CS4051

Information Retrieval

Week 02

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Phrase and Positional Indexing

Phrase queries

- Want to be able to answer queries such as "***stanford university"*** – as a phrase
- Thus the sentence *"I went to university at Stanford"* is not a match.
  - The concept of phrase queries has proven easily understood by users; one of the few "advanced search" ideas that works
  - Many more queries are *implicit phrase queries*
- For this, it no longer suffices to store only <*term* : *docs*> entries

Solution 1: Bi-word indexes

- Index every consecutive pair of terms in the text as a phrase
- For example the text "Friends, Romans, Countrymen" would generate the biwords
  - ***friends romans***
  - ***romans countrymen***
- Each of these biwords is now a dictionary term
- Two-word phrase query-processing is now immediate.

Sec. 2.4.1

Longer phrase queries

- Longer phrases are processed as we did with wild-cards:
- ***stanford university palo alto*** can be broken into the Boolean query on biwords:

stanford university *AND* ***university palo*** *AND* ***palo alto***

Without the docs, we cannot verify that the docs matching the above Boolean query do contain the phrase.

Can have false positives!

Sec. 2.4.1

Extended biwords

- Parse the indexed text and perform part-of-speech-tagging (POST).
- Bucket the terms into (say) Nouns (N) and articles/prepositions (X).
- Call any string of terms of the form NX*N an extended biword.
  - Each such extended biword is now made a term in the dictionary.
- Example: ***coins are in pocket***

  N X X N
- Query processing: parse it into N's and X's
  - Segment query into enhanced biwords
  - Look up in index: ***coin pocket***

Sec. 2.4.1

Issues for biword indexes

- False positives, as noted before
- Index blowup due to bigger dictionary
  - Infeasible for more than biwords, big even for them
- Biword indexes are not the standard solution (for all biwords) but can be part of a compound strategy

Sec. 2.4.2

Solution 2: Positional indexes

- In the postings, store for each ***term*** the position(s) in which tokens of it appear:

  <***term****,* number of docs containing ***term***;
  doc1: position1, position2 … ;
  doc2: position1, position2 … ;
  etc.>

Sec. 2.4.2

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 docs 1,2,4,5 could contain "***to be or not to be***"?

- For phrase queries, we use a merge algorithm recursively at the document level
- But we now need to deal with more than just equality

Sec. 2.4.2

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 with "***to be or not to be***".
    - ***to****:*
        - 2:1,17,74,222,551; *4*:8,16,190,429,433; *7*:13,23,191; ...
    - ***be****:*
        - *1*:17,19; *4*:17,191,291,430,434; *5*:14,19,101; ...
- Same general method for proximity searches

Positional Intersect

```
PositionalIntersect($p_1$, $p_2$, $k$)
answer ← ⟨ ⟩
while $p_1 \neq$ NIL and $p_2 \neq$ NIL
do if $docID(p_1) = docID(p_2)$
      then $l \leftarrow \langle\ \rangle$
           $pp_1 \leftarrow positions(p_1)$
           $pp_2 \leftarrow positions(p_2)$
           while $pp_1 \neq$ NIL
           do while $pp_2 \neq$ NIL
                 do if $|pos(pp_1) - pos(pp_2)| \leq k$
                          then ADD($l$, $pos(pp_2)$)
                          else if $pos(pp_2) > pos(pp_1)$
                                  then break
                    $pp_2 \leftarrow next(pp_2)$
                 while $l \neq \langle\ \rangle$ and $|l[0] - pos(pp_1)| > k$
                 do DELETE($l[0]$)
                 for each $ps \in l$
                 do ADD($answer$, $\langle docID(p_1), pos(pp_1), ps \rangle$)
                 $pp_1 \leftarrow next(pp_1)$
           $p_1 \leftarrow next(p_1)$
           $p_2 \leftarrow next(p_2)$
      else if $docID(p_1) < docID(p_2)$
              then $p_1 \leftarrow next(p_1)$
              else $p_2 \leftarrow next(p_2)$
return answer
```

Sec. 2.4.2

Proximity queries

- LIMIT! /3 STATUTE /3 FEDERAL /2 TORT
  - Again, here, /*k* means "within *k* words of".
- Clearly, positional indexes can be used for such queries; biword indexes cannot.
- Exercise: Adapt the linear merge of postings to handle proximity queries. Can you make it work for any value of *k*?
  - This is a little tricky to do correctly and efficiently
  - See Figure 2.12 of IIR
  - There's likely to be a problem on it!

Positional index size

- You can compress position values/offsets: we'll talk about that in lecture 5
- Nevertheless, a positional index expands postings storage *substantially*
- Nevertheless, a positional index is now standardly used because of the power and usefulness of phrase and proximity queries … whether used explicitly or implicitly in a ranking retrieval system.

Positional index size

- Need an entry for each occurrence, not just once per document
- Index size depends on average document size
  - Average web page has <1000 terms **Why?**
  - SEC filings, books, even some epic poems … easily 100,000 terms
- Consider a term with frequency 0.1%

Document size	Postings	Positional postings
1000	1	1
100,000	1	100

Sec. 2.4.2

Rules of thumb

- A positional index is 2–4 as large as a non-positional index
- Positional index size 35–50% of volume of original text
- Caveat: all of this holds for "English-like" languages

