INFM 603: Information Technology and Organizational Context

Session 10: Information Retrieval

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Thursday, November 8, 2012

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.

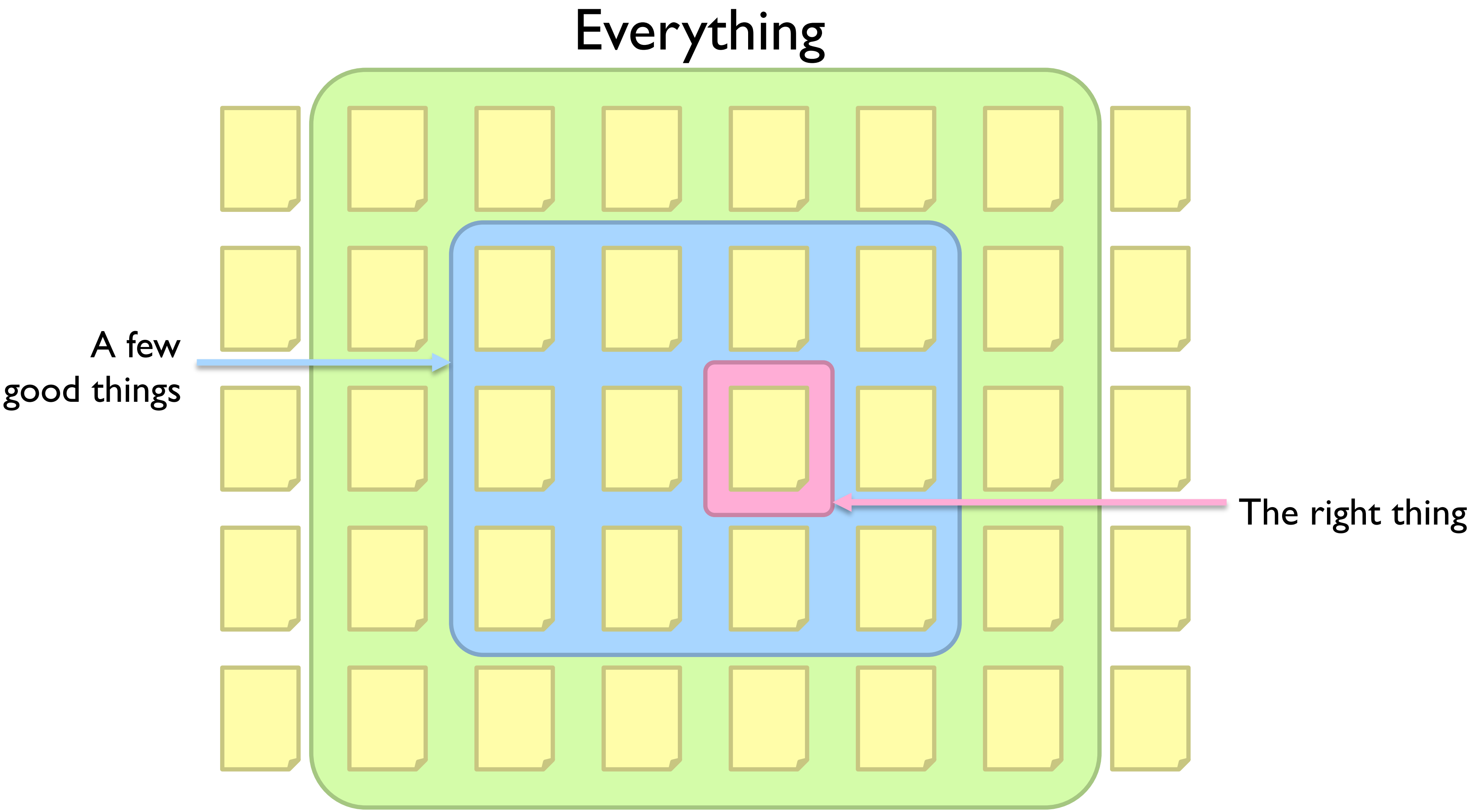
“Definition”

