Introduction to Information Retrieval

CS4422/7263 Information Retrieval
Lecture 01

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CS4422/7263 Spring 2025

1. About this course

2. What is Information Retrieval (IR)

3. Challenges in IR

4. Course Objectives

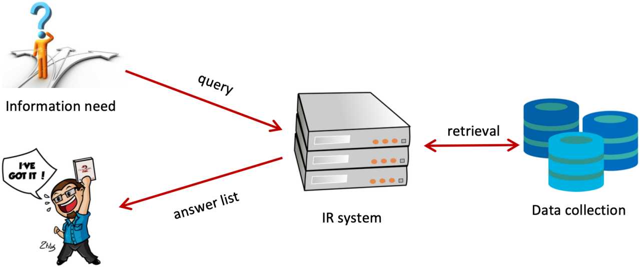
About this course

Course Details: https://jiho.us/teaching/cs7263-sp2025

1. About this course
2. **What is Information Retrieval (IR)**
3. Challenges in IR
4. Course Objectives

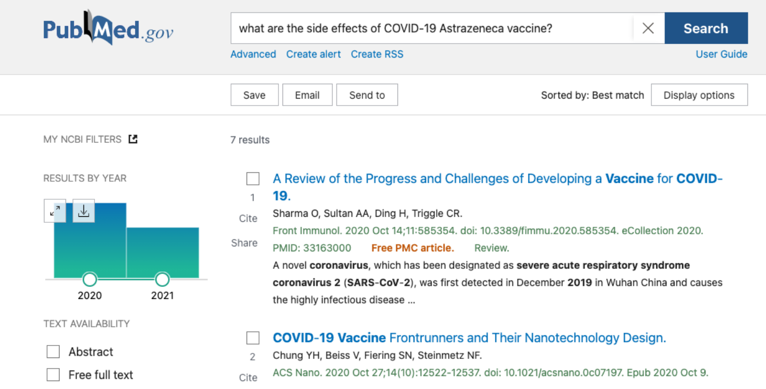
Information Retrieval (IR) Systems

- The goal of IR is
  - to find a small set of items
  - relevant to the user's information need
  - from a large collection of data.



Document Search Engine — PubMed

PubMed is a search engine of references and abstracts of life science and biomedical topics.



what are the side effects of COVID-19 Astrazeneca vaccine?

Sorted by: Best match

7 results

☐ Abstract

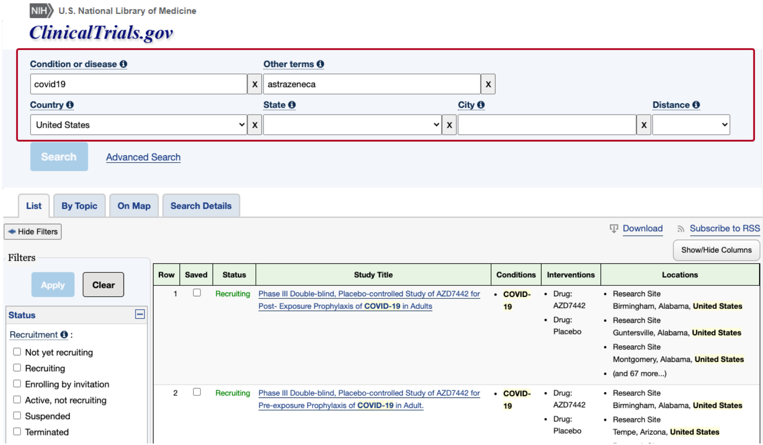
☐ Free full text

☐ 1 A Review of the Progress and Challenges of Developing a **Vaccine** for **COVID-19**.
Sharma O, Sultan AA, Ding H, Triggle CR.
Front Immunol. 2020 Oct 14;11:585354. doi: 10.3389/fimmu.2020.585354. eCollection 2020.
PMID: 33163000 **Free PMC article.** Review.
A novel **coronavirus**, which has been designated as **severe acute respiratory syndrome coronavirus 2** (**SARS-CoV-2**), was first detected in December **2019** in Wuhan China and causes the highly infectious disease ...