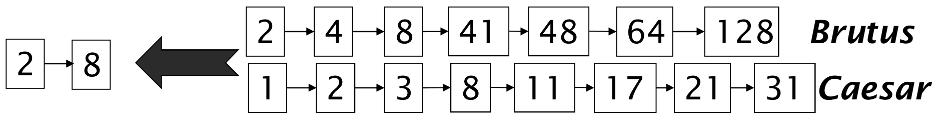
Sec. 2.4.3

Combination schemes

- These two approaches can be profitably combined
  - For particular phrases (***"Michael Jackson", "Britney Spears"***) it is inefficient to keep on merging positional postings lists
    - Even more so for phrases like ***"The Who"***
- Williams et al. (2004) evaluate a more sophisticated mixed indexing scheme
  - A typical web query mixture was executed in ¼ of the time of using just a positional index
  - It required 26% more space

Recall basic merge

- Walk through the two postings simultaneously, in time linear in the total number of postings entries

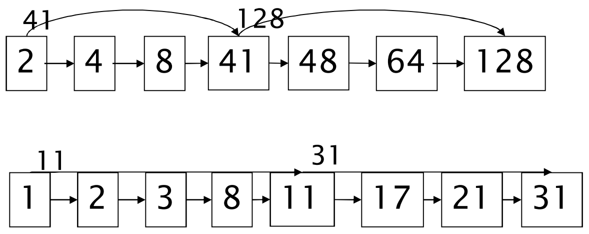


2 → 8
2 → 4 → 8 → 41 → 48 → 64 → 128 Brutus
1 → 2 → 3 → 8 → 11 → 17 → 21 → 31 Caesar

If the list lengths are *m* and *n*, the merge takes O(*m*+*n*) operations.

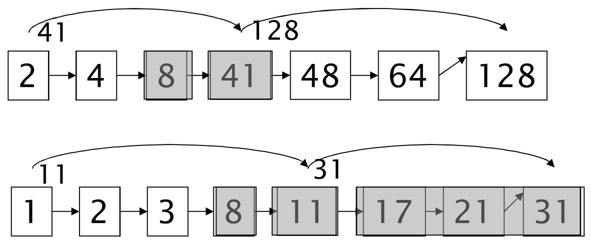
Can we do better?
Yes (if the index isn't changing too fast).

Augment postings with skip pointers (at indexing time)



- Why?
- <u>To skip postings that will not figure in the search results.</u>
- How?
- Where do we place skip pointers?

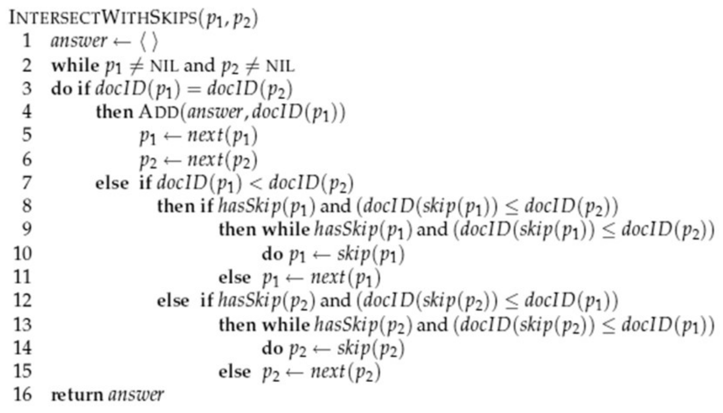
Query processing with skip pointers



Suppose we’ve stepped through the lists until we process **8** on each list. We match it and advance.

We then have **41** and **11** on the lower. **11** is smaller. But the skip successor of **11** on the lower list is **31**, so we can skip ahead past the intervening postings.

Faster Skip Lists

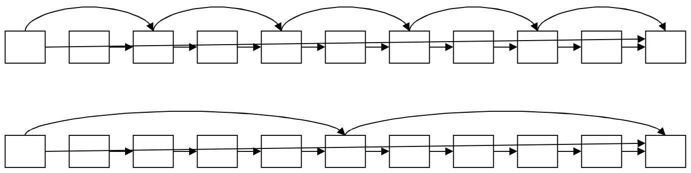


```
INTERSECTWITHSKIPS($p_1, p_2$)
answer ← ⟨ ⟩
while $p_1 \neq$ NIL and $p_2 \neq$ NIL
do if $docID(p_1) = docID(p_2)$
      then ADD(answer, $docID(p_1)$)
           $p_1 \leftarrow next(p_1)$
           $p_2 \leftarrow next(p_2)$
      else if $docID(p_1) < docID(p_2)$
              then if $hasSkip(p_1)$ and $(docID(skip(p_1)) \leq docID(p_2))$
                      then while $hasSkip(p_1)$ and $(docID(skip(p_1)) \leq docID(p_2))$
                                do $p_1 \leftarrow skip(p_1)$
                      else $p_1 \leftarrow next(p_1)$
              else if $hasSkip(p_2)$ and $(docID(skip(p_2)) \leq docID(p_1))$
                      then while $hasSkip(p_2)$ and $(docID(skip(p_2)) \leq docID(p_1))$
                                do $p_2 \leftarrow skip(p_2)$
                      else $p_2 \leftarrow next(p_2)$
return answer
```

► **Figure 2.10** Postings lists intersection with skip pointers.

Where do we place skips?

- Tradeoff:
  - More skips → shorter skip spans ⇒ more likely to skip. But lots of comparisons to skip pointers.
  - Fewer skips → few pointer comparison, but then long skip spans ⇒ few successful skips.



Placing skips

- Simple heuristic: for postings of length *L*, use √*L* evenly-spaced skip pointers [Moffat and Zobel 1996]
- This ignores the distribution of query terms.
- Easy if the index is relatively static; harder if *L* keeps changing because of updates.
- This definitely used to help; with modern hardware it may not unless you're memory-based [Bahle et al. 2002]
  - The I/O cost of loading a bigger postings list can outweigh the gains from quicker in memory merging!