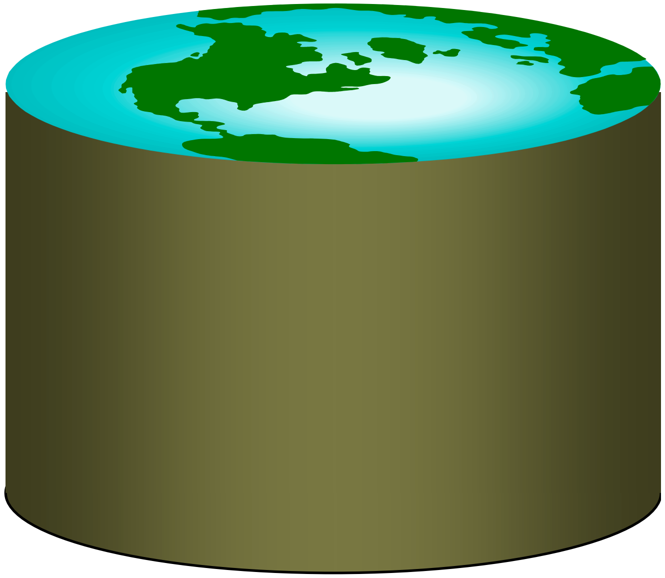
Elementary IR: Scalable Boolean Text Search

(Compare with R & G 27.1-3)



Information Retrieval: History

- **A research field traditionally separate from Databases**
  - Hans P. Luhn, IBM, 1959: “Keyword in Context (KWIC)”
  - G. Salton at Cornell in the 60’s/70’s: SMART
    - Around the same time as relational DB revolution
  - Tons of research since then
    - Especially in the web era
- **Products traditionally separate**
  - Originally, document management systems for libraries, government, law, etc.
  - Gained prominence in recent years due to web search
    - Still used for non-web document management. (“Enterprise search”).

Today: Simple (naïve!) IR

- **Boolean Search on keywords**
- **Goal:**
  - Show that you already have the tools to do this from your study of relational DBs
- **We'll skip:**
  - Text-oriented storage formats
  - Intelligent result ranking (hopefully later!)
  - Parallelism
    - Critical for modern relational DBs too
  - Various bells and whistles (lots of little ones!)
    - Engineering the specifics of (written) human language
      - E.g. dealing with tense and plurals
      - E.g. identifying synonyms and related words
      - E.g. disambiguating multiple meanings of a word
      - E.g. clustering output

IR vs. DBMS

- **Seem like very different beasts**

IR	DBMS
Imprecise Semantics	Precise Semantics
Keyword search	SQL
Unstructured data format	Structured data
Read-Mostly. Add docs occasionally	Expect reasonable number of updates
Page through top *k* results	Generate full answer

- **Under the hood, not as different as they might seem**
  - But in practice, you have to choose between the 2 today

IR’s “Bag of Words” Model

- **Typical IR data model:**
  - Each document is just a bag of words (“terms”)
- **Detail 1: “Stop Words”**
  - Certain words are not helpful, so not placed in the bag
  - e.g. real words like “the”
  - e.g. HTML tags like <H1>
- **Detail 2: “Stemming”**
  - Using language-specific rules, convert words to basic form
  - e.g. “surfing”, “surfed” --> “surf”
  - Unfortunately have to do this for each language
    - Yuck!

Boolean Text Search

- **Find all documents that match a Boolean containment expression:**
  - "Windows"
    AND ("Glass" OR "Door")
    AND NOT "Microsoft"
- **Note: query terms are also filtered via stemming and stop words**
- **When web search engines say "10,000 documents found", that's the Boolean search result size**
  - More or less ;-)

Text “Indexes”

- **When IR folks say “text index”…**
  – usually mean more than what DB people mean
- **In our terms, both “tables” and indexes**
  – Really a logical schema (i.e. tables)
  – With a physical schema (i.e. indexes)
  – Usually not stored in a DBMS
    - Tables implemented as files in a file system
    - We’ll talk more about this decision soon

A Simple Relational Text Index

- **Given: a *corpus* of text files**
  - Files(docID string, content string)
- **Create and populate a table**
  InvertedFile(term string, docID string)
- **Build a B+-tree or Hash index on InvertedFile.term**
  - Something like "Alternative 3" critical here!!
    - Keep lists of dup keys *sorted by docID*
      - Will provide "interesting orders" later on!
    - Fancy list compression important, too
    - Typically called a *postings list* by IR people
  - Note: URL instead of RID, the web is your "heap file"!
    - Can also *cache* pages and use RIDs
- **This is often called an "inverted file" or "inverted index"**
  - Maps from words -> docs, rather than docs -> words