☐ 2 **COVID-19 Vaccine** Frontrunners and Their Nanotechnology Design.
Chung YH, Beiss V, Fiering SN, Steinmetz NF.
ACS Nano. 2020 Oct 27;14(10):12522-12537. doi: 10.1021/acsnano.0c07197. Epub 2020 Oct 9.

Document Search Engine — Clinical Trials

Clinical Trials is a database of clinical studies conducted around the world



NIH U.S. National Library of Medicine

ClinicalTrials.gov

Condition or disease: covid19

Other terms: astrazeneca

Country: United States

State:

City:

Distance:

Status

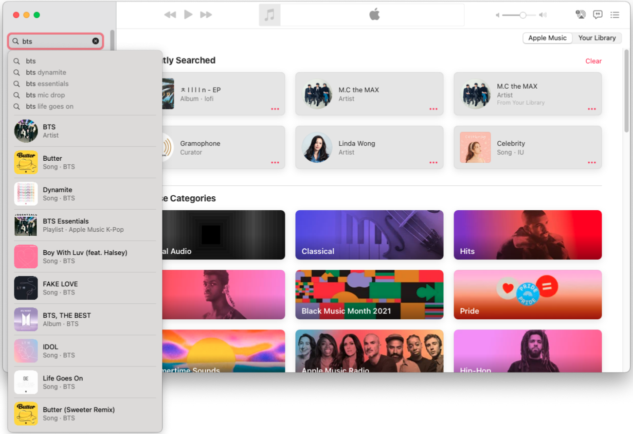
Recruitment:

- □ Not yet recruiting
- □ Recruiting
- □ Enrolling by invitation
- □ Active, not recruiting
- □ Suspended
- □ Terminated

Row	Saved	Status	Study Title	Conditions	Interventions	Locations
1	□	Recruiting	Phase III Double-blind, Placebo-controlled Study of AZD7442 for Post- Exposure Prophylaxis of **COVID-19** in Adults	• **COVID-19**	• Drug: AZD7442 • Drug: Placebo	• Research Site Birmingham, Alabama, **United States** • Research Site Guntersville, Alabama, **United States** • Research Site Montgomery, Alabama, **United States** • (and 67 more...)
2	□	Recruiting	Phase III Double-blind, Placebo-controlled Study of AZD7442 for Pre-exposure Prophylaxis of **COVID-19** in Adult.	• **COVID-19**	• Drug: AZD7442 • Drug: Placebo	• Research Site Birmingham, Alabama, **United States** • Research Site Tempe, Arizona, **United States**

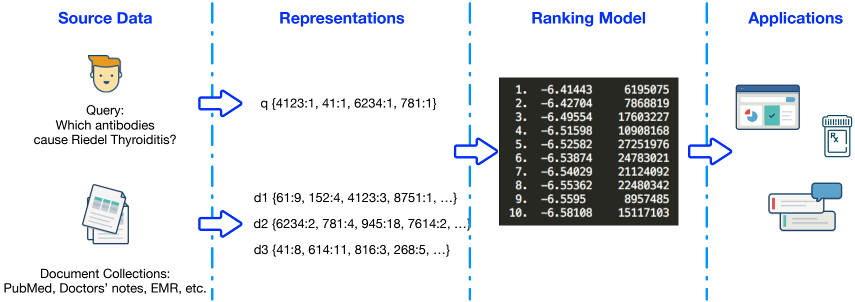
Search for Other Contents — Songs

Examples of Content — text, images, videos, music, any other items for recommendation systems



