CIS 455/555: Internet and Web Systems

Web Services

November 1, 2021

University of Pennsylvania

Plan for today

- Web services ✓
  - REST vs SOAP ✓
  - Real REST services ← NEXT
- Information retrieval
  - Basics
  - Precision and recall
  - Taxonomy of IR models

Representational State Transfer (REST)

- Another example of a messaging protocol
- Not really a standard – a style of development
  - Data is represented in JSON or XML, e.g., with a schema
  - Function call interface uses HTTP Requests
    - GET/POST/PUT/PATCH/DELETE
    - Server is to be stateless
  - And the HTTP request type specifies the operation
    - e.g., GET http://my.com/rest/service1
    - e.g., POST http://my.com/rest/service1 {body} adds the body to the service

Example: The Facebook Graph API

https://developers.facebook.com/docs/graph-api

- Like many other web systems, Facebook offers API access to its system
- Programs can use the API to:
  - Read data from profiles and pages
  - Navigate the graph (e.g., via friends lists)
  - Issue queries (for posts, people, pages, ...)
  - Add or modify data (e.g., create new posts)
  - Get real-time updates, issue batch requests, ...
- How you can access it:
  - Graph API, Marketing API

JSON

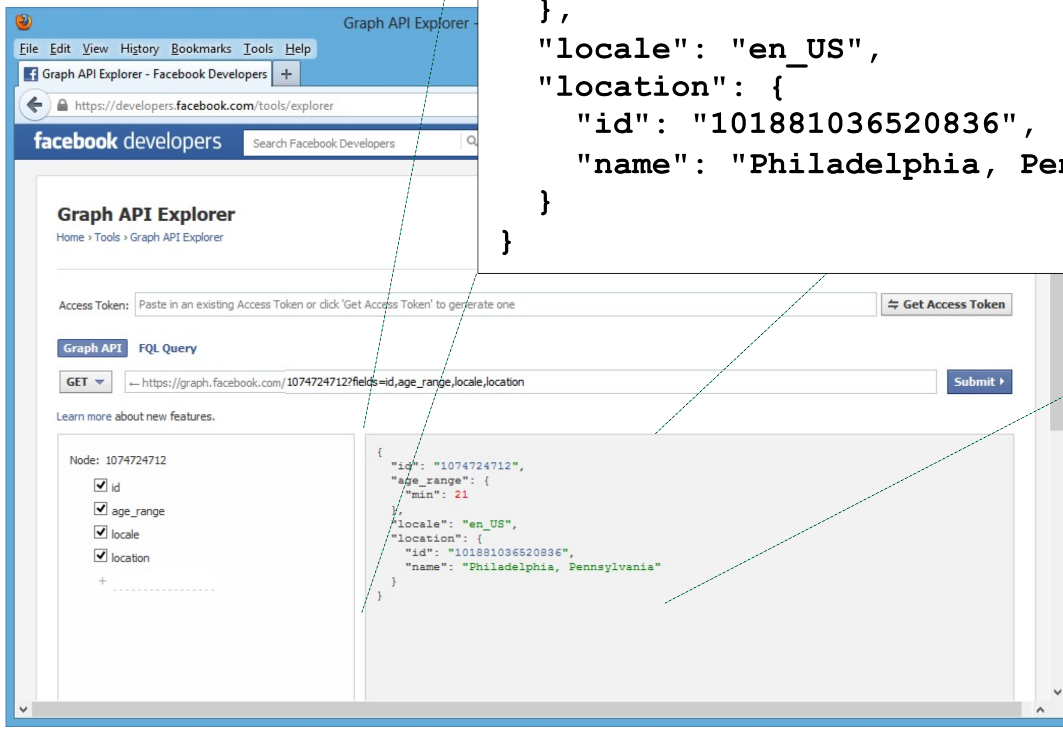
"Object": Unordered collection of key-value pairs

```
{
  "firstName": "John",
  "lastName": "Smith",
  "age": 25,
  "address": {
    "streetAddress": "21 2nd Street",
    "city": "New York",
    "state": "NY",
    "postalCode": 10021
  },
  "phoneNumber": [
    { "type": "home", "number": "212 555-1234" },
    { "type": "fax", "number": "646 555-4567" }
  ]
}
```

