

INFM 603: Information Technology and Organizational Context

Session 10: Information Retrieval



Jimmy Lin
The iSchool
University of Maryland

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Information Retrieval



What you search for!



Satisfying an information need
“Scratching an information itch”

User
Process
System
Information

What types of information?

- Text (documents and portions thereof)
- XML and structured documents
- Images
- Audio (sound effects, songs, etc.)
- Video
- Source code
- Applications/web services

Our focus today is on textual information...

Types of Information Needs

○ Retrospective

- “Searching the past”
- Different queries posed against a static collection
- Time invariant

○ Prospective

- “Searching the future”
- Static query posed against a dynamic collection
- Time dependent

Retrospective Searches (I)

- Topical search

Identify positive accomplishments of the Hubble telescope since it was launched in 1991.

Compile a list of mammals that are considered to be endangered, identify their habitat and, if possible, specify what threatens them.

- Open-ended exploration

Who makes the best chocolates?

What technologies are available for digital reference desk services?

Retrospective Searches (II)

- Known item search

Find Jimmy Lin's homepage.

What's the ISBN number of "Modern Information Retrieval"?

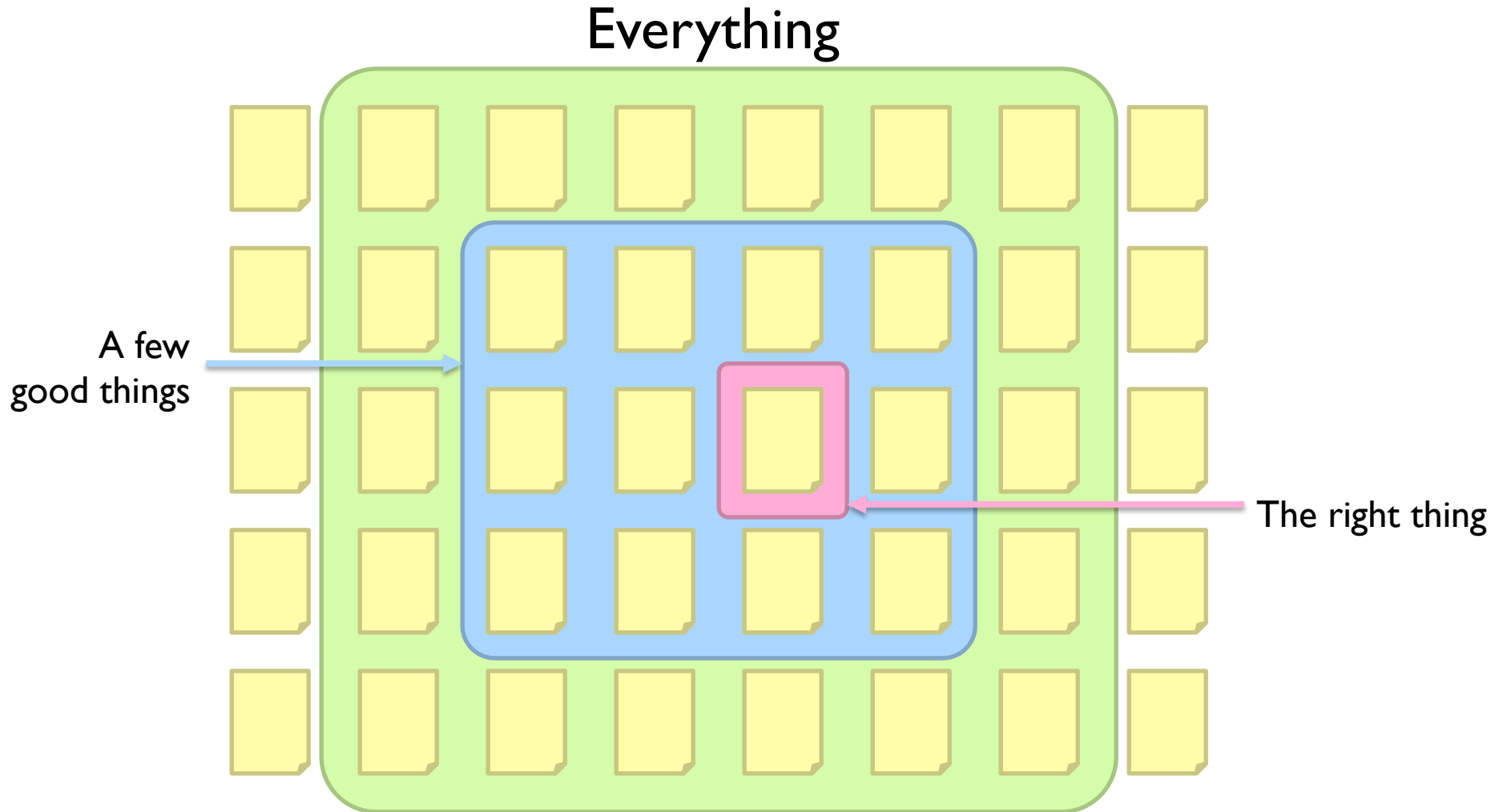
- Question answering

"Factoid"	Who discovered Oxygen?
	When did Hawaii become a state?
	Where is Ayer's Rock located?
	What team won the World Series in 1992?
"List"	What countries export oil?
	Name U.S. cities that have a "Shubert" theater.
"Definition"	Who is Aaron Copland?
	What is a quasar?

Prospective “Searches”

- Filtering
 - Make a binary decision about each incoming document
- Routing
 - Sort incoming documents into different bins