Document Retrieval Pipeline

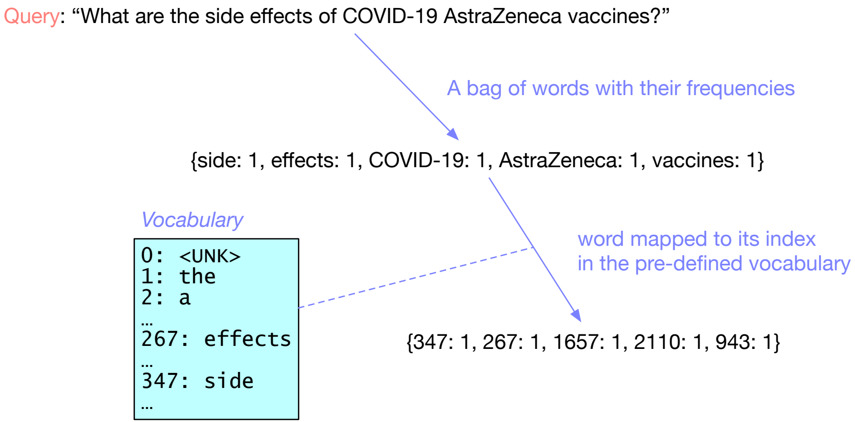
- Document Retrieval is the process of semantic matching between a stated user query and free-text documents



Source Data
Representations
Ranking Model
Applications
Query:
Which antibodies
cause Riedel Thyroiditis?
Document Collections:
PubMed, Doctors' notes, EMR, etc.
q {4123:1, 41:1, 6234:1, 781:1}
d1 {61:9, 152:4, 4123:3, 8751:1, ...}
d2 {6234:2, 781:4, 945:18, 7614:2, ...}
d3 {41:8, 614:11, 816:3, 268:5, ...}

```
 1.  -6.41443      6195075
 2.  -6.42704      7868819
 3.  -6.49554     17603227
 4.  -6.51598     10908168
 5.  -6.52582     27251976
 6.  -6.53874     24783021
 7.  -6.54029     21124092
 8.  -6.55362     22480342
 9.  -6.5595       8957485
10.  -6.58108     15117103
```

Bag-of-words Model



Query: “What are the side effects of COVID-19 AstraZeneca vaccines?”

A bag of words with their frequencies

{side: 1, effects: 1, COVID-19: 1, AstraZeneca: 1, vaccines: 1}

Vocabulary

```
0: <UNK>
1: the
2: a
…
267: effects
…
347: side
…
```

word mapped to its index
in the pre-defined vocabulary

{347: 1, 267: 1, 1657: 1, 2110: 1, 943: 1}

Ranking Documents

Query (q):

- What are the side effects of COVID-19 AstraZeneca vaccines?

A Document (d):

- The most common side effects with COVID-19 Vaccine AstraZeneca in the trials were usually mild or moderate pain and tenderness at the injection site, headache, tiredness, muscle pain. ...

```
q: {347:1, 267:1, 1657:1, 2110:1, 943:1}
d: {0:14, 1:163,
       ..., 347:3, 267:3, 1657:17, 2110:5, 943:7, .. }
```

A ranking model measures the relevance of d to q, such as BM25(q, d) which are typically based on exact-term matching.

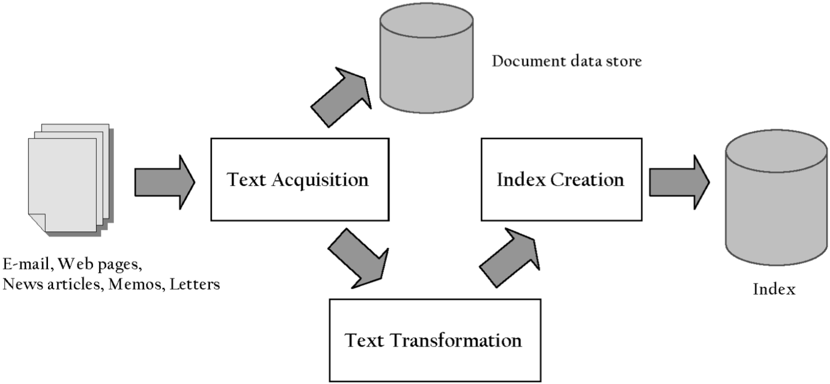
Relevance

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)

Indexing Process

- The **indexing process** builds the structure that enable searching: collect information from external resource, process data, create index, and store them for searching needs.