- ***Given this, you can now do single-word text search queries!***

An Inverted File

- **Snippets from:**
  - Old class web page
  - Old microsoft.com home page
- **Search for**
  - databases
  - microsoft

Term	docID
data	http://www-inst.eecs.berkeley.edu/~cs186
database	http://www-inst.eecs.berkeley.edu/~cs186
date	http://www-inst.eecs.berkeley.edu/~cs186
day	http://www-inst.eecs.berkeley.edu/~cs186
dbms	http://www-inst.eecs.berkeley.edu/~cs186
decision	http://www-inst.eecs.berkeley.edu/~cs186
demonstrate	http://www-inst.eecs.berkeley.edu/~cs186
description	http://www-inst.eecs.berkeley.edu/~cs186
design	http://www-inst.eecs.berkeley.edu/~cs186
desire	http://www-inst.eecs.berkeley.edu/~cs186
developer	http://www.microsoft.com
differ	http://www-inst.eecs.berkeley.edu/~cs186
disability	http://www.microsoft.com
discussion	http://www-inst.eecs.berkeley.edu/~cs186
division	http://www-inst.eecs.berkeley.edu/~cs186
do	http://www-inst.eecs.berkeley.edu/~cs186
document	http://www-inst.eecs.berkeley.edu/~cs186
document	http://www.microsoft.com
microsoft	http://www.microsoft.com
microsoft	http://www-inst.eecs.berkeley.edu/~cs186
midnight	http://www-inst.eecs.berkeley.edu/~cs186
midterm	http://www-inst.eecs.berkeley.edu/~cs186
minibase	http://www-inst.eecs.berkeley.edu/~cs186
million	http://www.microsoft.com
monday	http://www.microsoft.com
more	http://www.microsoft.com
most	http://www-inst.eecs.berkeley.edu/~cs186
ms	http://www-inst.eecs.berkeley.edu/~cs186
msn	http://www.microsoft.com
must	http://www-inst.eecs.berkeley.edu/~cs186
necessary	http://www-inst.eecs.berkeley.edu/~cs186
need	http://www-inst.eecs.berkeley.edu/~cs186

Handling Boolean Logic

- **How to do "term1" OR "term2"?**
  - Union of two postings lists (docID sets)!
- **How to do "term1" AND "term2"?**
  - Intersection of two postings lists!
    - Can be done via merge-join over postings lists
    - Remember: postings list per key sorted by docID in index
- **How to do "term1" AND NOT "term2"?**
  - Set subtraction
    - Also easy because sorted (basically merge join logic again)
- **How to do "term1" OR NOT "term2"**
  - Union of "term1" and "NOT term2".
    - "Not term2" = all docs not containing term2. Yuck!
  - Usually not allowed!
- **Query Optimization: what order to handle terms if you have many ANDs?**

"Windows" AND ("Glass" OR "Door")
AND NOT "Microsoft"

Boolean Search in SQL

- ```
  (SELECT docID FROM InvertedFile
    WHERE word = "window"
   INTERSECT
   SELECT docID FROM InvertedFile
    WHERE word = "glass" OR word = "door")
  EXCEPT
  SELECT docID FROM InvertedFile
   WHERE word="Microsoft"
  ORDER BY magic_rank()
  ```