Array (ordered sequence of values; can be different types)

- Another standard for data interchange
  - "JavaScript Object Notation"; MIME type application/json
  - Basically legal JavaScript code; can be parsed with eval()
    - Caution: Security!
  - Often used in AJAX-style applications
  - Data types: Numbers, strings, booleans, arrays, "objects"

The Graph API

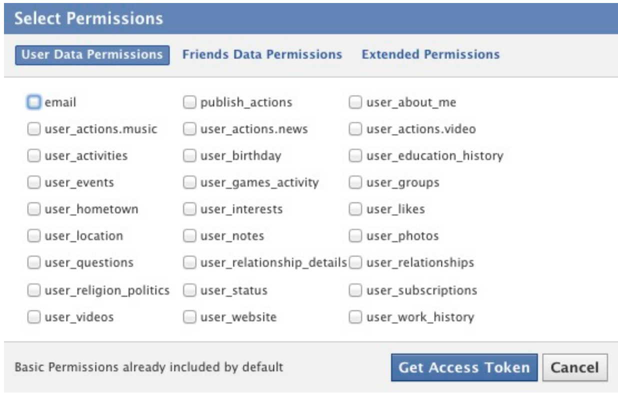



```
{
  "id": "1074724712",
  "age_range": {
    "min": 21
  },
  "locale": "en_US",
  "location": {
    "id": "101881036520836",
    "name": "Philadelphia, Pennsylvania"
  }
}
```


- Requests are mapped directly to HTTP:
  - https://graph.facebook.com/(identifier)?fields=(fieldList)
- Response is in JSON

The Graph API

- Uses several HTTP methods:
  - GET for reading
  - POST for adding or modifying
  - DELETE for removing
- IDs can be numeric or names
  - /1074724712 or /vincent.liu
  - Pages also have IDs
- Authorization is via 'access tokens'
  - Opaque string; encodes specific permissions (access user location, but not interests, etc.)
  - Has an expiration date, so may need to be refreshed



Other API options

- Facebook Query Language (FQL)
  - SQL-style queries over the data provided via the Graph API
  - Example: SELECT name FROM user WHERE uid=me()
  - Supports 'multi-queries' (JSON-encoded dictionary of queries)
  - 72 different tables are available for querying

- Legacy REST API
  - See description of REST in the previous lecture
  - In the process of being deprecated
  - Large number of methods available
    - Examples: friends.get, comments.add, status.set, video.upload, ...

Other Services

- Google Maps, Google Search, Kaggle, many other sites support REST services
- Almost all require you to request an "access token" and have a limit on free requests
- Many use the OAuth standard for user authentication – log in e.g., with your Google or Facebook ID

REST Implementation in Java

REST – REpresentational State Transfer

- Basic idea: use HTTP *navigation* to abstract parameters in a hierarchy
  http://my.service.com/lookup/{user}/{folder}/{file}

Typically use JSON to encompass the request + response. Two useful tools used in HW3:

- Jackson allows us to serialize/de-serialize Java objects in JSON

```
ObjectMapper om …;
str = om.writeValueAsString(myObj);
obj = om.readValue(str);
```

- "Route" based programming via Spark Java

```
public static void main(String[] args) {
  get("/myfn/:arg", (req, res) -> handle(req.body(), req.params(":arg")));
}
```

Summary

- Web services are an HTTP-based version of Remote Procedure Calls
  - Calls are synchronous, ie they wait for the server to return
- Key issue: how do we marshal parameters?
  - Pass by value, but may need to pass along typing info, references, etc.
  - Formalized W3C standards (SOAP, WSDL) vs ad hoc REST (+ JSON)

Plan for today

- Web services ✔
- Information retrieval ← NEXT
  - Basics
  - Precision and recall
  - Taxonomy of IR models
- Classic IR models
  - Boolean model
  - Vector model
  - TF/IDF

Web search

- Goal is to find information relevant to a user's interests - and this is hard!
- Challenge 1: Data quality
  - A significant amount of content on the web is not quality information
  - Many pages contain nonsensical rants, etc.
  - The web is full of misspellings, multiple languages, etc.
  - Many pages are designed <u>not</u> to convey information – but to get a high ranking (e.g., SEO, clickbait, fake news etc.)
- Challenge 2: Scale
  - Billions of documents
- Challenge 3: Very little structure
  - No explicit schema
  - However, hyperlinks and tags encode information!