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Vocabulary Mismatch

- Vocabulary Mismatch is a common phenomenon in the usage of natural language, occurring when different people name the same thing or concept differently.
- q: What are the side effects of COVID-19 AstraZeneca vaccines?
- d+: The most common risks associated with coronavirus vaccines are mild pain at the injection site, . . .
- d-: The economic effects of COVID-19 containment measures . . . On the supply side . . ., until when vaccines are widely available . . .

Vocabulary Mismatch (Cont.)

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

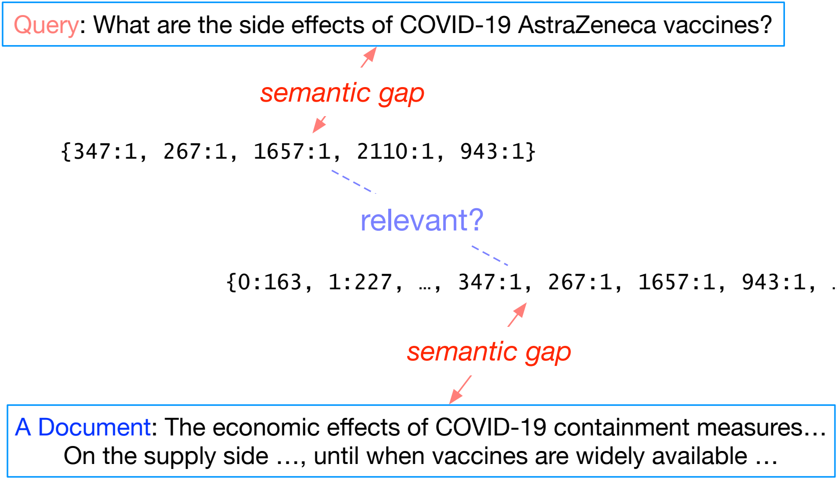
- We will cover the basics of keyword-based IR, but ...
- We will focus on extensions and recent developments that go beyond keywords.
- We will cover the basics of building an efficient IR systems,

but . . .

- We will focus on basic capabilities and algorithms rather than systems that allow scaling to industrial size databases.

Semantic Gap

- Semantic Gap is the difference between two descriptions of a theme by different linguistic representations.



Query: What are the side effects of COVID-19 AstraZeneca vaccines?

semantic gap

`{347:1, 267:1, 1657:1, 2110:1, 943:1}`

relevant?

`{0:163, 1:227, …, 347:1, 267:1, 1657:1, 943:1, …}`

semantic gap

A Document: The economic effects of COVID-19 containment measures… On the supply side …, until when vaccines are widely available …

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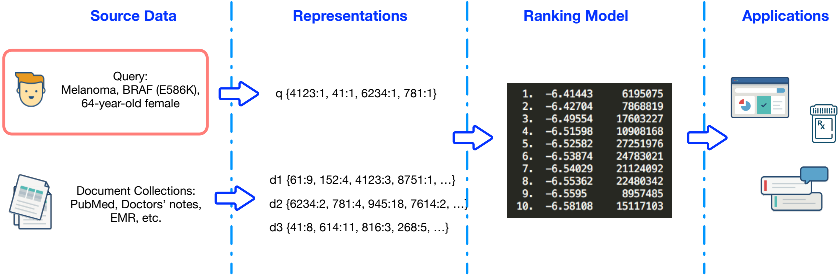
Course Objectives



Query:
Melanoma, BRAF (E586K),
64-year-old female

q {4123:1, 41:1, 6234:1, 781:1}

Document Collections:
PubMed, Doctors' notes,
EMR, etc.

