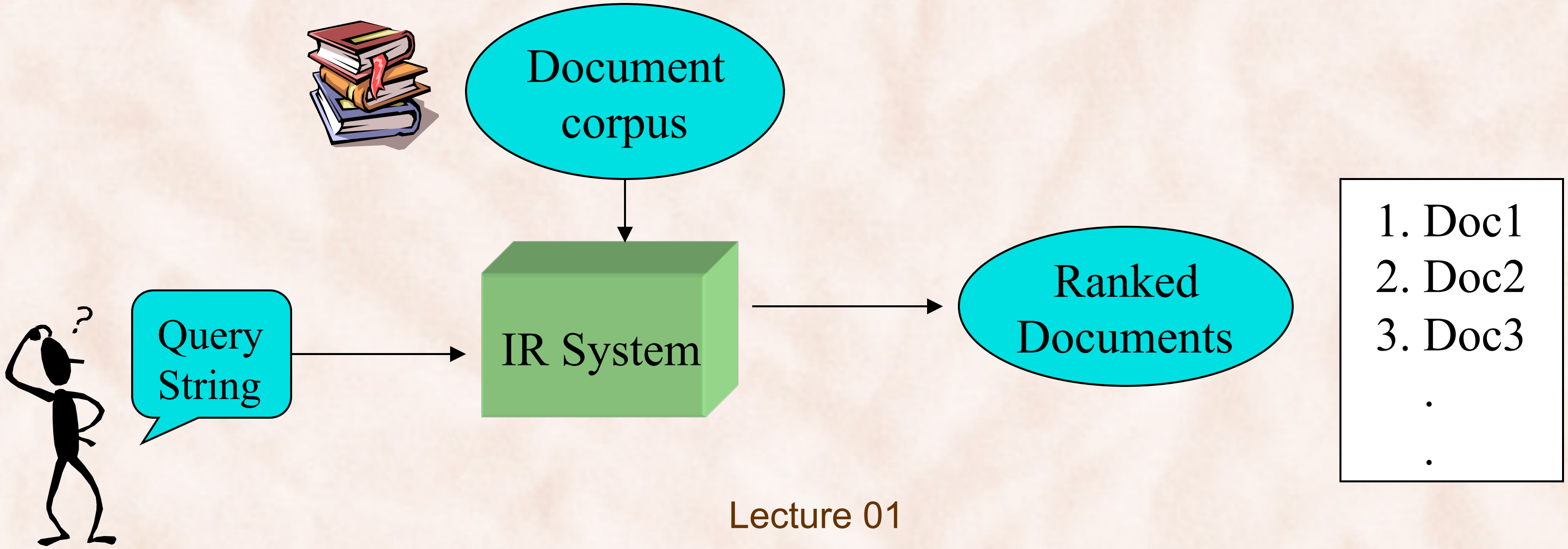
Information Retrieval

- Information Retrieval (IR) is finding material of an unstructured nature that satisfies an information need from within large collections.

- Examples of large collections and informations needs:
  1) Large corpus of literary texts:
     - Find Shakespeare plays that talk about the meaning of life.
  2) World Wide Web:
     - Find affordable hotels on the beach in Destin, Florida.
  3) My computer:
     - Find files that contain the words "information retrieval".

Typical IR task

- Input:
  - A large collection of unstructured text documents.
  - A user query expressed as text.
- Output:
  - A ranked list of documents that are relevant to the query



Document corpus

Query String

IR System

Ranked Documents

1. Doc1
2. Doc2
3. Doc3

.

.

IR on a Large Text Corpus

1. *“Find Shakespeare plays that talk about the meaning of life”:*
   - Information Need expressed as a string Query:
     - Boolean:
       - Naïve: meaning AND life
       - Better: (meaning OR signify) AND life
     - Phrase: “the meaning of life”
     - Proximity: meaning NEAR life
     - Keywords: meaning life
   - Material of an unstructured nature:
     - text documents (plays).

IR on the Web (Web Search)

- *"Find affordable hotels on the beach in Destin, Florida"*:
  - Information Need, typically expressed as a keyword query:
    - Keywords: 3 star hotel on the beach in Destin FL.
  - Material of an unstructured nature:
    - Text (unstructured)
    - HTML (semistructured).
      - Exploit the HTML structure.
      - Exploit the link structure of the Web (PageRank, HITS).