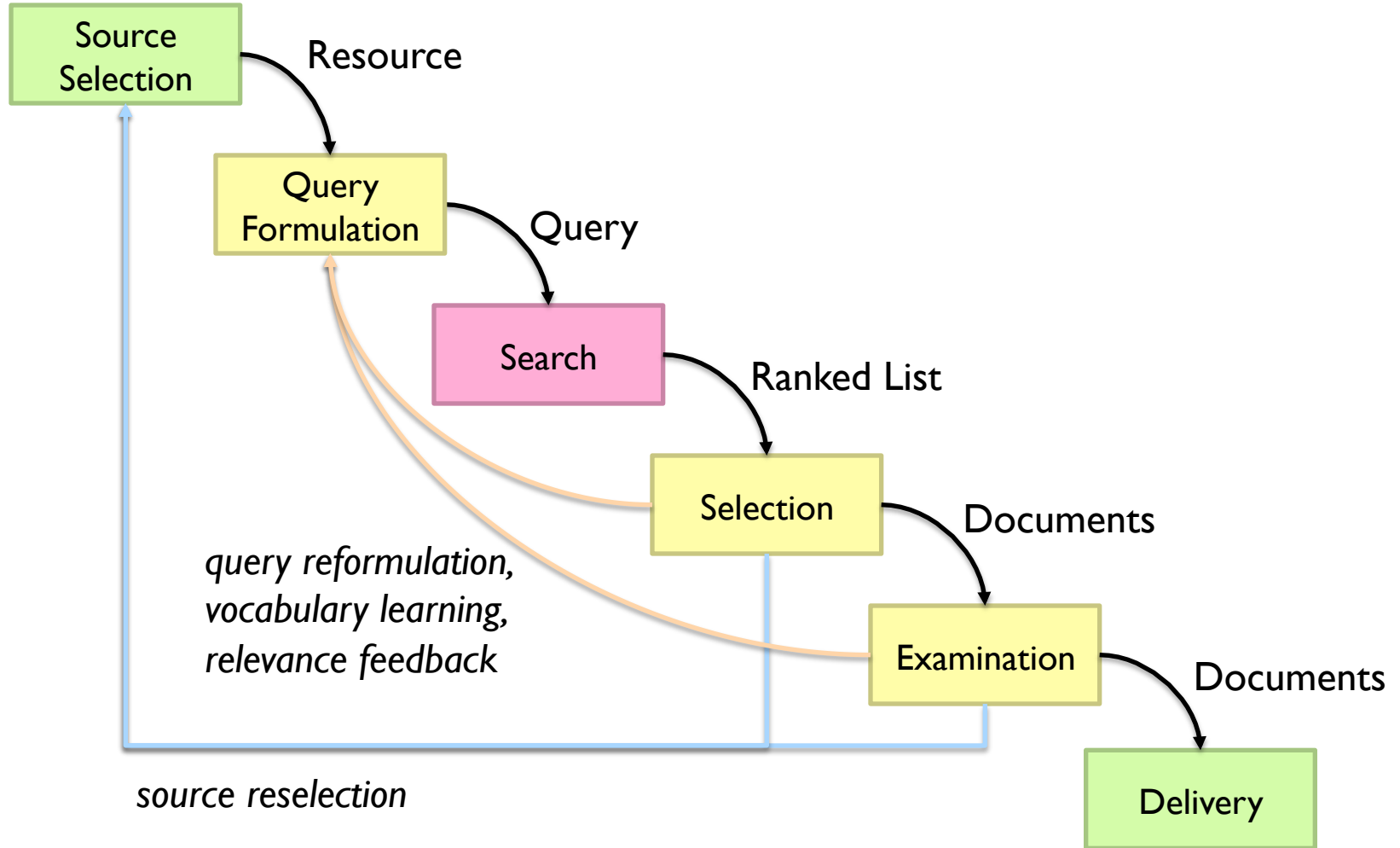
Scope of Information Needs



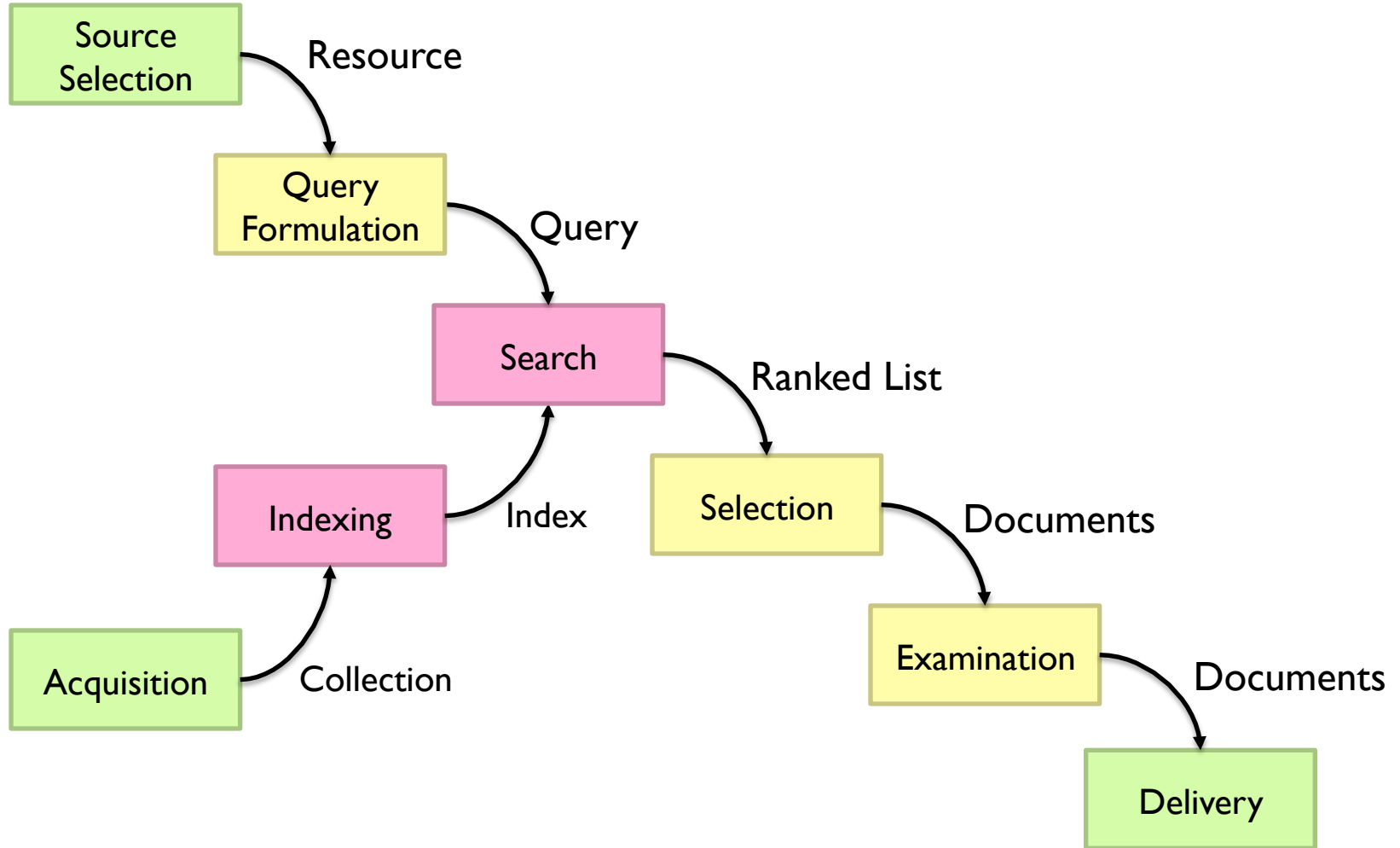
Relevance

- How well information addresses your needs
 - Harder to pin down than you think!
 - Complex function of user, task, and context
- Types of relevance:
 - Topical relevance: is it about the right thing?
 - Situational relevance: is it useful?