d1 {61:9, 152:4, 4123:3, 8751:1, ...}

d2 {6234:2, 781:4, 945:18, 7614:2, ...}

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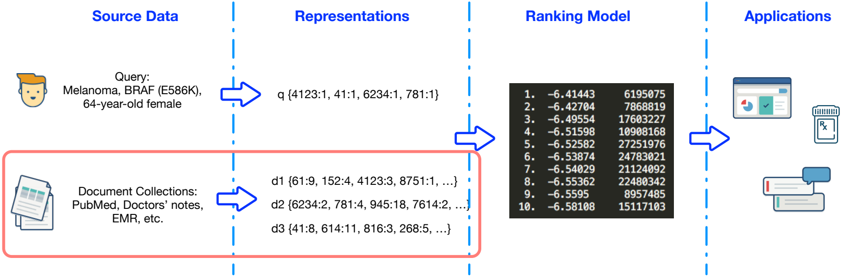
```

- Query Transformation and Refinement
  - How can we enhance the query representation of the user's information need?
  - spell checking, query expansion, relevance feedback, controlled vocabulary, · · ·

Course Objectives (Cont.)



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```
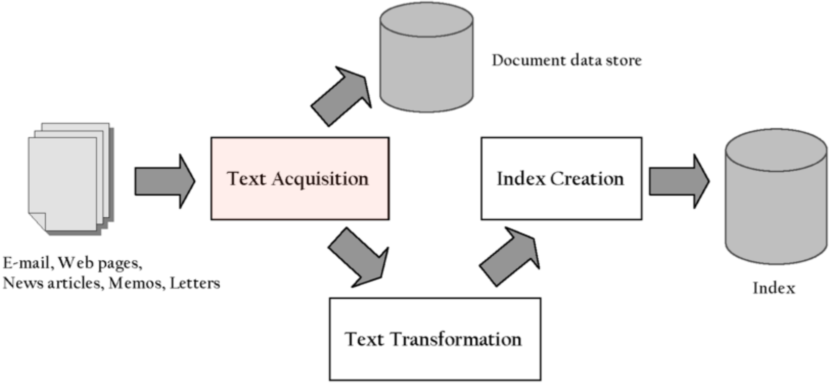
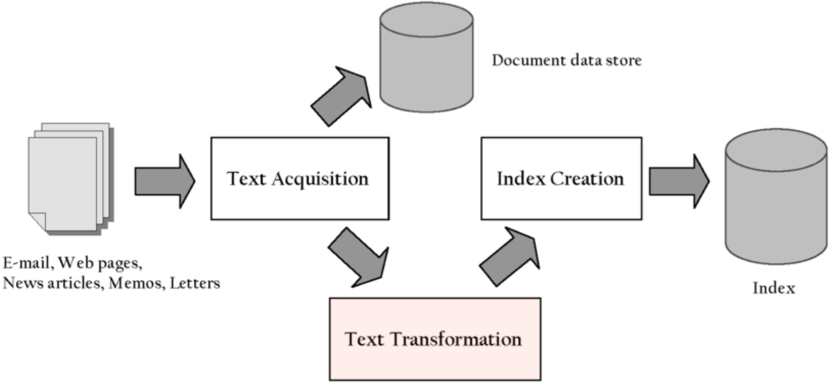

- Retrieval Models
  - What are the retrieval models and how can we improve the scoring methods for measuring the document relevance?
  - set theory/algebraic/probabilistic models, TF-IDF, Okapi BM25, ...

Course Objectives (Cont.)



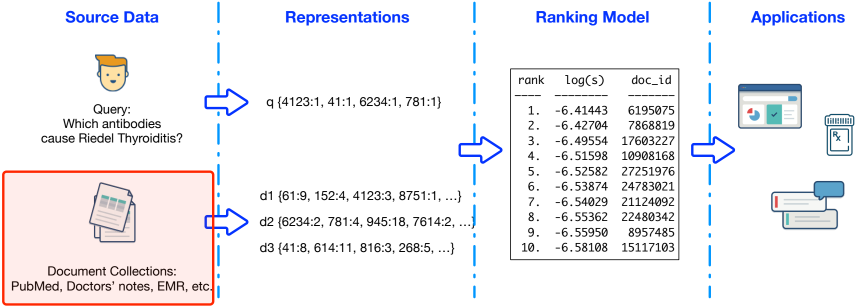
- Web Crawler
  - How do we collect and store information on the Internet, effectively and efficiently?
  - HTTP requests, URL management, graph traversal, webpage access policies, database, detecting duplicates, ...

Course Objectives (Cont.)



- Text Processing
  - How do analyze and process the collection of the Internet data to simplify searching?
  - text statistics, techniques for handling textual data, document parsing, lemmatization, stopping, stemming, encoding schemes, ...

Course Objectives (Cont.)



Source Data

Query:
Which antibodies
cause Riedel Thyroiditis?

Document Collections:
PubMed, Doctors' notes, EMR, etc.

Representations

q {4123:1, 41:1, 6234:1, 781:1}

d1 {61:9, 152:4, 4123:3, 8751:1, ...}

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d3 {41:8, 614:11, 816:3, 268:5, ...}

Ranking Model