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

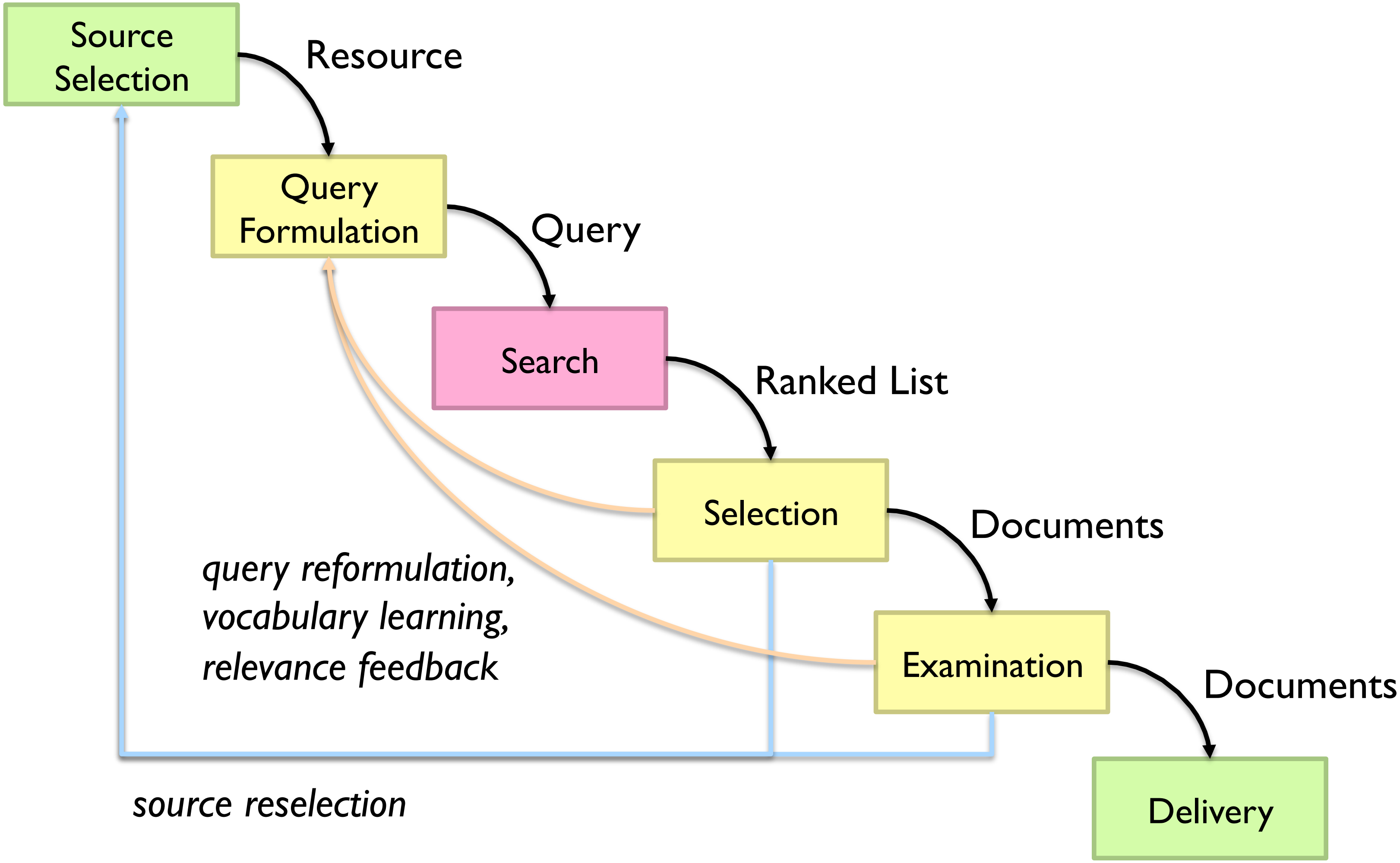
Scope of Information Needs



Relevance

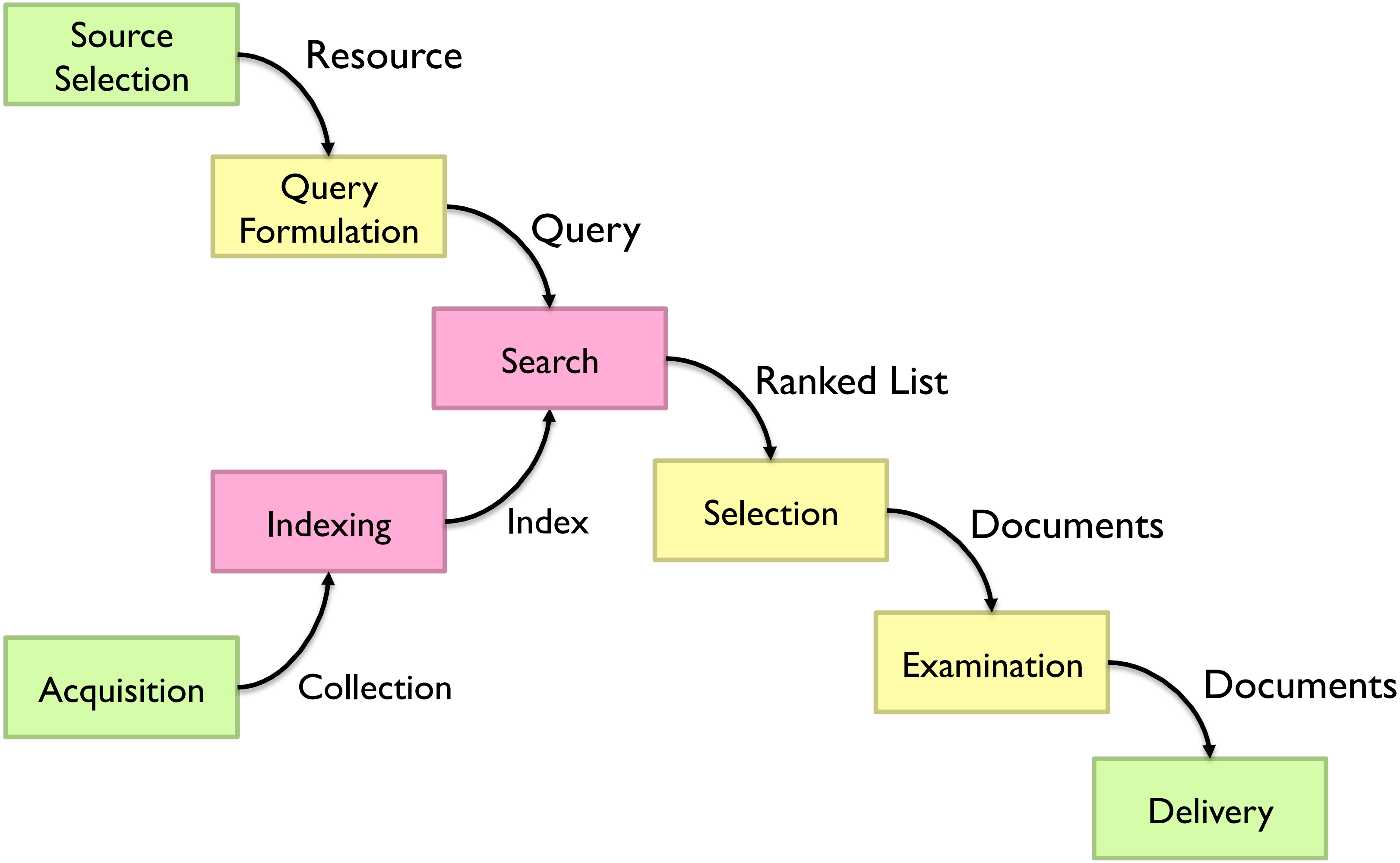
- How well information addresses your needs
  - Harder to pin down than you think!
  - Complex function of user, task, and context
- Types of relevance:
  - Topical relevance: is it about the right thing?
  - Situational relevance: is it useful?

The Information Retrieval Cycle



source reselection

Supporting the Search Process



Spiders, Crawlers, and Robots: Oh My!

The Central Problem in Search

Searcher

Author

Concepts ↓ **Query Terms**

"tragic love story"

⟷

Concepts ↓ **Document Terms**

"fateful star-crossed romance"

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 decided when they want to stop reading

"Best-first"? Easier said than done!