Our discussion of web search

- Begin with traditional information retrieval
  - Document models
  - Stemming and stop words
- Web-specific issues
  - Crawlers and robots.txt (already discussed)
  - Scalability
  - Models for exploiting hyperlinks in ranking
    - Google and PageRank
    - Latent Semantic Indexing

Information Retrieval

- Traditional information retrieval is basically text search
  - A corpus or body of text documents, e.g., in a document collection in a library or on a CD
  - Documents are generally high-quality and designed to convey information
  - Documents are assumed to have no structure beyond words
- Searches are generally based on meaningful phrases, perhaps including predicates over categories, dates, etc.
  - The goal is to find the document(s) that best match the search phrase, according to a search model
- <u>Assumptions are typically different from Web</u>: quality text, limited-size corpus, no hyperlinks

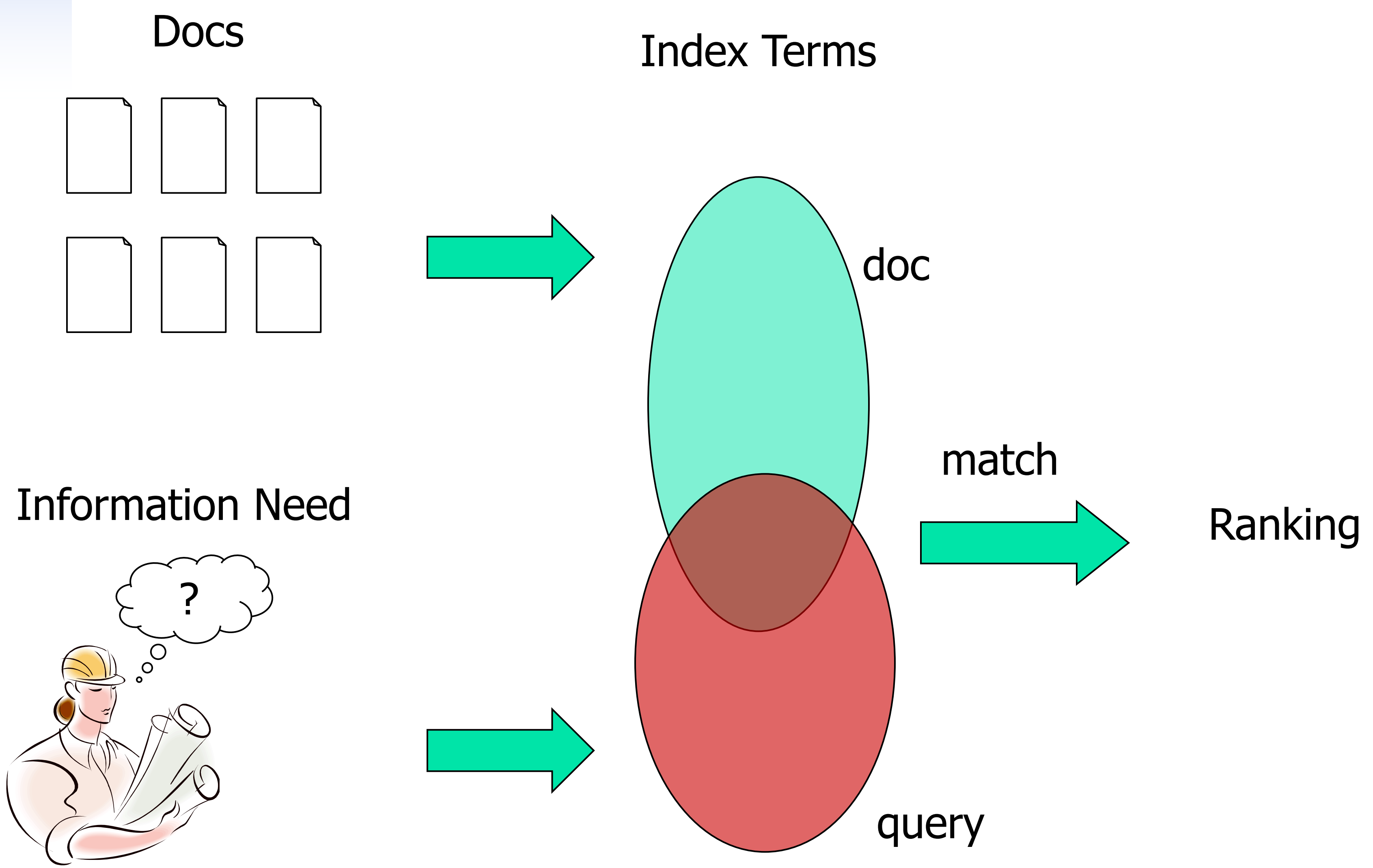
Motivation for Information Retrieval

- Information Retrieval (IR) is about:
  - Representation
  - Storage
  - Organization of
  - And access to "information items"
- Focus is on user's information need rather than a precise query:
  - User enters: "March Madness"
  - Goal: Find information on college basketball teams which (1) are maintained by a US university and (2) participate in the NCAA tournament
- Emphasis is on the retrieval of information (not data)

Data vs. Information Retrieval

- Data retrieval, analogous to database querying: which docs contain a set of keywords?
  - Well-defined, precise logical semantics
    - Example: All documents with (('CIS455' OR 'CIS555') AND ('midterm'))
  - A single erroneous object implies failure!
- Information retrieval:
  - Information about a subject or topic
  - Semantics is frequently loose; we want approximate matches
  - Small errors are tolerated (and in fact inevitable)
- IR system:
  - Interpret contents of information items
  - Generate a ranking which reflects relevance
  - Notion of relevance is most important – needs a model