The Information Retrieval Cycle

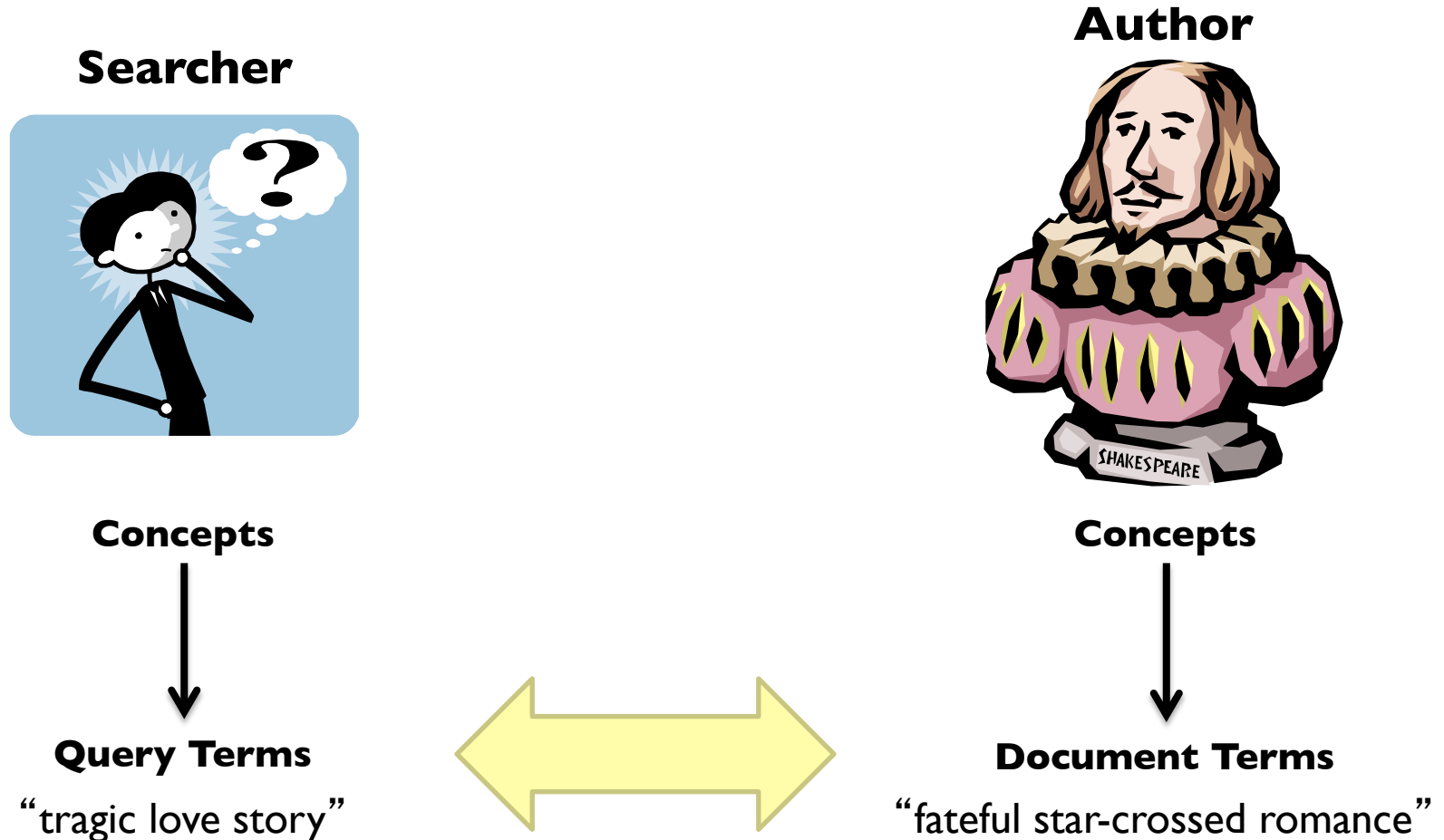


Supporting the Search Process



Spiders, Crawlers, and Robots:
Oh My!

The Central Problem in Search



Do these represent the same concepts?

Ambiguity
Synonymy
Polysemy
Morphology
Paraphrase
Anaphora
Pragmatics

How do we represent documents?

- Remember: computers don't “understand” anything!
- “Bag of words” representation:
 - Break a document into words
 - Disregard order, structure, meaning, etc. of the words
 - Simple, yet effective!

