Information Retrieval

Weike Pan

The slides are **adapted from those provided by Prof. Hinrich Schütze** at University of Munich (http://www.cis.lmu.de/~hs/teach/14s/ir/).

Chapter 1 Boolean retrieval

- 1.1 An example information retrieval problem
- 1.2 A first take at building an inverted index
- 1.3 Processing Boolean queries
- 1.4 The extended Boolean model versus ranked retrieval
- 1.5 References and further reading

Outline

- 1.1 An example information retrieval problem
- 1.2 A first take at building an inverted index
- 1.3 Processing Boolean queries
- 1.4 The extended Boolean model versus ranked retrieval
- 1.5 References and further reading

1.1 An example information retrieval problem

Definition of information retrieval

- Information retrieval (IR) is finding material (usually documents) of an unstructured nature (usually text) that satisfies an information need from within large collections (usually stored on computers).

1.1 An example information retrieval problem

Boolean retrieval

- The Boolean model is arguably the simplest model to base an information retrieval system on.
- Queries are Boolean expressions, e.g., CAESAR AND BRUTUS
- The search engine returns all documents that satisfy the Boolean expression.

1.1 An example information retrieval problem

Does Google use the Boolean model?

- On Google, the default interpretation of a query [w1 w2 ... wn] is w1 AND w2 AND ... AND wn

- Cases where you get hits that do not contain one of wi:
  - anchor text (锚文本)
  - a page contains a variant of wi (e.g., morphology, spelling correction, synonym)
  - long queries (i.e., n is large)
  - Boolean expression generates very few hits

1.1 An example information retrieval problem

- Simple Boolean vs. Ranking of result set
  - Simple Boolean retrieval returns matched documents in no particular order
  - Google (and most well designed Boolean engines) rank the result set -- they rank good hits (according to some estimator of relevance) higher than bad hits

1.1 An example information retrieval problem

Term-document incidence matrix

- Entry is 1 if a term occurs. Entry is 0 if a term doesn't occur.

Documents

Terms

	Anthony and Cleopatra	Julius Caesar	The Tempest	Hamlet	Othello	Macbeth	...
ANTHONY	1	1	0	0	0	1	
BRUTUS	1	1	0	1	0	0	
CAESAR	1	1	0	1	1	1	
CALPURNIA	0	1	0	0	0	0	
CLEOPATRA	1	0	0	0	0	0	
MERCY	1	0	1	1	1	1	
WORSER	1	0	1	1	1	0	
...							

1.1 An example information retrieval problem

Incidence vectors

- So we have a 0/1 vector for each term

- To answer the query BRUTUS AND CAESAR AND NOT CALPURNIA:

  - Step 1. Take the vectors for BRUTUS, CAESAR, and CALPURNIA

  - Step 2. Complement the vector of CALPURNIA

  - Step 3. Do a (bitwise) AND on the three vectors 110100 AND 110111 AND 101111 = 100100

1.1 An example information retrieval problem

Bigger collections

- Consider N=10^6 documents, each with about 1000 tokens -> total of 10^9 tokens

- On average 6 bytes per token, including spaces and punctuation -> size of document collection is about 6*10^9=6GB