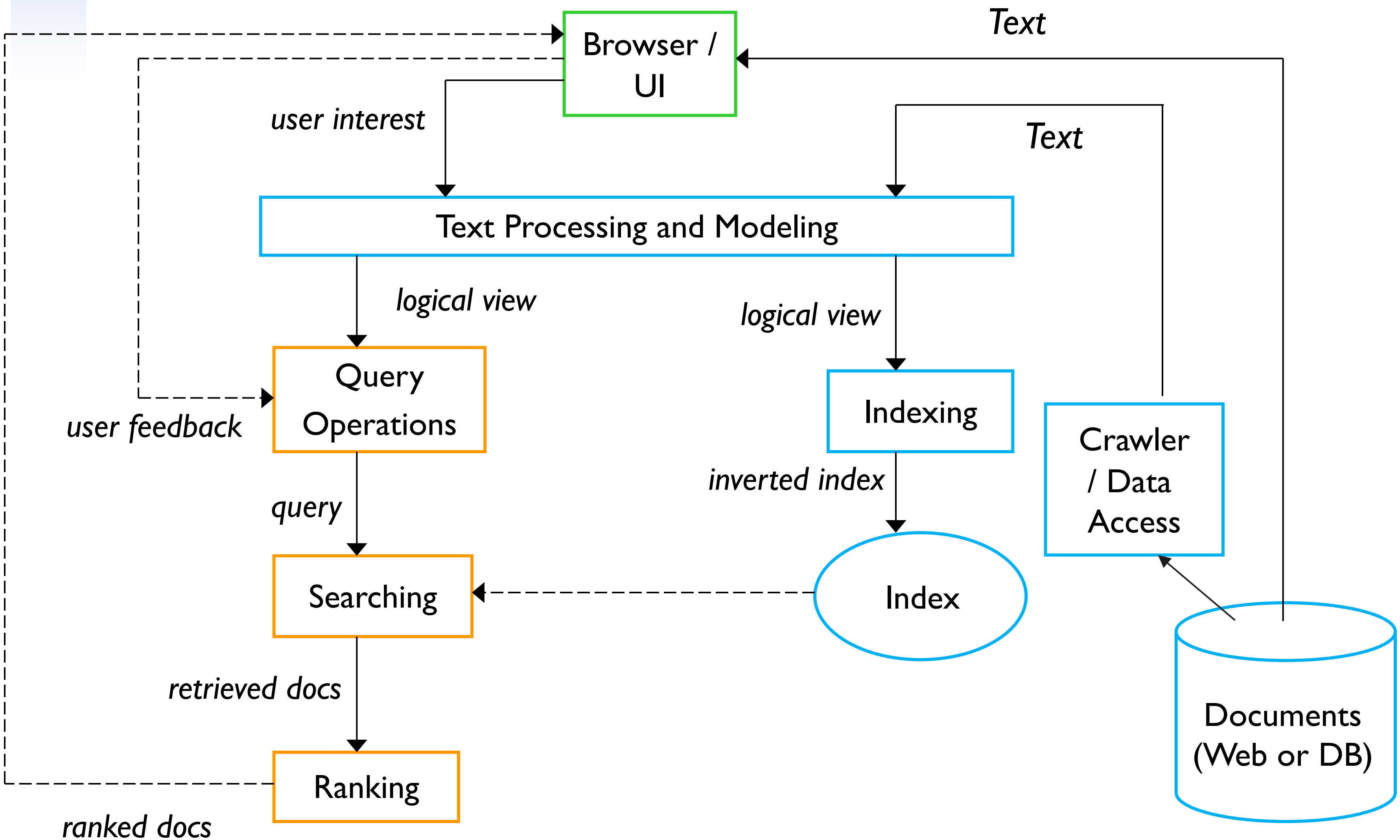
Basic model



Information Retrieval as a field

- IR addressed many issues in the last 30 years:
  - Classification and categorization of documents
  - Systems and languages for searching
  - User interfaces and visualization of results
- Area was seen as of narrow interest – libraries, mainly
- And then – the advent of the web:
  - Universal "library"
  - Free (low cost) universal access
  - No central editorial board