- **There's only one SQL query template in Boolean Search**
  - Single-table selects, UNION, INTERSECT, EXCEPT
- **magic_rank() is the "secret sauce" in the search engines**
  - Hopefully we'll study this later in the semester
  - Combos of statistics, linguistics, and graph theory tricks!
  ```

One step fancier: Phrases and "Near"

- **Suppose you want a phrase**
  - E.g. "Happy Days"
- **Different schema:**
  - InvertedFile (term string, position int, docID string)
  - Alternative 3 index on term
  - Postings lists sorted by (docID, position)
- **Post-process the results**
  - Find "Happy" AND "Days"
  - Keep results where positions are 1 off
    - Can be done during merge-join to AND the 2 lists!
- **Can do a similar thing for "term1" NEAR "term2"**
  - Position < *k* off
  - Think about refinement to merge-join…

Somewhat better compression

- InvertedFile (term string, position int, docID int)
- Files(docID int, docID string, snippet string, …)
- Btree on InvertedFile.term
- Btree on Docs.docID

- Requires a final join step between typical query result and Files.docID
  - Can do this lazily: cursor to generate a page full of results

Updates and Text Search

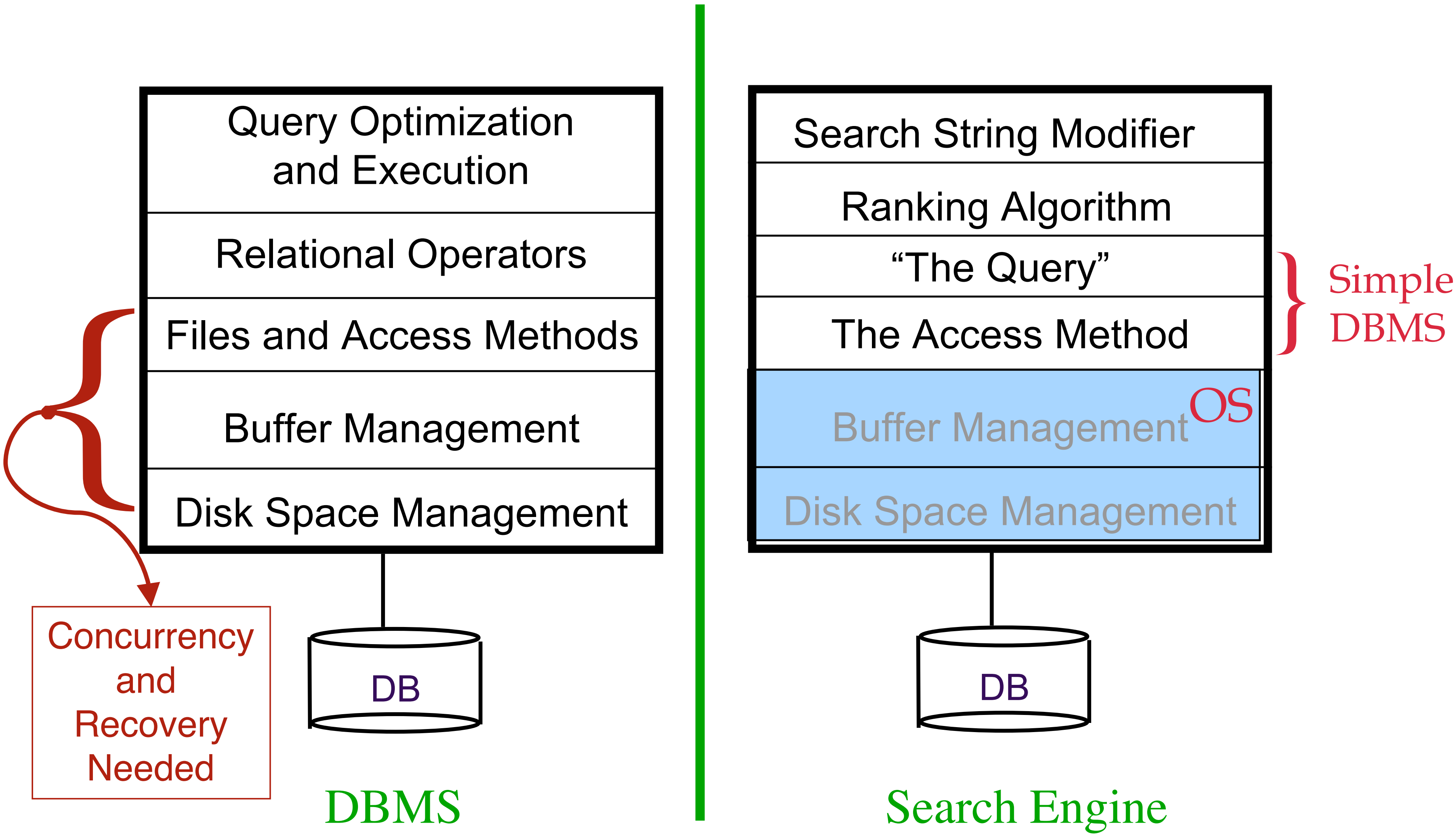
- **Text search engines are designed to be query-mostly**
  - Deletes and modifications are rare
  - Can postpone updates (nobody notices, no transactions!)
    - Can work off a union of indexes
    - Merge them in batch (typically re-bulk-load a new index)
  - Can't afford to go offline for an update?
    - Create a 2nd index on a separate machine
    - Replace the 1st index with the 2nd!
  - So no concurrency control problems
  - Can compress to search-friendly, update-unfriendly format
  - Can keep postings lists sorted
- **For these reasons, text search engines and DBMSs are usually separate products**
  - Also, text-search engines tune that one SQL query to death!
  - The benefits of a special-case workload.

Lots more tricks in IR

- **How to "rank" the output?**
  - A mix of simple tricks works well
  - Some fancier tricks can help (use hyperlink graph)
- **Other ways to help users paw through the output?**
  - Document "clustering" (e.g. Clusty.com)
  - Document visualization
- **How to use compression for better I/O performance?**
  - E.g. making postings lists smaller
  - Try to make things fit in RAM
    - Or in processor caches
- **How to deal with synonyms, misspelling, abbreviations?**
- **How to write a good web crawler?**

- **We'll return to some of these later**
  - The book *Managing Gigabytes* covers some of the details

Recall From the First Lecture



You Know The Basics!

- **“Inverted files” are the workhorses of all text search engines**
  - Just B+-tree or Hash indexes on bag-of-words
- **Intersect, Union and Set Difference (Except)**
  - Usually implemented via sorting
  - Or can be done with hash or index joins
- **Most of the other stuff is not “systems” work**
  - A lot of it is cleverness in dealing with language
  - Both linguistics and statistics (more the latter!)

Revisiting Our IR/DBMS Distinctions

- **Semantic Guarantees on Storage**
  - DBMS guarantees transactional semantics