- Assume there are M=500,000 distinct terms in the collection

- Notice that we are making a term/token distinction

1.1 An example information retrieval problem

Can't build the incidence matrix

- 500,000*10^6 = half a trillion 0s and 1s

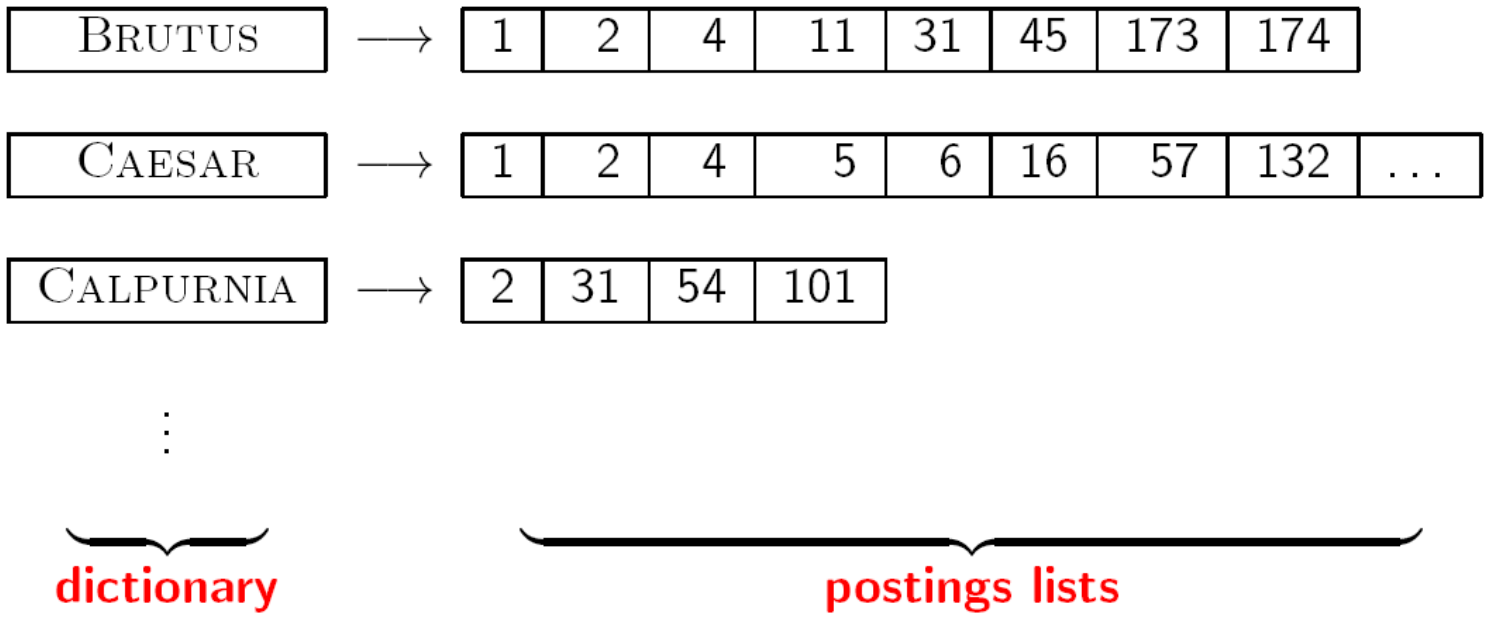
- But the matrix has no more than one billion 1s -> The incidence matrix is extremely sparse

- What is a better representation?
  - We only record the 1s

1.1 An example information retrieval problem

Inverted index

- For each term t, we store a list of documents that contain t.



Outline

- 1.1 An example information retrieval problem
- 1.2 A first take at building an inverted index
- 1.3 Processing Boolean queries
- 1.4 The extended Boolean model versus ranked retrieval
- 1.5 References and further reading

1.2 A first take at building an inverted index

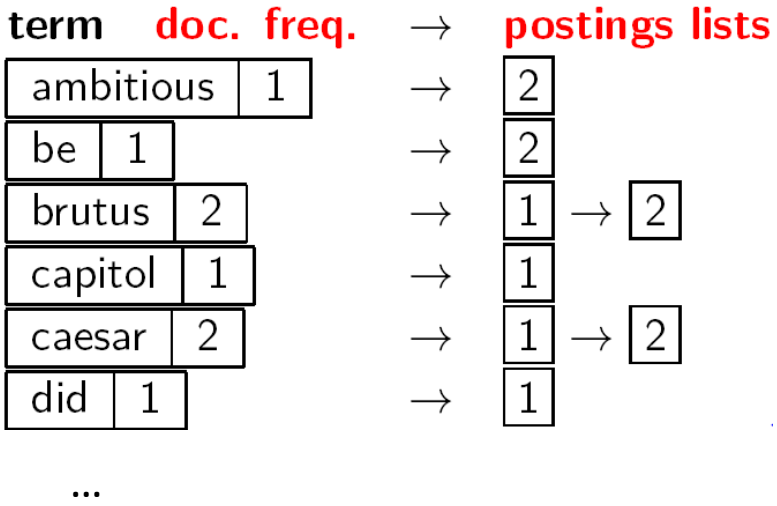
Inverted index construction (1/2)