  - Many problems in finding information: IR seen as key to finding the solutions!

The full Information Retrieval process



Terminology

- IR systems usually adopt index terms to process queries
- Index term:
  - a keyword or group of selected words
  - any word (more general)
- Stemming or lemmatization might be used:
  - connect: connecting, connection, connections
- An inverted index is built for the chosen index terms

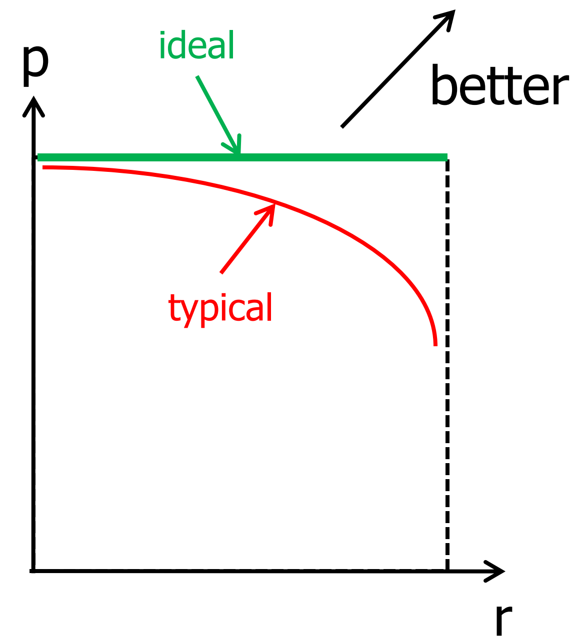
What is a meaningful result?