Boolean Text Retrieval

- Keep track of which documents have which terms
- Queries specify constraints on search results
 - a AND b: document must have both terms “a” and “b”
 - a OR b: document must have either term “a” or “b”
 - NOT a: document must not have term “a”
 - Boolean operators can be arbitrarily combined
- Results are not ordered!

Index Structure

Document 1

The quick brown
fox jumped over
the lazy dog's
back.

Document 2

Now is the time
for all good men
to come to the
aid of their party.

Stopword List

for
is
of
the
to

Term	Document 1	Document 2
aid	0	1
all	0	1
back	1	0
brown	1	0
come	0	1
dog	1	0
fox	1	0
good	0	1
jump	1	0
lazy	1	0
men	0	1
now	0	1
over	1	0
party	0	1
quick	1	0
their	0	1
time	0	1

Boolean Searching

Term	Document							
	1	2	3	4	5	6	7	8
aid	0	0	0	1	0	0	0	1
all	0	1	0	1	0	1	0	0
back	1	0	1	0	0	0	1	0
brown	1	0	1	0	1	0	1	0
come	0	1	0	1	0	1	0	1
dog	0	0	1	0	1	0	0	0
fox	0	0	1	0	1	0	1	0
good	0	1	0	1	0	1	0	1
jump	0	0	1	0	0	0	0	0
lazy	1	0	1	0	1	0	1	0
men	0	1	0	1	0	0	0	1
now	0	1	0	0	0	1	0	1
over	1	0	1	0	1	0	1	1
party	0	0	0	0	0	1	0	1
quick	1	0	1	0	0	0	0	0
their	1	0	0	0	1	0	1	0
time	0	1	0	1	0	1	0	0

- dog AND fox
 - Doc 3, Doc 5
- dog NOT fox
 - Empty
- fox NOT dog
 - Doc 7
- dog OR fox
 - Doc 3, Doc 5, Doc 7
- good AND party
 - Doc 6, Doc 8
- good AND party NOT over
 - Doc 6

Extensions

- Stemming (“truncation”)
 - Technique to handle morphological variations
 - Store word stems: love, loving, loves ... → lov
- Proximity operators
 - More precise versions of AND
 - Store a list of positions for each word in each document

Why Boolean Retrieval Works

- Boolean operators approximate natural language
- AND can specify relationships between concepts
 - good party
- OR can specify alternate terminology
 - excellent party
- NOT can suppress alternate meanings
 - Democratic party

Why Boolean Retrieval Fails

- Natural language is way more complex
- AND “discovers” nonexistent relationships
 - Terms in different paragraphs, chapters, ...
- Guessing terminology for OR is hard
 - good, nice, excellent, outstanding, awesome, ...
- Guessing terms to exclude is even harder!
 - Democratic party, party to a lawsuit, ...

Strengths and Weaknesses

○ Strengths

- Precise, if you know the right strategies
- Precise, if you have an idea of what you're looking for
- Implementations are fast and efficient

○ Weaknesses

- Users must learn Boolean logic
- Boolean logic insufficient to capture the richness of language
- No control over size of result set: either too many hits or none
- When do you stop reading? All documents in the result set are considered “equally good”
- What about partial matches? Documents that “don't quite match” the query may be useful also

Ranked Retrieval Paradigm

- Pure Boolean systems provide no ordering of results
 - ... but some documents are more relevant than others!
- “Best-first” ranking can be superior
 - Select n documents
 - Put them in order, with the “best” ones first
 - Display them one screen at a time
 - Users can decide when they want to stop reading

“Best-first”? Easier said than done!

Extending Boolean retrieval:

Order results based on number of matching terms

$a \text{ AND } b \text{ AND } c$

What if multiple documents have the same number of matching terms?

What if no single document matches the query?

Similarity-Based Queries

- Treat both documents and queries as “bags of words”
 - Assign a weight to each word
- Find the similarity between the query and each document
 - Compute similarity based on weights of the words
- Rank order the documents by similarity
 - Display documents most similar to the query first

Surprisingly, this works pretty well!