IR on My Computer (Personal IR)

- *“Find files that contain the words Information Retrieval”*:
  - Information Need, typically expressed as a keyword query:
    - Keywords: information retrieval
      - Interpreted as a conjunctive Boolean query in MS Vista Instant Search and Mac OS X Spotlight:
        - » Boolean: information AND retrieval
  - Material of an unstructured nature:
    - Need to handle a broad range of documents types:
      - Text, HTML, XML, PDF, ODT, DOCX, PPTX, …

Information Retrieval vs. Database Search

- Information Retrieval:
  - Finding information in unstructured repositories (text).
  - Queries: Boolean, keyword, phrase, proximity, …
    - 3 star hotel on the beach in Destin FL
- Database Search:
  - Finding information stored in structured repositories (relational databases, graph databases, etc.).
  - Queries: SQL, SPARQL, RPQ, Cypher, …
    - SELECT * FROM Book WHERE price > 100

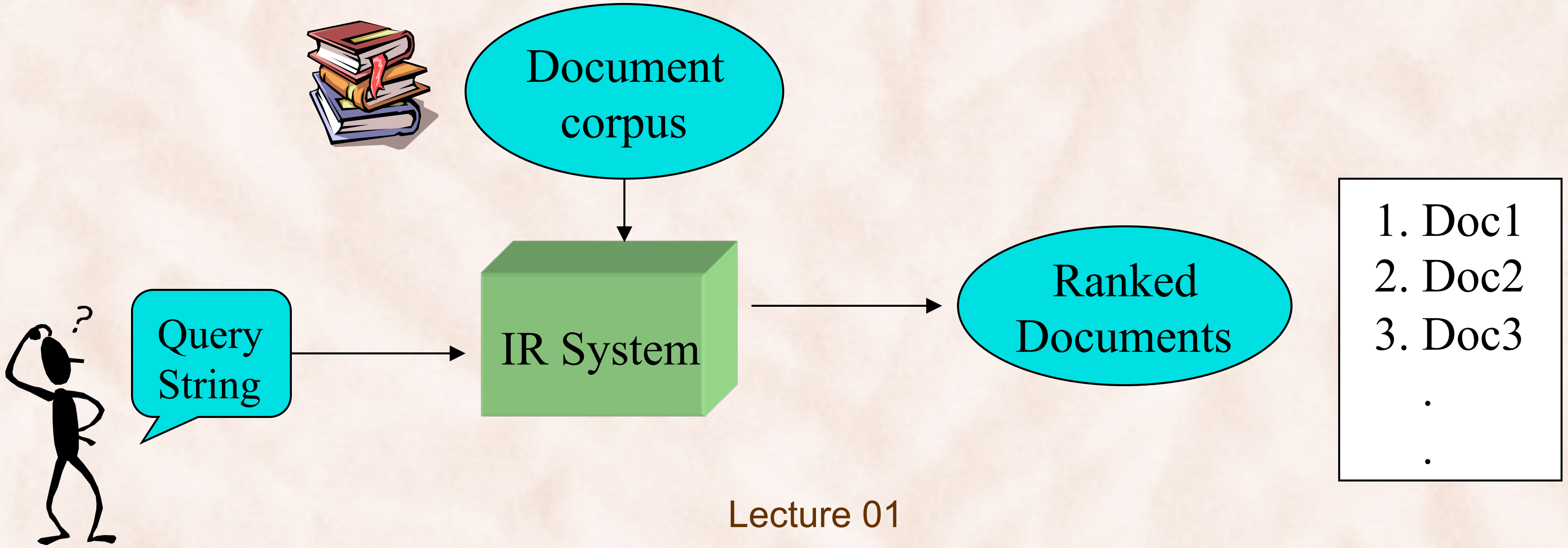
      ORDER BY title;

(Semi)Structured Information Retrieval

- (Semi)Structured IR: find information in text with markup:
  - Queries combine textual criteria with structural criteria:
    - Digital libraries: give me a full-length article on fast fourier transforms
    - Patent DBs: give me patents whose claims mention RSA public key encryption and that cite US patent 4,405,829.
    - Entity-tagged text: give me articles about sightseeing tours of the Vatican and the Coliseum.
  - Markup languages: HTML, XML, ODT (OpenOffice), …

Typical IR task

- Input:
  - A large collection of unstructured text documents.
  - A user query expressed as text.
- Output:
  - A ranked list of documents that are **relevant** to the query



Relevance

- Relevance is a subjective judgment and may include:
  - Being on the subject.
  - Being timely (recent information).
  - Being authoritative (from a trusted source).
  - Satisfying the user’s information need i.e. his/her goals and intended use of the information.
    - “Find Shakespeare plays that talk about the meaning of life”.
    - Typically expressed as a Query String:
      - meaning of life