- Matching at index term level is quite imprecise
  - Users are frequently dissatisfied
  - One problem: users are generally poor at formulating queries
  - Frequent dissatisfaction of Web users (who often give single-keyword queries)

- Issue of deciding relevance is critical for IR systems: ranking
  - Show more relevant documents first
  - May leave out documents with low relevance

Precision and recall

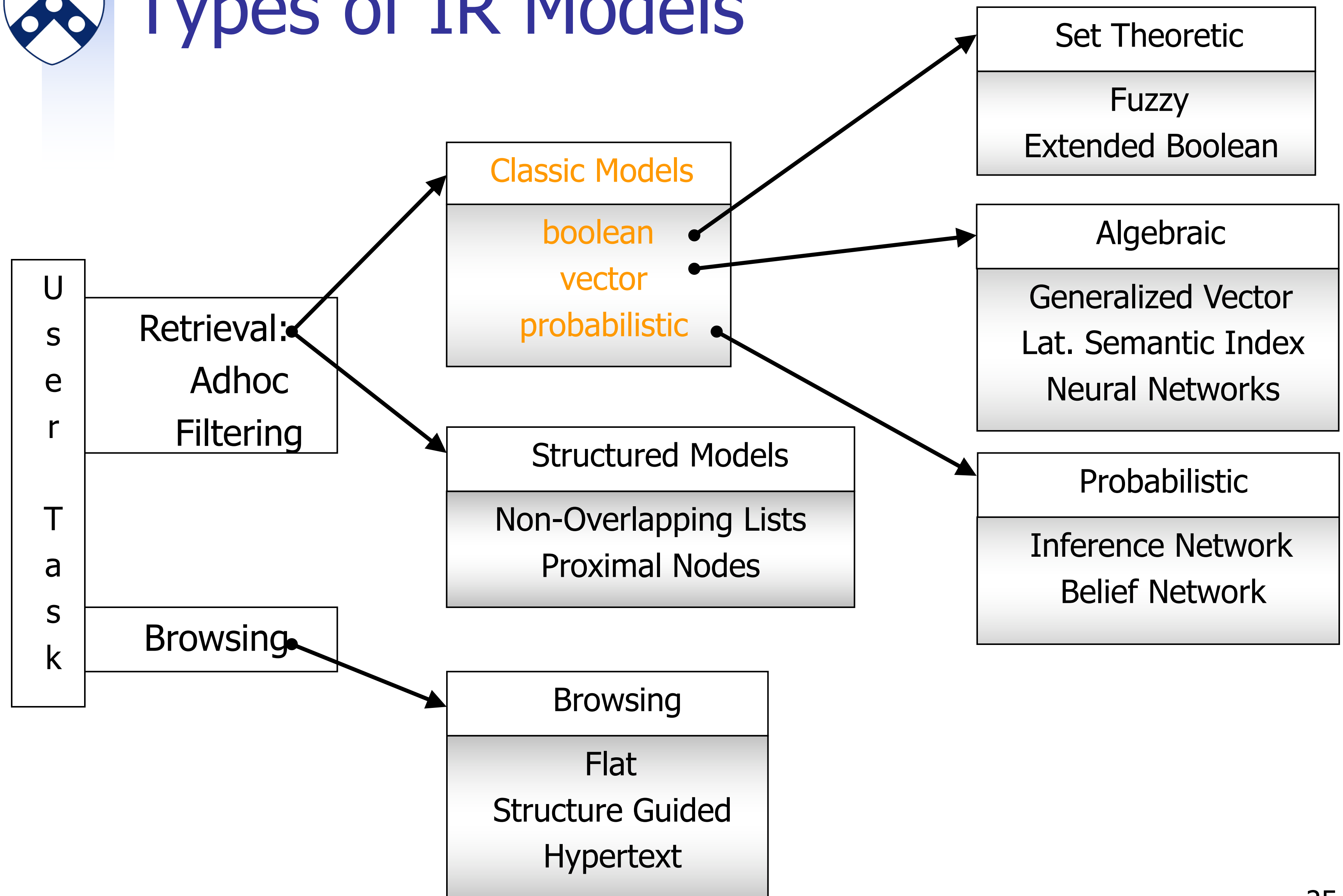
- How good is our IR system?
- Two common metrics:
  - Precision: What fraction of the returned documents is relevant?
  - Recall: What fraction of the relevant documents are returned?
  - How can you build trivial systems that optimize one of them?
- Tradeoff: Increasing precision will usually lower recall, and vice versa