Extending Boolean retrieval:
Order results based on number of matching terms

a AND *b* 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

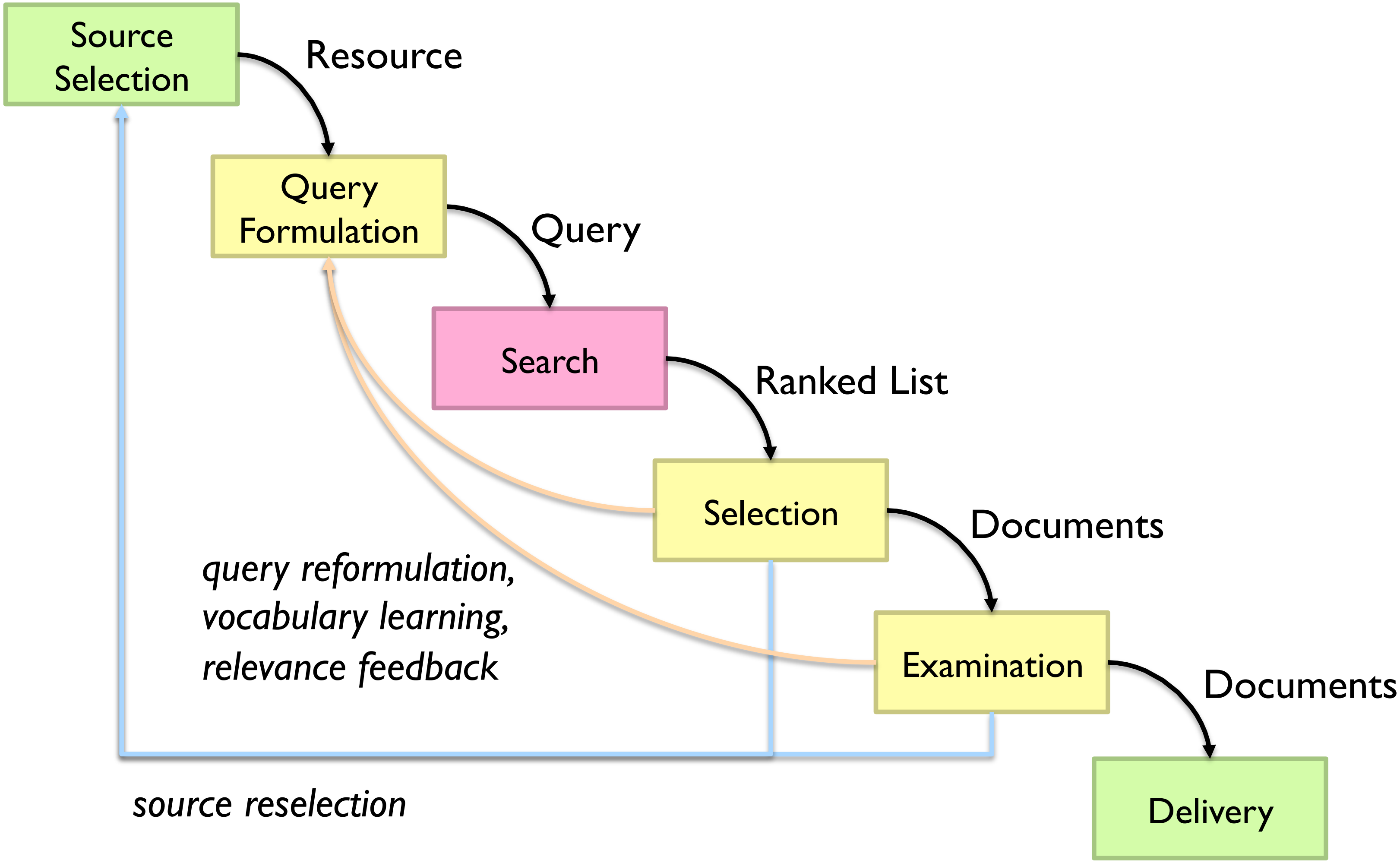
- Term weights consist of two components
  - Local: how important is the term in this doc?
  - Global: how important is the term in the collection?
- Here’s the intuition:
  - Terms that appear often in a document should get high weights
  - Terms that appear in many documents should get low weights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