From Queries to Relevant Documents

- **Phrase Queries**:
  - Simplest notion of relevance is that the query string appears verbatim in the document.
  - “meaning of life”

- **Keyword Queries**:
  - Slightly less strict notion is that the words in the query appear frequently in the document, in any order (bag-of-words).
  - meaning life

“Find Shakespeare plays that talk about the meaning of life”
Keyword Query: meaning life

Tomorrow, and tomorrow, and tomorrow,
Creeps in this petty pace from day to day,
To the last syllable of recorded time;
And all our yesterdays have lighted fools
The way to dusty death. Out, out, brief candle!
Life's but a walking shadow, a poor player
That struts and frets his hour upon the stage
And then is heard no more. It is a tale
Told by an idiot, full of sound and fury
Signifying nothing.

— Skakespeare’s Macbeth (Act 5, Scene 5, lines 17-28)

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=> need to bridge the **Lexical Gap**

"Find Shakespeare plays that talk about the meaning of life"
Boolean Query: (meaning OR signify) AND life

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From Information Retrieval (IR) to Question Answering (QA)

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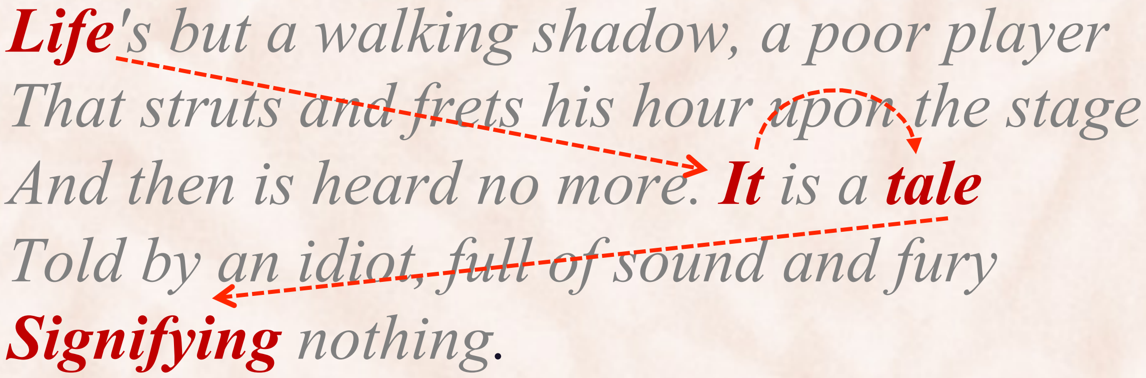

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Q: What is the meaning of life?
A: Nothing!

Question Answering vs. Information Retrieval

- QA enables users to express information needs through questions in natural language.
  - Answer in QA is focused, typically a noun phrase for factual QA.
  - Answer in IR is a ranked list of relevant documents.
- QA needs deeper linguistic processing of the text ⇒ more difficult than classical keyword–based IR:
  - Coreference Resolution.
  - Syntactic/Dependency Parsing.
  - Word Sense Disambiguation.

Problems with Simple Keyword-based IR

- May not retrieve relevant documents that include synonymous terms.
  - meaning vs. signifying
  - FL v
- May re
  polyse
  - Python (baseball vs. mammal)
  - Apple (company vs. fruit)
  - play (theater play vs. act of playing)

In this course:

- We will cover the basics of keyword-based IR.
- Also address more complex techniques for “intelligent” IR.

Intelligent IR

- Take into account the *meaning* of the words used.
- Take into account the *order* of words in the query.
- Adapt to the user based on automatic or semi-automatic *feedback.*
- *Expand* search query with related terms.
- Perform automatic *spell checking* / *diacritics restoration.*
- Take into account the *authority* of the source.

Classic IR Models

- Each document represented by a set of representative keywords or **index terms**.
- An **index term** is a document word useful for remembering the document main themes.
- Index terms may be selected to be only nouns, since nouns have meaning by themselves:
  - Should reduce the size of the index.
  - ... But it requires the identification of nouns ⇒ Part of Speech tagger
- However, search engines assume that all words are index terms (full text representation).

Classic IR Models

- Not all terms are equally useful for representing the document contents:
  - less frequent terms allow identifying a narrower set of documents
- The importance of the index terms is represented by weights associated to them.
- Let:
  - k_i be an index term
  - d_j be a document
  - w_{ij} is a weight associated with (k_i,d_j)
- The weight w_{ij} quantifies the importance of the index term for describing the document contents.

