CS317

Information Retrieval

Week 03

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Dictionaries & Tolerant Retrieval

Review Chapter No. 2

- We developed idea of inverted indexes for handling Boolean and proximity queries.
- We discussed positional indexes for supporting general phrase queries.
- We modify intersection of posting list to speedup in generating result-set.
- What about the dictionary? Large Dictionary are still a challenge?

Chapter No. 3

- In this chapter we will develop techniques that are robust to typographical errors in the query, as well as alternative spellings.
- We also develop data structures that help search for terms in the vocabulary in an inverted index.
- We explore the idea of a wildcard query: a query such as *a*e*i*o*u*, which seeks documents containing any term that includes all the five vowels in sequence.

Data Structures for Dictionary

- There are two choices
  - Trees
  - Hashtable
- IR systems can use either of the approach.

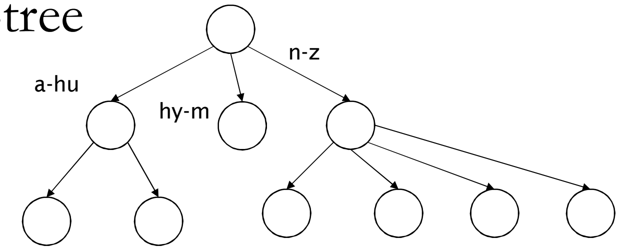
Sec. 3.1

Hashtables

- Each vocabulary term is hashed to an integer
  - (We assume you've seen hashtables before)
- Pros:
  - Lookup is faster than for a tree: O(1)
- Cons:
  - No easy way to find minor variants:
    - judgment/judgement
  - No prefix search [tolerant retrieval]
  - If vocabulary keeps growing, need to occasionally do the expensive operation of rehashing *everything*

Sec. 3.1

Tree: B-tree



- Definition: Every internal nodel has a number of children in the interval [*a*,*b*] where *a, b* are appropriate natural numbers, e.g., [2,4].

Sec. 3.1

Trees

- Simplest: binary tree
- More usual: B-trees
- Trees require a standard ordering of characters and hence strings … but we typically have one
- Pros:
  - Solves the prefix problem (terms starting with *hyp*)
- Cons:
  - Slower: O(log *M*) [and this requires *balanced* tree]
  - Rebalancing binary trees is expensive
    - But B-trees mitigate the rebalancing problem

Wild Card Queries (*)

- Wildcard queries are used in any of the following situations:
  - the user is uncertain of the spelling of a query term (e.g., Sydney vs. Sidney, which leads to the wildcard query S*dney);
  - the user is aware of multiple variants of spelling a term and (consciously) seeks documents containing any of the variants (e.g., color vs. colour);

Wild Card Queries (*)

- Wildcard queries are used in any of the following situations:
  - the user seeks documents containing variants of a term that would be caught by stemming, but is unsure whether the search engine performs stemming (e.g., judicial vs. judiciary, leading to the wildcard query judicia*);
  - the user is uncertain of the correct rendition of a foreign word or phrase (e.g., the query Universit* Stuttgart).

Sec. 3.2

Wild-card queries: *

- ***mon*:*** find all docs containing any word beginning with "mon".
- Easy with binary tree (or B-tree) lexicon: retrieve all words in range: ***mon ≤ w < moo***
- ****mon:*** find words ending in "mon": harder
  - Maintain an additional B-tree for terms *backwards.*

  Can retrieve all words in range: ***nom ≤ w < non****.*

Exercise: from this, how can we enumerate all terms meeting the wild-card query ***pro*cent*** ?

Sec. 3.2

Query processing

- At this point, we have an enumeration of all terms in the dictionary that match the wild-card query.
- We still have to look up the postings for each enumerated term.
- E.g., consider the query:

  se*ate *AND* ***fil*er***

  This may result in the execution of many Boolean *AND* queries.

Sec. 3.2

B-trees handle *'s at the end of a query term

- How can we handle *'s in the middle of query term?
  - ***co*tion***
- We could look up ***co**** AND ****tion*** in a B-tree and intersect the two term sets
  - Expensive
- The solution: transform wild-card queries so that the *'s occur at the end
- This gives rise to the **Permuterm** Index.

General Wild Card Query

- We now study two techniques for handling general wildcard queries.
  - Both techniques share a common strategy: express the given wildcard query q_w as a Boolean query Q on a specially constructed index, such that the answer to Q is a superset of the set of vocabulary terms matching q_w.
  - Then, we check each term in the answer to Q against q_w, discarding those vocabulary terms that do not match q_w. At this point we have the vocabulary terms matching q_w and can resort to the standard inverted index.

Sec. 3.2.1

Permuterm index

- For term ***hello***, index under:
  - ***hello$, ello$h, llohe, lohel, o$hell***

  where $ is a special symbol.
- Queries:
  - **X** lookup on **X$** **X*** lookup on $**X***
  - ***X** lookup on **X$*** ***X*** lookup on **X***
  - **X*Y** lookup on **Y$X*** **X*Y*Z** ??? Exercise!

Query = ***hel*o***
X=*hel*, Y=*o*
Lookup ***o$hel****

Sec. 3.2.1

Permuterm query processing

- Rotate query wild-card to the right
- Now use B-tree lookup as before.
- *Permuterm problem: ≈ quadruples lexicon size*

Empirical observation for English.

Bigram (*k*-gram) indexes

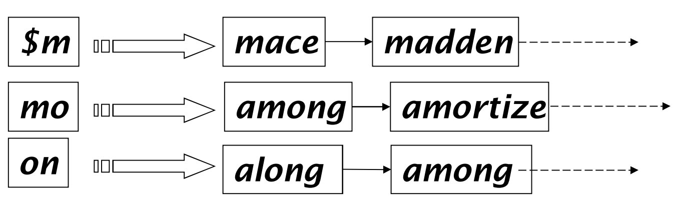
- Enumerate all *k*-grams (sequence of *k* chars) occurring in any term
- *e.g.,* from text "***April is the cruelest month***" we get the 2-grams (*bigrams*)

  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

  - $ is a special word boundary symbol
- Maintain a <u>*second*</u> inverted index <u>*from bigrams to*</u> <u>*dictionary terms*</u> that match each bigram.

Bigram index example

- The *k*-gram index finds *terms* based on a query consisting of *k*-grams (here *k*=2).



Sec. 3.2.2

Processing wild-cards

- Query ***mon**** can now be run as
  - ***$m** AND **mo** AND **on***
- Gets terms that match AND version of our wildcard query.
- But we'd enumerate ***moon***.
- Must post-filter these terms against query.
- Surviving enumerated terms are then looked up in the term-document inverted index.
- Fast, space efficient (compared to permuterm).

Sec. 3.2.2

Processing wild-card queries

- As before, we must execute a Boolean query for each enumerated, filtered term.
- Wild-cards can result in expensive query execution (very large disjunctions…)
  - pyth* AND prog*
- If you encourage "laziness" people will respond!