TF.IDF Term Weighting

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

$w_{i,j}$	weight assigned to term *i* in document *j*
$\mathrm{tf}_{i,j}$	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

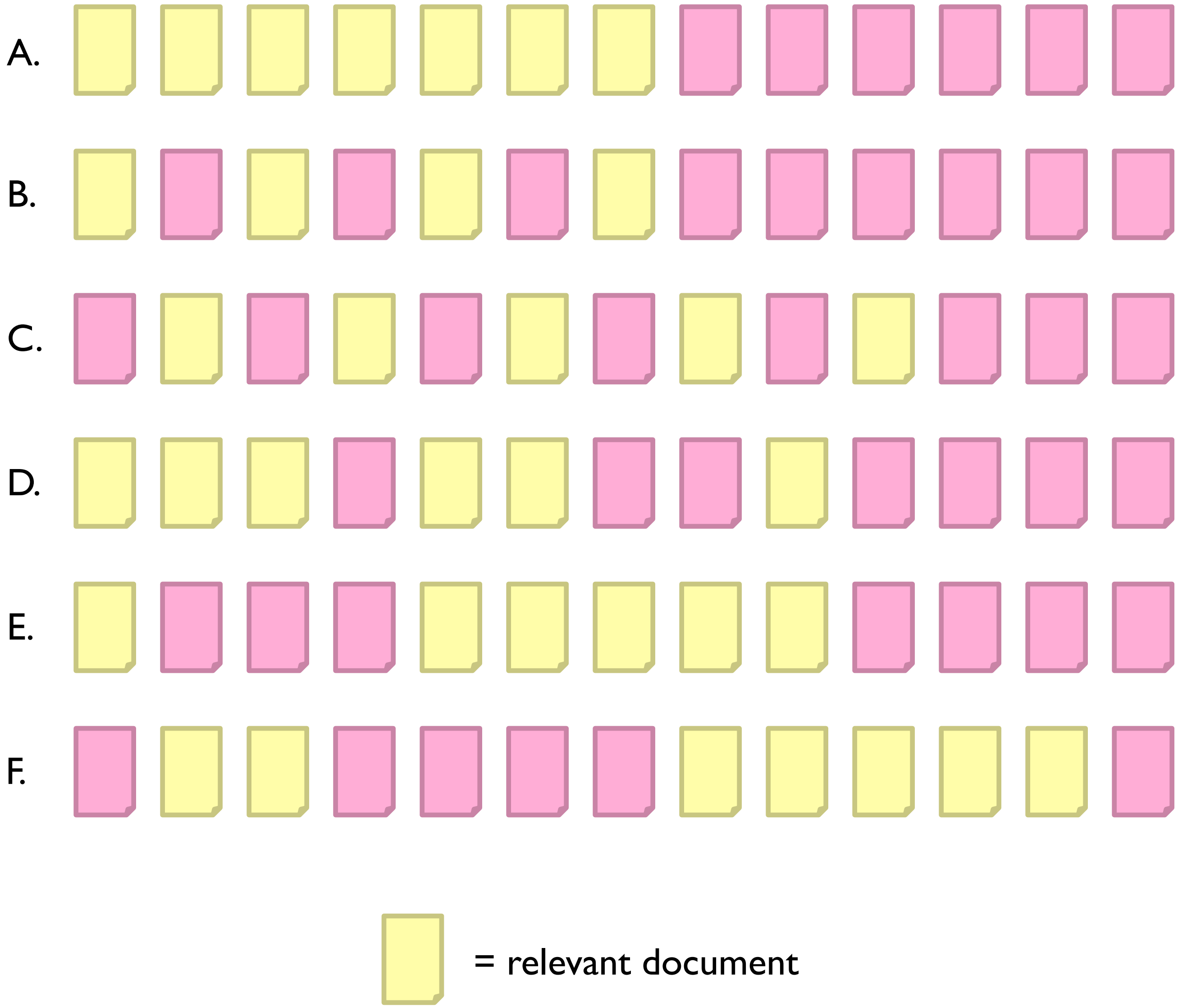
Evaluating IR Systems

- 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?