- Step 1. Collect the documents to be indexed
- Step 2. Tokenize the text, turning each document into a list of tokens
- Step 3. Do linguistic preprocessing, producing a list of normalized tokens, which are the indexing terms
- Step 4. Index the documents that each term occurs in by creating an inverted index, consisting of a dictionary and postings lists

1.2 A first take at building an inverted index

Inverted index construction (2/2)

- Doc 1. I did enact Julius Caesar: I was killed I' the Capitol; Brutus killed me.
- Doc 2. So let it be with Caesar. The noble Brutus hath told you Caesar was ambitious.



1.2 A first take at building an inverted index

Other issues

- Index construction: how can we create inverted indexes for large collections?
- How much space do we need for dictionary and index?
- Index compression: how can we efficiently store and process indexes for large collections?
- Ranked retrieval: what does the inverted index look like when we want the "best" answer?

1.2 A first take at building an inverted index

Unstructured data in 1650

- Which plays of Shakespeare contain the words BRUTUS AND CAESAR, but NOT CALPURNIA?

- One could grep all of Shakespeare's plays for BRUTUS and CAESAR, then strip out lines containing CALPURNIA.

1.2 A first take at building an inverted index

- Why is grep not the solution?
  - Slow (for large collections)
  - grep is line-oriented, IR is document-oriented
  - "NOT CALPURNIA" is non-trivial
  - Other operations (e.g., find the word ROMANS near COUNTRYMAN) are not feasible

Outline

- 1.1 An example information retrieval problem
- 1.2 A first take at building an inverted index
- 1.3 Processing Boolean queries
- 1.4 The extended Boolean model versus ranked retrieval
- 1.5 References and further reading

1.3 Processing Boolean queries

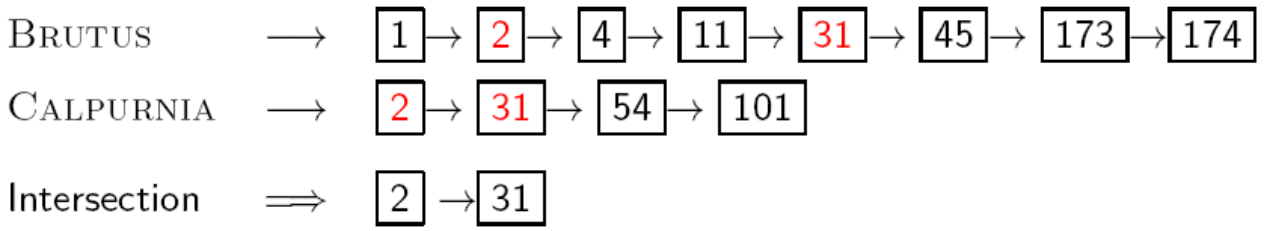
Simple conjunctive query (two terms)

- Consider the query: BRUTUS AND CALPURNIA

- To find all matched documents using inverted index:
  - Locate BRUTUS in the dictionary
  - Retrieve its postings list from the postings file
  - Locate CALPURNIA in the dictionary
  - Retrieve its postings list from the postings file
  - Intersect the two postings lists
  - Return the intersection to the user

1.3 Processing Boolean queries

Intersecting two postings lists (1/2)



- This is linear in the length of the postings lists.
- Note: This only works if postings lists are sorted.