    - If an inserting transaction commits, a subsequent query *will see* the update
    - Handles multiple concurrent updates correctly
  - IR systems do not do this; nobody notices!
    - Postpone insertions until convenient
    - No model of correct concurrency.
    - Can even return incorrect answers for various reasons!
- **Data Modeling & Query Complexity**
  - DBMS supports any schema & queries
    - But requires you to define schema
    - And SQL is hard to figure out for the average citizen
  - IR supports only one schema & query
    - No schema design required (unstructured text)
    - Trivial (natural?) query language for simple tasks
    - No data correlation or analysis capabilities -- “search” only

Revisiting Distinctions, Cont.

- **Performance goals**
  - DBMS supports general SELECT
    - plus mix of INSERT, UPDATE, DELETE
    - general purpose engine must always perform “well”
  - IR systems expect only one stylized SELECT
    - plus delayed INSERT, unusual DELETE, no UPDATE.
    - special purpose, must run super-fast on “The Query”
    - users rarely look at the full answer in Boolean Search
      - Postpone any work you can to subsequent index joins
      - But make sure you can rank!

Summary

- **IR & Relational systems share basic building blocks for scalability**
  - IR internal representation is relational!
  - Equality indexes (B-trees)
  - Iterators
  - "Join" algorithms, esp. merge-join
  - "Join" ordering and selectivity estimation
- **IR constrains queries, schema, promises on semantics**
  - Affects storage format, indexing and concurrency control
  - Affects join algorithms & selectivity estimation
- **IR has different performance goals**
  - Ranking and best answers **fast**
- **Many challenges in IR related to "text engineering"**
  - But don't tend to change the scalability infrastructure

IR Buzzwords to Know (so far!)

- **Learning this in the context of relational foundations is fine, but you need to know the IR lingo!**
  - *Corpus:* a collection of documents
  - *Term:* an isolated string (searchable unit)
  - *Index:* a mechanism mapping terms to documents
  - *Inverted File (= Postings File):* a file containing terms and associated postings lists
  - *Postings List:* a list of pointers (“postings”) to documents

Exercise!

- **Implement Boolean search directly in Postgres**
  - Using the schemas and indexes here.
    - Write a simple script to load files.
    - You can ignore stemming and stop-words.
  - Run the SQL versions of Boolean queries
    - Measure how slow search is in Postgres
  - Identify contributing factors in performance
    - E.g. how much disk space does the postgres version use (including indexes) vs. the raw documents vs. the documents gzip'ed
    - E.g. is PG identifying the "interesting orders" in the postings lists? (use EXPLAIN) If not, can you force it to do so?
- **Compare PG to an idealized implementation**
  - Calculate the idealized size of the InvertedFile table for your data
  - Use the cost models for IndexScan and MergeJoin to calculate the expected number of IOs. Distinguish sequential and random Ios.
  - Why is PG slow? Storage overhead? Optimizer smarts?