Precision and Recall

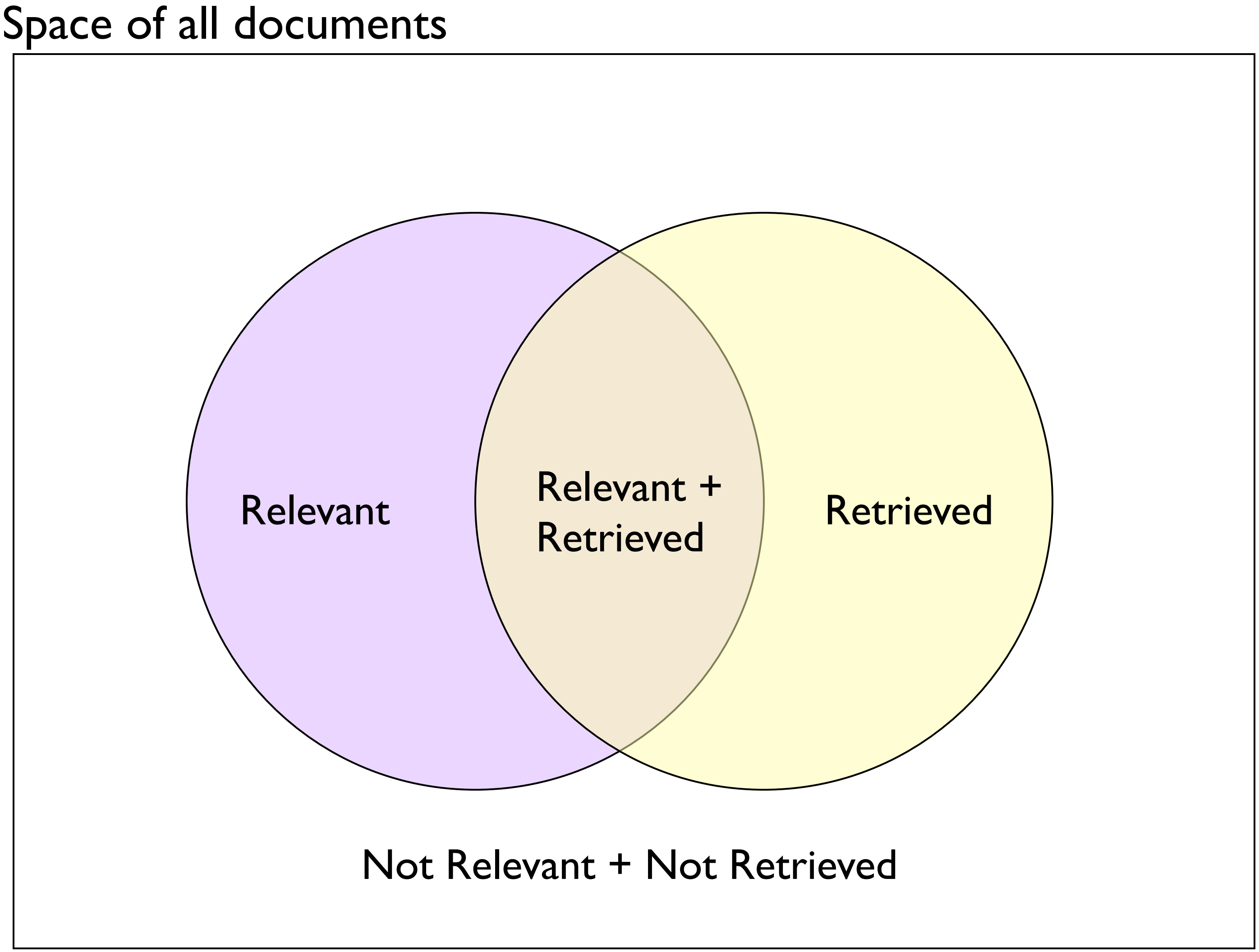
	Relevant	Not relevant
Retrieved	A	B
Not retrieved	C	D

Collection size = A+B+C+D
Relevant = A+C
Retrieved = A+B

Precision = A / (A+B)
Recall = A / (A+C)

When is precision important?
When is recall important?