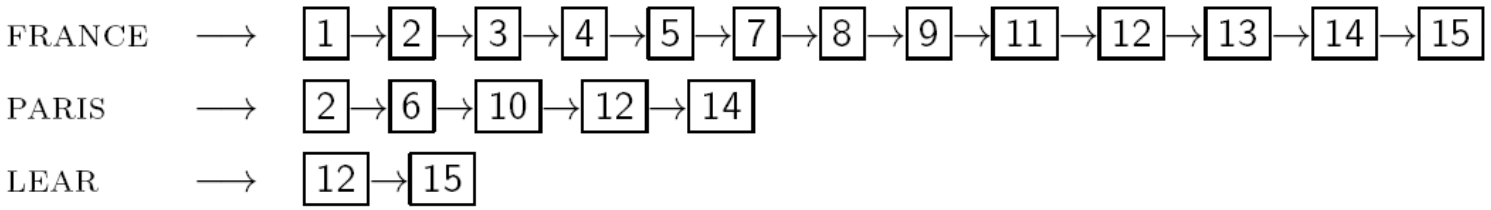
1.3 Processing Boolean queries

Intersecting two postings lists (2/2)

```
INTERSECT(p1, p2)
 1  answer ← ⟨ ⟩
 2  while p1 ≠ NIL and p2 ≠ NIL
 3  do if docID(p1) = docID(p2)
 4        then ADD(answer, docID(p1))
 5             p1 ← next(p1)
 6             p2 ← next(p2)
 7        else if docID(p1) < docID(p2)
 8                then p1 ← next(p1)
 9                else p2 ← next(p2)
10  return answer
```

1.3 Processing Boolean queries

Exercise



- Compute the hit list for ((PARIS AND NOT FRANCE) OR LEAR)

1.3 Processing Boolean queries

Boolean retrieval model: Assessment

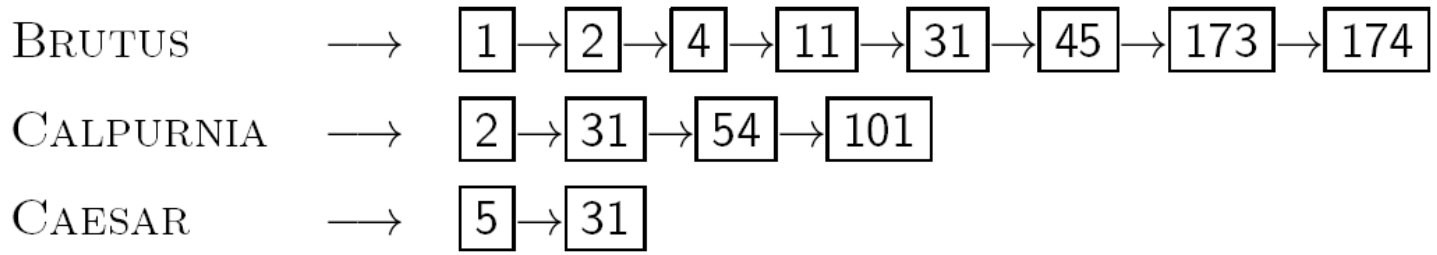
- The Boolean retrieval model can answer any query that is a Boolean expression
  - Boolean queries are queries that use AND, OR and NOT to join query terms
  - Views each document as a set of terms
  - Is precise: Document matches the condition or not
- Primary commercial retrieval tool for 3 decades
- Many professional searchers (e.g., lawyers) still like Boolean queries, because you know exactly what you are getting
- Many search systems you use are also Boolean: email, intranet, etc

1.3 Processing Boolean queries

Query optimization

- Consider a query that is an AND of n terms, where n>2
- For each of the terms, get its postings list, then AND them together

- Example query: BRUTUS AND CALPURNIA AND CAESAR
- What is the best order for processing this query?
- Simple and effective optimization: Process in order of increasing frequency



1.3 Processing Boolean queries

More general optimization

- Example query: (MADDING OR CROWD) AND (IGNOBLE OR STRIFE)
- Get frequencies for all terms
- Estimate the size of each OR by the sum of its frequencies (conservative)
- Process in increasing order of OR sizes

Summary

- 1.1 An example information retrieval problem
- 1.2 A first take at building an inverted index
- 1.3 Processing Boolean queries
- 1.4 The extended Boolean model versus ranked retrieval
- 1.5 References and further reading