Rankings

- A ranking is an ordering of the documents retrieved that (hopefully) reflects the relevance of the documents to the user query
- A ranking is based on fundamental premises regarding the notion of relevance, such as:
  - common sets of index terms
  - sharing of weighted terms
  - likelihood of relevance
- Each set of premises leads to a distinct IR model

Types of IR Models



Classic IR models – Basic concepts

- Each document represented by a set of representative keywords or index terms
- An index term is a document word useful for remembering the document's main themes
- Traditionally, index terms were nouns because nouns have meaning by themselves
- Search engines assume that all words are index terms (full text representation)

Classic IR Models – Weights

- 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} be a weight associated with (k_i, d_j)
- The weight w_{ij} quantifies the importance of the index term for describing the document contents

Classic IR Models – Notation

k_i	is an index term (keyword)
d_j	is a document
t	is the total number of index terms
$K = (k_1, k_2, \ldots, k_t)$	is the set of all index terms
$w_{ij} \geq 0$	is a weight associated with (k_i,d_j)
$w_{ij} = 0$	indicates that term does not belong to doc
$g_i(d_j) = w_{ij}$	is a function which returns the weight associated with pair (k_i, d_j)
$\vec{d_j} = (w_{1j}, w_{2j}, \ldots, w_{tj})$	is a weighted vector associated with the document d_j

Plan for today

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  - Basics ✔
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  - Taxonomy of IR models ✔
- Classic IR models ← NEXT
  - Boolean model
  - Vector model
  - TF/IDF
- HITS and PageRank

Boolean model

- Simple model based on set theory
- Queries specified as boolean expressions
  - precise semantics
  - neat formalism

- Terms are either present or absent. Thus,

$$w_{ij} \in \{0,1\}$$

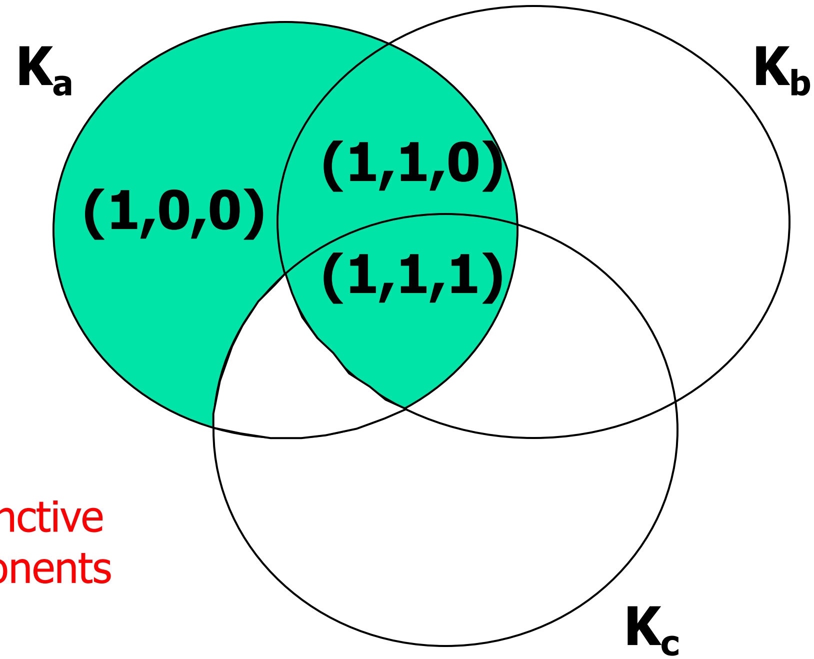
- An example query

$$q = k_a \wedge (k_b \vee \neg k_c)$$

Boolean model for similarity

Query:

$$q = k_a \wedge (k_b \vee \neg k_c)$$



In disjunctive normal form:

$$q = (k_a \wedge k_b \wedge k_c) \vee (k_a \wedge k_b \wedge \neg k_c) \vee (k_a \wedge \neg k_b \wedge \neg k_c)$$

conjunctive components

$$sim(d_j, q) = \begin{cases} 1 & \text{if } \exists \vec{q}_{cc} \mid (\vec{q}_{cc} \in \vec{q}_{dnf}) \wedge (\forall k_i : g_i(\vec{d}_j) = g_i(\vec{q}_{cc})) \\ 0 & \text{otherwise} \end{cases}$$

