CS347

Lecture 2

April 9, 2001

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Today's topics

- Inverted index storage
  - Compressing dictionaries into memory
- Processing Boolean queries
  - Optimizing term processing
  - Skip list encoding
- Wild-card queries
- Positional/phrase queries
- Evaluating IR systems

Recall dictionary and postings files

Term	Doc #	Freq
ambitious	2	1
be	2	1
brutus	1	1
brutus	2	1
capitol	1	1
caesar	1	1
caesar	2	2
did	1	1
enact	1	1
hath	2	1
I	1	2
i'	1	1
it	2	1
julius	1	1
killed	1	2
let	2	1
me	1	1
noble	2	1
so	2	1
the	1	1
the	2	1
told	2	1
you	2	1
was	1	1
was	2	1
with	2	1

Term	N docs	Tot Freq
ambitious	1	1
be	1	1
brutus	2	2
capitol	1	1
caesar	2	3
did	1	1
enact	1	1
hath	1	1
I	1	2
i'	1	1
it	1	1
julius	1	1
killed	1	2
let	1	1
me	1	1
noble	1	1
so	1	1
the	2	2
told	1	1
you	1	1
was	2	2
with	1	1

In memory

Doc #	Freq
2	1
2	1
1	1
2	1
1	1
1	1
2	2
1	1
1	1
2	1
1	2
1	1
2	1
1	1
1	2
2	1
1	1
2	1
2	1
1	1
2	1
2	1
2	1
1	1
2	1
2	1

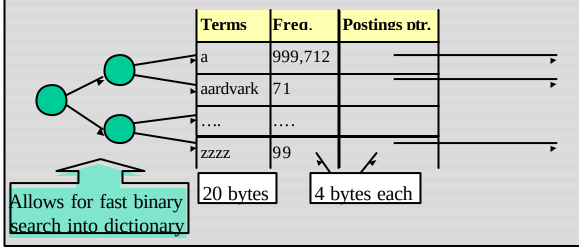
Gap-encoded, on disk

Inverted index storage

- Last time: Postings compression by gap encoding
- Now: Dictionary storage
  - Dictionary in main memory, postings on disk
- Tradeoffs between compression and query processing speed
  - Cascaded family of techniques

Dictionary storage - first cut

- Array of fixed-width entries
  - 28bytes/term = 14MB.



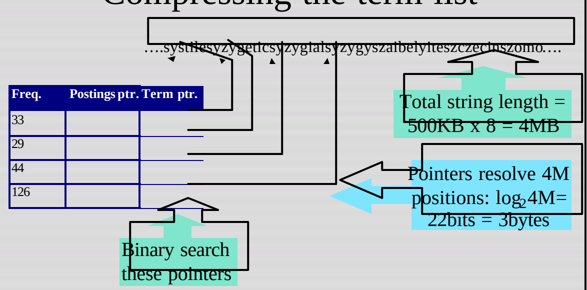
Exercise

- Is binary search really a good idea?
- What’s a better alternative?

Fixed-width terms are wasteful

- Most of the bytes in the **Term** column are wasted - we allot 20 bytes even for 1-letter terms.
  - Still can’t handle *supercalifragilisticexpialidocius.*
- Average word in English: ~8 characters.
  - *Written English averages ~4.5 characters: short words dominate usage.*
- Store dictionary as a string of characters:
  - Hope to save upto 60% of dictionary space.

Compressing the term list



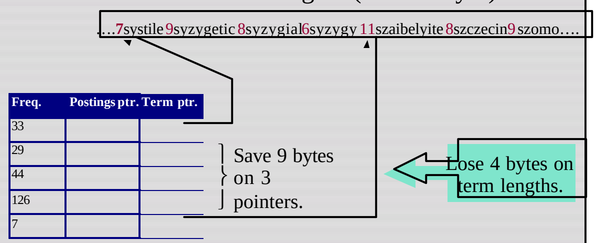
Total space for compressed list

- 4 bytes per term for Freq.
- 4 bytes per term for pointer to Postings.
- 3 bytes per term pointer
- Avg. 8 bytes per term in term string
- 500K terms ⇒ 9.5MB

(Last two points above:) Now avg. 11 bytes/term, not 20.

Blocking

- Store pointers to every *k*th on term string.
- Need to store term lengths (1 extra byte)

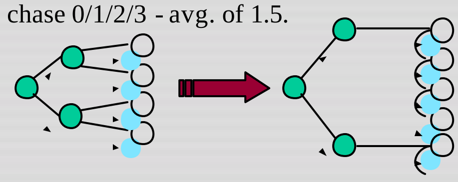


Exercise

- Estimate the space usage (and savings compared to 9.5MB) with blocking, for block sizes of $k = 4, 8$ and 16.

Impact on search

- Binary search down to 4-term block;
- Then linear search through terms in block.
- Instead of chasing 2 pointers before, now chase 0/1/2/3 - avg. of 1.5.



Extreme compression

- Using perfect hashing to store terms "within" their pointers
  - not good for vocabularies that change.
- Partition dictionary into pages
  - use B-tree on first terms of pages
  - pay a disk seek to grab each page
  - if we're paying 1 disk seek anyway to get the postings, "only" another seek/query term.