Term Weighting

- Term weights consist of two components
 - Local: how important is the term in this doc?
 - Global: how important is the term in the collection?
- Here's the intuition:
 - Terms that appear often in a document should get high weights
 - Terms that appear in many documents should get low weights
- How do we capture this mathematically?
 - Term frequency (local)
 - Inverse document frequency (global)

TF.IDF Term Weighting

$$w_{i,j} = \text{tf}_{i,j} \cdot \log \frac{N}{n_i}$$

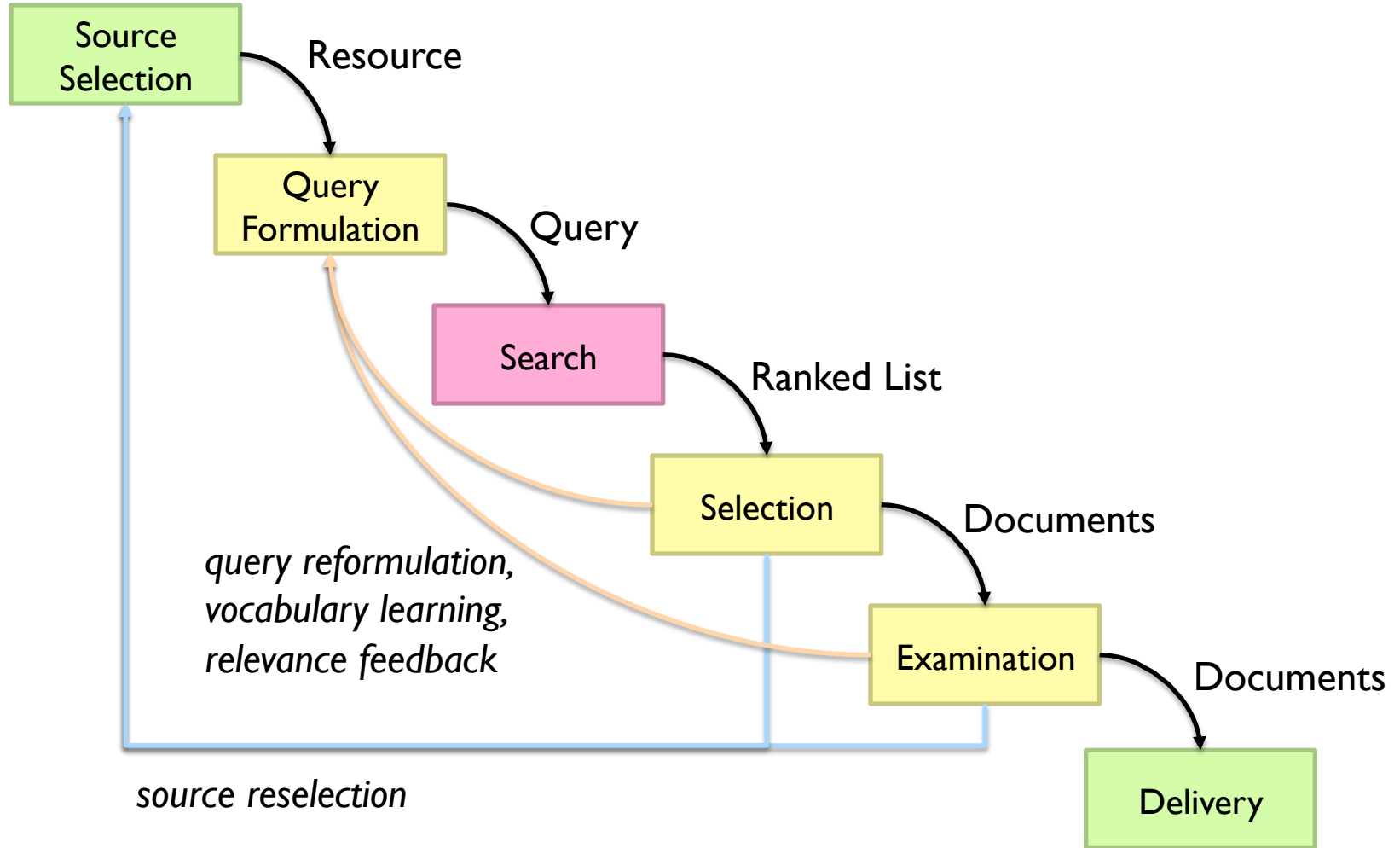
$w_{i,j}$ weight assigned to term i in document j

$\text{tf}_{i,j}$ number of occurrence of term i in document j

N number of documents in entire collection

n_i number of documents with term i

The Information Retrieval Cycle



Search Output

- What now?
 - User identifies relevant documents for “delivery”
 - User issues new query based on content of result set
- What can the system do?
 - Assist the user to identify relevant documents
 - Assist the user to identify potentially useful query terms

Selection Interfaces

- One dimensional lists
 - What to display? title, source, date, summary, ratings, ...
 - What order to display? similarity score, date, alphabetic, ...
 - How much to display? number of hits
 - Other aids? related terms, suggested queries, ...
- Two+ dimensional displays
 - Clustering, projection, contour maps, VR
 - Navigation: jump, pan, zoom