Drawbacks of boolean model

- Retrieval based on binary decision criteria with no notion of partial matching
- No ranking of the documents is provided (absence of a grading scale)
- Information need has to be translated into a Boolean expression, which most users find awkward
- The Boolean queries formulated by the users are most often too simplistic
- As a consequence, the Boolean model frequently returns either too few or too many documents in response to a user query

- We need something more tolerant!

Plan for today

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  - Vector model ← NEXT
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Vector model

- A refinement of the boolean model, which does not focus strictly on exact matching
  - Non-binary weights provide consideration for partial matches
  - These term weights are used to compute a degree of similarity between a query and each document

- Ranked set of documents provides for better matching

Vector model

- Define:

  $w_{ij} > 0$ whenever $k_i \in d_j$

  $w_{iq} \geq 0$ associated with the pair (k_i,q)

  $\vec{d_j} = (w_{1j}, w_{2j}, ..., w_{tj})$

  $\vec{q} = (w_{1q}, w_{2q}, ..., w_{tq})$

  - With each term k_i, associate a vector *vec(i)*
  - These vectors (e.g., *vec(i)* and *vec(j)*) are assumed to be orthonormal (i.e., index terms are assumed to occur independently within the documents)
    - Does this assumption ("independence assumption") hold in practice?

- The *t* vectors *vec(i)* form an orthonormal basis for a t-dimensional space
- In this space, queries and documents are represented as weight vectors

Bag of words

- In this model, $w_{ij} > 0$ whenever $k_i \in d_j$
  - Exact ordering of terms in the document is ignored
  - This is called the "bag of words" model
- What will be the vectors for the following two documents?
  - "Ape eats banana"
  - "Banana eats ape"
- What needs to be done to fix this?

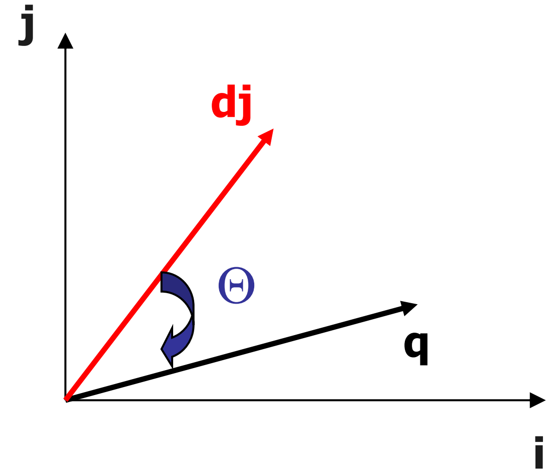
Similarity

Term	Sense and Sensibility	Pride and Prejudice	Wuthering Heights
affection	115	58	20
jealous	10	7	11
gossip	2	0	6

From: An Introduction to Information Retrieval, Cambridge UP

- In the vector model, queries may return documents that are not a 'perfect match'
  - Hence, we need a metric for the similarity between different documents, or between a document and a query
  - Could we simply subtract the vectors? (L1 norm of distance)
  - Could we use a dot product?
  - Does normalization help?

Cosine similarity



$$sim(d_j, q) = \cos\theta = \frac{\vec{d}_j \cdot \vec{q}}{|\vec{d}_j| \cdot |\vec{q}|} = \frac{\sum_{i=1}^{t} w_{i,j} \cdot w_{i,q}}{\sqrt{\sum_{i=1}^{t} w_{i,j}^2} \cdot \sqrt{\sum_{j=1}^{t} w_{i,q}^2}}$$

- All weights are nonnegative; hence, $0 \le sim(q,d_j) \le 1$