```
rank   log(s)     doc_id
----  --------   -------
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 8.   -6.55362  22480342
 9.   -6.55950   8957485
10.   -6.58108  15117103
```
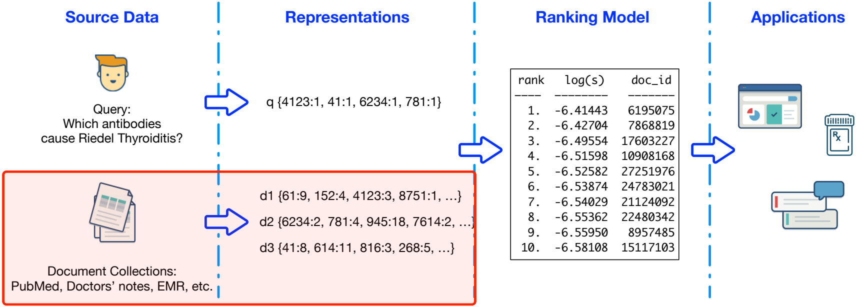

Applications

- Machine Learning Approaches for Document Understanding
  - How can we leverage machine learning methods to better understand the 'real' meaning of documents?
  - text classification, clustering, topic modeling, learning-to-rank, ...

Course Objectives (Cont.)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Document Collections:
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```
rank   log(s)     doc_id
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 10.  -6.58108  15117103
```
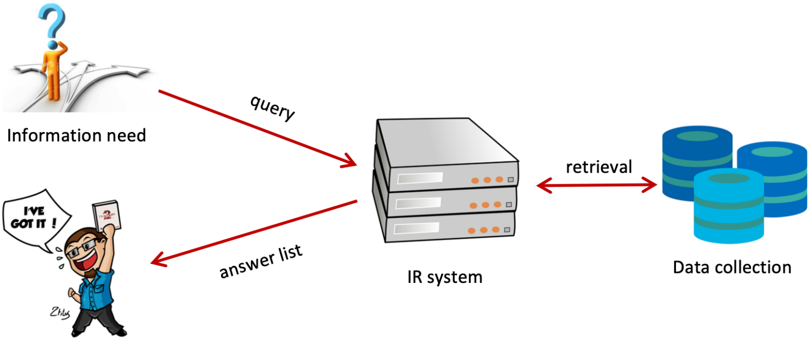

- Deep Learning Approaches
  - How can we bridge the semantic gaps between source data and their representations?
  - neural networks, word embeddings, language models and transformer

Course Objectives (Cont.)



- Deep Learning Approaches
  - What are the evaluation methods to measure the utility of the IR system?
  - IR evaluation metrics, ranking measures

Beyond Information Retrieval

- Semantic Understanding
- Multimodal Retrieval
- Personalization
- Cross-domain recommendation
- Large Language Models for IR
- Retrieval Augmented Machine Learning
- Question Answering
- Conversational IR models

Beyond Information Retrieval (Cont.)

- Interactive search
- FATE (Fairness, Accountability, Transparency, Ethics, and Explainability)
- Knowledge representation and reasoning
- Document representation and content analysis
  - Summarization
  - Readability
  - Opinion mining and sentiment analysis
  - ...

Summary

- and discussion