Query Enrichment

- Relevance feedback
 - User designates “more like this” documents
 - System adds terms from those documents to the query
- Manual reformulation
 - Initial result set leads to better understanding of the problem domain
 - New query better approximates information need
- Automatic query suggestion

Example Interfaces

- Google
- Amazon
- Clusty
- PubMed






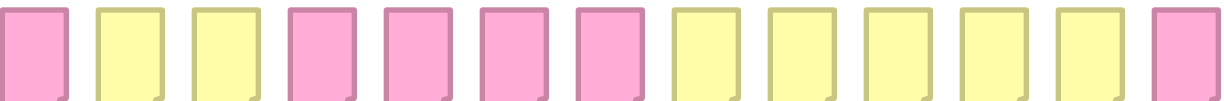
Evaluating IR Systems

- User-centered strategy
 - Recruit several users
 - Observe each user working with one or more retrieval systems
 - Measure which system works the “best”
- System-centered strategy
 - Given documents, queries, and relevance judgments
 - Try several variant of the retrieval method
 - Measure which variant is more effective

Good Effectiveness Measures

- Capture some aspect of what the user wants
- Have predictive value for other situations
- Easily replicated by other researchers
- Easily compared

Which is the Best Rank Order?

- A. 
- B. 
- C. 
- D. 
- E. 
- F. 

 = relevant document

Precision and Recall

	Relevant	Not relevant
Retrieved	A	B
Not retrieved	C	D

Collection size = $A+B+C+D$

Relevant = $A+C$

Retrieved = $A+B$

$$\text{Precision} = A / (A+B)$$

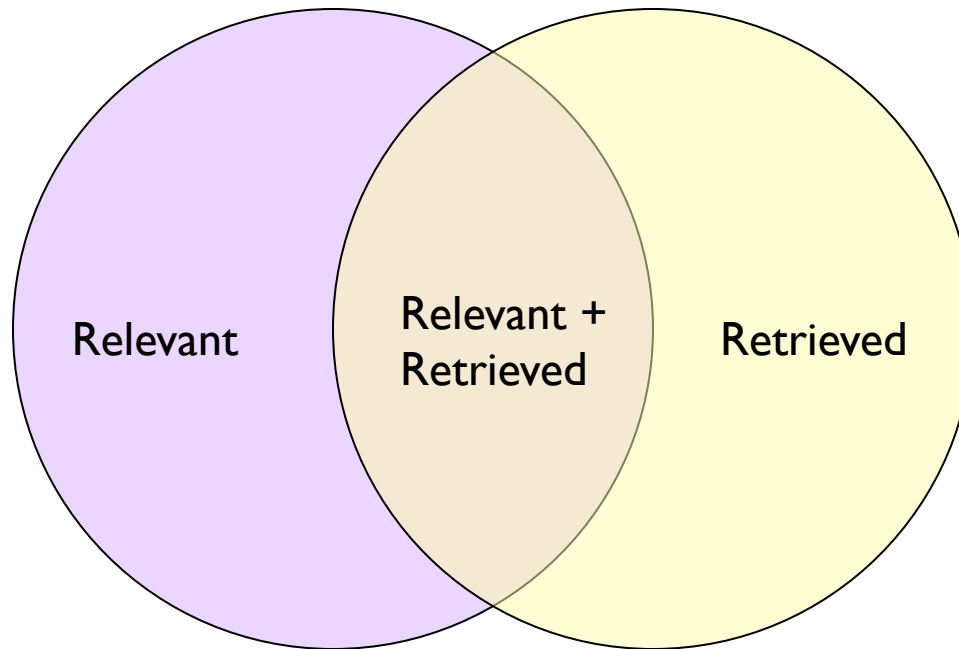
$$\text{Recall} = A / (A+C)$$

When is precision important?

When is recall important?