Another View



Space of all documents

Relevant

Relevant +
Retrieved

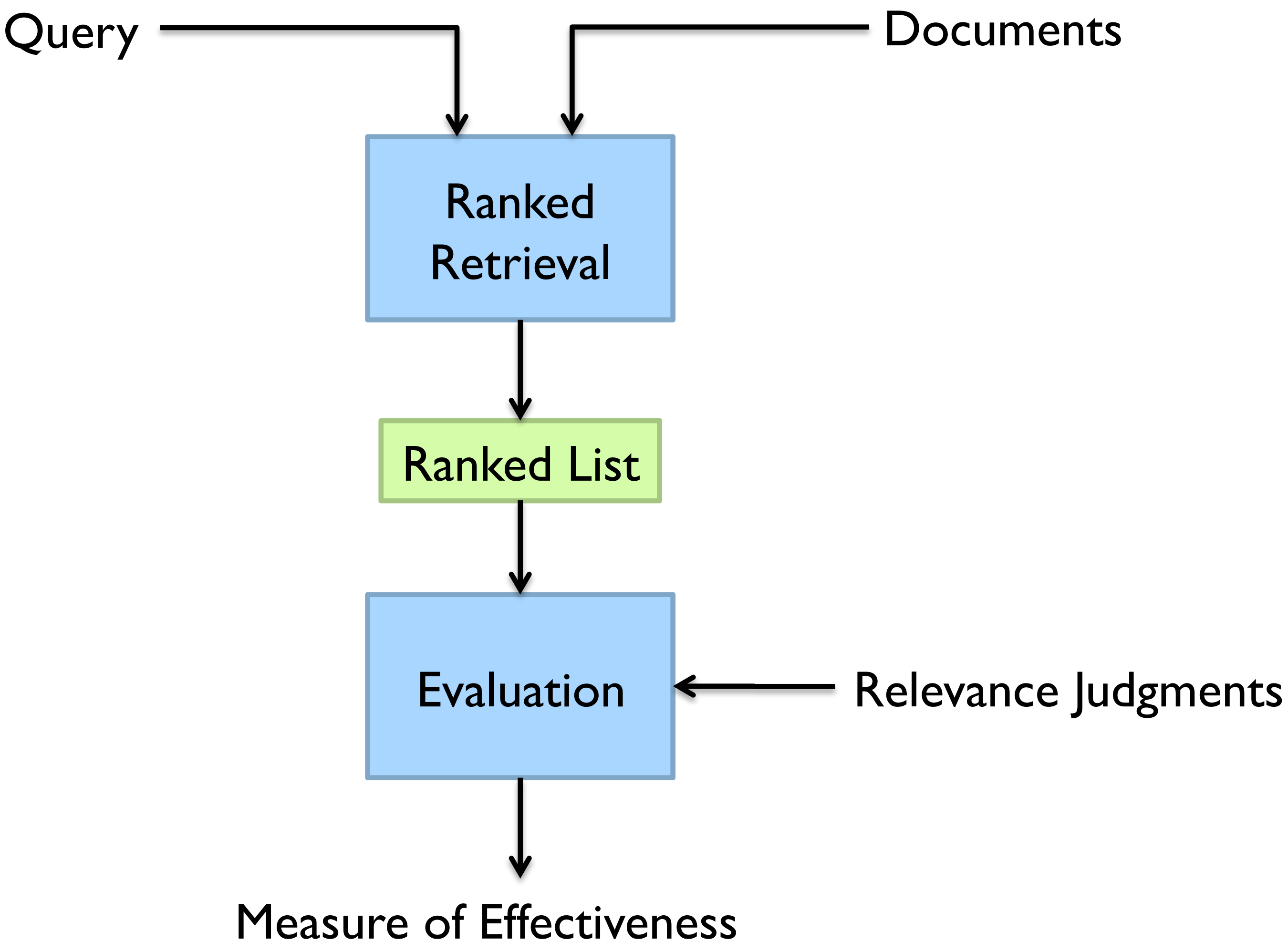
Retrieved

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