Query optimization

- Consider a query that is an *AND* of *t* terms.
- The idea: for each of the *t* terms, get its term-doc incidence from the postings, then *AND* together.
- Process in order of increasing freq:
  - *start with smallest set, then keep cutting further.*

This is why we kept freq in dictionary

Query processing exercises

- If the query is ***friends*** *AND* ***romans*** *AND* *(NOT* ***countrymen****)*, how could we use the freq of ***countrymen***?
- How can we perform the *AND* of two postings entries without explicitly building the 0/1 term-doc incidence vector?

General query optimization

- e.g., *(****madding*** *OR* ***crowd****) AND (****ignoble*** *OR* ***strife****)*
- Get freq's for all terms.
- Estimate the size of each *OR* by the sum of its freq's.
- Process in increasing order of *OR* sizes.

Exercise

- Recommend a query processing order for

(tangerine *OR* ***trees)*** *AND*
(marmalade *OR* ***skies)*** *AND*
(kaleidoscope *OR* ***eyes)***

Term	Freq
eyes	213312
kaleidoscope	87009
marmalade	107913
skies	271658
tangerine	46653
trees	316812

Speeding up postings merges

- Insert skip pointers
- Say our current list of candidate docs for an *AND* query is 8,13,21.
  - (having done a bunch of *AND*s)
- We want to *AND* with the following postings entry: 2,4,6,8,10,12,14,16,18,20,22
- Linear scan is slow.

Augment postings with skip pointers (at indexing time)

2,4,6,8,10,12,14,16,18,20,22,24, ...

- At query time:
- As we walk the current candidate list, concurrently walk inverted file entry - can skip ahead
  - (*e.g.*, 8,21).
- Skip size: recommend about √(list length)

Query vs. index expansion

- Recall, from lecture 1:
  - thesauri for term equivalents
  - soundex for homonyms
- How do we use these?
  - Can “expand” query to include equivalences
    - Query ***car tyres*** → ***car tyres automobile tires***
  - Can expand index
    - Index docs containing ***car*** under ***automobile***, as well

Query expansion

- Usually do query expansion
  - No index blowup
  - Query processing slowed down
    - Docs frequently contain equivalences
  - May retrieve more junk
    - ***puma*** → ***jaguar***
  - Carefully controlled *wordnets*

Wild-card queries

- ***mon****: find all docs containing any word beginning "mon".
- Solution: index all *k*-grams occurring in any doc (any sequence of *k* chars).
- *e.g.*, from text "April is the cruelest month" we get the 2-grams (*bigrams*)
  - $ is a special word boundary symbol

  a,ap,pr,ri,il,l,i,is,s,t,th,he,e,c,cr,ru,ue,el,le,es,st,t, m,mo,on,nt,h

Processing wild-cards

- Query *mon** can now be run as
  - ***$m AND mo AND on***
- But we'd get a match on *moon*.
- Must post-filter these results against query.
- Exercise: Work out the details.

Further wild-card refinements

- Cut down on pointers by using blocks
- Wild-card queries tend to have few bigrams
  - keep postings on disk
- *Exercise: given a trigram index, how do you process an arbitrary wild-card query?*

Phrase search

- Search for ***"to be or not to be"***
- No longer suffices to store only <*term*:*docs*> entries.
- Instead store, for each ***term***, entries
  - <number of docs containing ***term***;
  - *doc1*: position1, position2 … ;
  - *doc2*: position1, position2 … ;
  - etc.>

Positional index example

<***be***: 993427;
1: 7, 18, 33, 72, 86, 231;
2: 3, 149;
4: 17, 191, 291, 430, 434;
5: 363, 367, …>

Which of these docs could contain "***to be or not to be***"?

Can compress position values/offsets as we did with docs in the last lecture.

Processing a phrase query

- Extract inverted index entries for each distinct term: ***to, be, or, not***
- Merge their *doc:position* lists to enumerate all positions where "***to be or not to be***" begins.
  - ***to***:
    - *2*:1,17,74,222,551; *4*:8,27,101,429,433; *7*:13,23,191; ...
  - ***be***:
    - *1*:17,19; *4*:17,191,291,430,434; *5*:14,19,101; ...

Evaluating an IR system

- What are some measures for evaluating an IR system's performance?
  - Speed of indexing
  - Index/corpus size ratio
  - Speed of query processing
  - "Relevance" of results

Standard relevance benchmarks

- TREC - National Institute of Standards and Testing (NIST)
- Reuters and other benchmark sets
- "Retrieval tasks" specified
  - sometimes as queries
- Human experts mark, for each query and for each doc, "Relevant" or "Not relevant"

Precision and recall

- Precision: fraction of retrieved docs that are relevant
- Recall: fraction of relevant docs that are retrieved
- Both can be measured as functions of the number of docs retrieved

Tradeoff

- Can get high recall (but low precision) by retrieving all docs for all queries!
- Recall is a non-decreasing function of the number of docs retrieved
  - but precision usually decreases (in a good system)

Difficulties in precision/recall

- Should average over large corpus/query ensembles
- Need human relevance judgements
- Heavily skewed by corpus/authorship

Glimpse of what's ahead

- Building indices
- Term weighting and vector space queries
- Clustering documents
- Classifying documents
- Link analysis in hypertext
- Mining hypertext
- Global connectivity analysis on the web
- Recommendation systems and collaborative filtering
- Summarization
- Large enterprise issues and the real world

Resources for today's lecture

- *Managing Gigabytes*, Chapter 4.
- *Modern Information Retrieval*, Chapter 3.
- Princeton Wordnet
  - http://www.cogsci.princeton.edu/~wn/