Another View

Space of all documents



Not Relevant + Not Retrieved

Precision and Recall

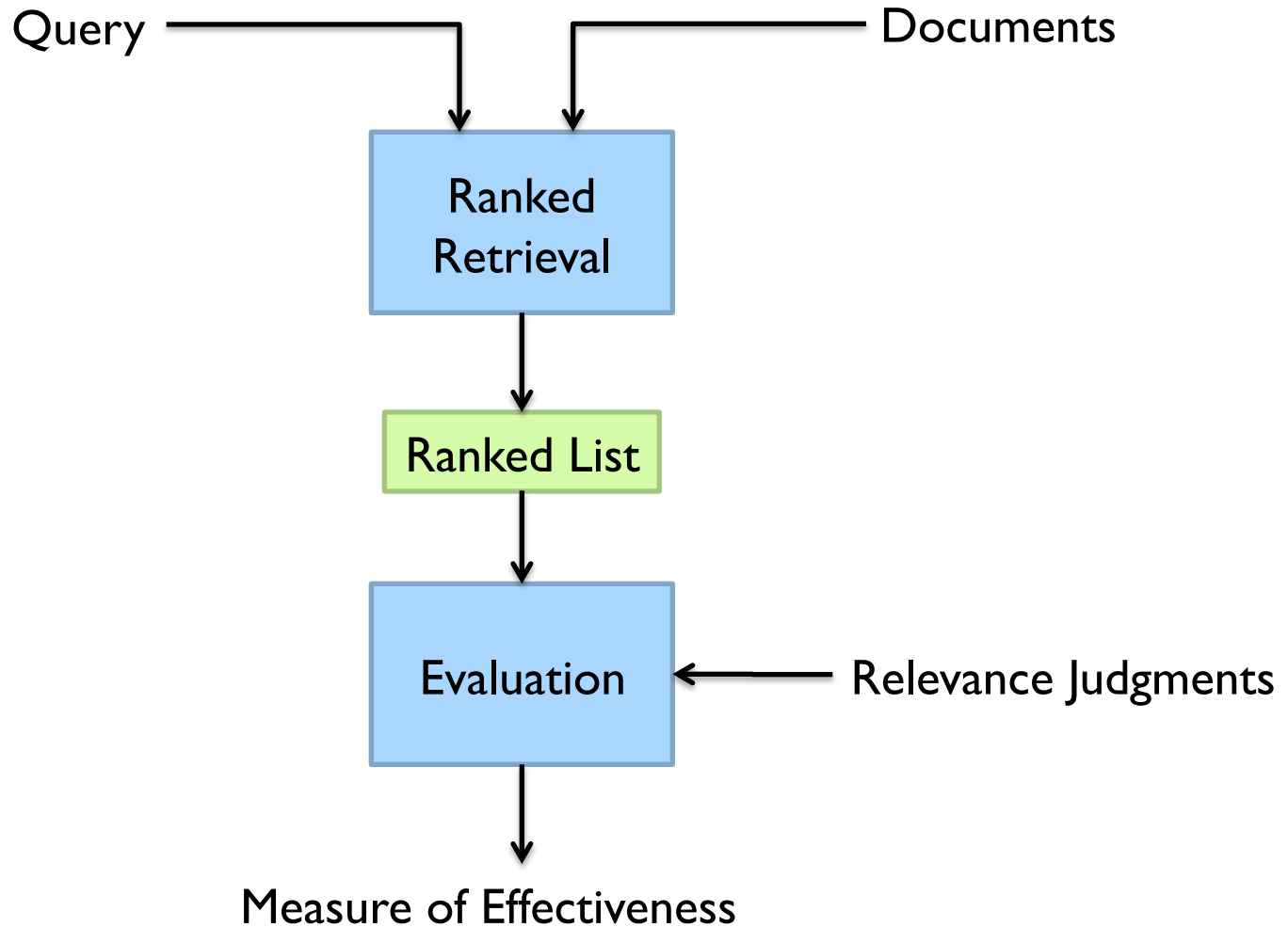
○ Precision

- How much of what was found is relevant?
- Often of interest, particularly for interactive searching

○ Recall

- How much of what is relevant was found?
- Particularly important for law, patents, and medicine

Abstract Evaluation Model



User Studies

- Goal is to account for interface issues
 - By studying the interface component
 - By studying the complete system
- Formative evaluation
 - Provide a basis for system development
- Summative evaluation
 - Designed to assess effectiveness

Quantitative User Studies

- Select independent variable(s)
 - E.g., what info to display in selection interface
- Select dependent variable(s)
 - E.g., time to find a known relevant document
- Run subjects in different orders
 - Average out learning and fatigue effects
- Compute statistical significance
 - Null hypothesis: independent variable has no effect

Qualitative User Studies

- Direct observation
- Think-aloud protocols

Objective vs. Subjective Data

- Subjective self-assessment
 - Which did they think was more effective?
- Preference
 - Which interface did they prefer? Why?

Often at odds with objective measures!

Take-Away Messages

- Search engines provide access to unstructured textual information
- Searching is fundamentally about bridging the gap between words and meaning
- Information seeking is an iterative process in which the search engine plays an important role