IR System Components

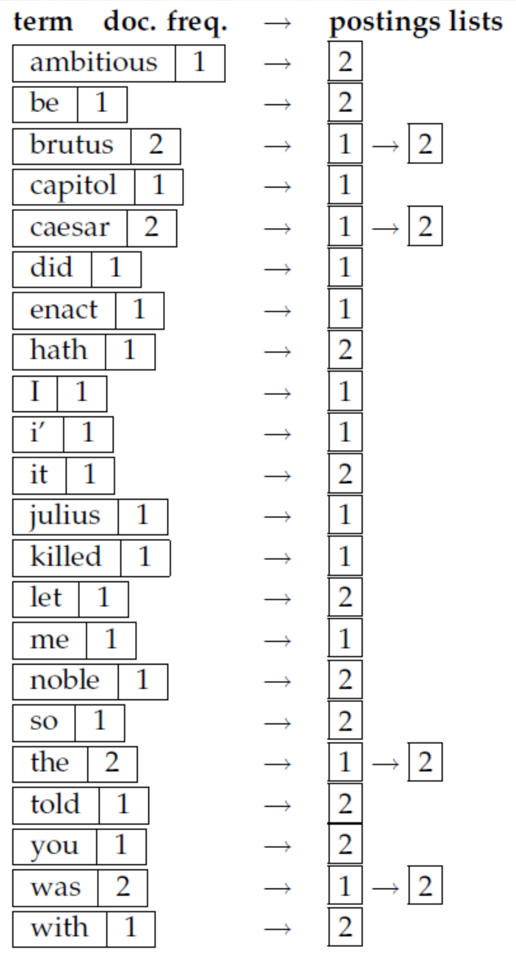
- **Text Operations** form index words (tokens)
  - Tokenization.
  - Stopword removal.
  - Stemming.
- **Indexing** constructs an *inverted index* of word to document pointers.
  - Mapping from tokens to document IDs.

Doc 1

I did enact Julius Caesar I was killed i' the Capitol; Brutus killed me.

Doc 2

So let it be with Caesar. The noble Brutus hath told you Caesar was ambitious



term	doc. freq.	→	postings lists
ambitious	1	→	2
be	1	→	2
brutus	2	→	1 → 2
capitol	1	→	1
caesar	2	→	1 → 2
did	1	→	1
enact	1	→	1
hath	1	→	2
I	1	→	1
i'	1	→	1
it	1	→	2
julius	1	→	1
killed	1	→	1
let	1	→	2
me	1	→	1
noble	1	→	2
so	1	→	2
the	2	→	1 → 2
told	1	→	2
you	1	→	2
was	2	→	1 → 2
with	1	→	2

IR System Components

- **Searching** retrieves documents that contain a given query token from the inverted index.
- **Ranking** scores all retrieved documents according to a relevance metric.
- **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.

Relevant Disciplines

- **Natural Language Processing**:
  - Tokenization & Stemming.
  - Part-Of-Speech (POS) tagging.
  - Syntactic Parsing, Word Sense Disambiguation, Information Extraction, …
- **Artificial Intelligence**:
  - Focused on the representation of knowledge, reasoning, and intelligent action.
  - Formalisms for representing knowledge and queries:
    - First-order Predicate Logic.
    - Bayesian Networks.

Relevant Disciplines

- **Machine Learning**:
  - 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 to rank relevant documents.
  - Learning models for basically any relevant NLP task:
    - Tokenization, POS tagging, syntactic parsing, WSD, …

Relevant Disciplines

- **Linear Algebra**:
  - Vector Space Models.
  - Latent Semantic Indexing.
  - Link Analysis.

- **Probability and Statistics**:
  - Probabilistic IR.
  - Language Models for IR.
  - Link Analysis.

Course Topics (Tentative)

1. Classical IR models:
   - Boolean & Vector Space Models.
   - Text operations & Indexing
2. Probabilistic IR.
3. Language Models for IR.
4. Evaluation of IR performance.
5. Relevance feedback and query expansion.
6. Web Search:
   - Web crawling.
   - Link analysis (PageRank, Hubs and Authorities).

Course Topics (Tentative)

7. Text Classification and Clustering.
8. Personalized IR.
9. Question Answering.

- Tutorials: Python & NLTK.
- Background: Linear Algebra, Probability and Statistics.