Introduction to Information Retrieval

(Manning, Raghavan, Schutze)

Chapter 7
Computing scores in a complete search system

Content

- **Speeding up vector space ranking**
- Putting together a complete search system

Efficiency bottleneck

- Top-k retrieval: we want to find the *K* docs in the collection "nearest" to the query $\Rightarrow$ *K* largest query-doc cosines.
- Primary computational bottleneck in scoring: cosine computation
- Can we avoid all this computation?
- Yes, but may sometimes get it wrong
  - a doc *not* in the top *K* may creep into the list of *K* output docs
  - Is this such a bad thing?

Cosine similarity is only a proxy

- User has a task and a query formulation
- Cosine matches docs to query
- Thus cosine is anyway a proxy for user happiness
- If we get a list of *K* docs "close" to the top *K* by cosine measure, should be ok
- Thus, it's acceptable to do inexact top k document retrieval

Inexact top K: generic approach

- Find a set *A* of *contenders*, with $K < |A| << N$
  - *A* does not necessarily contain the top *K*, but has many docs from among the top *K*
  - Return the top *K* docs in *A*
- The same approach is also used for other (non-cosine) scoring functions
- Will look at several schemes following this approach

Index elimination

- Only consider high-idf query terms

- Only consider docs containing many query terms

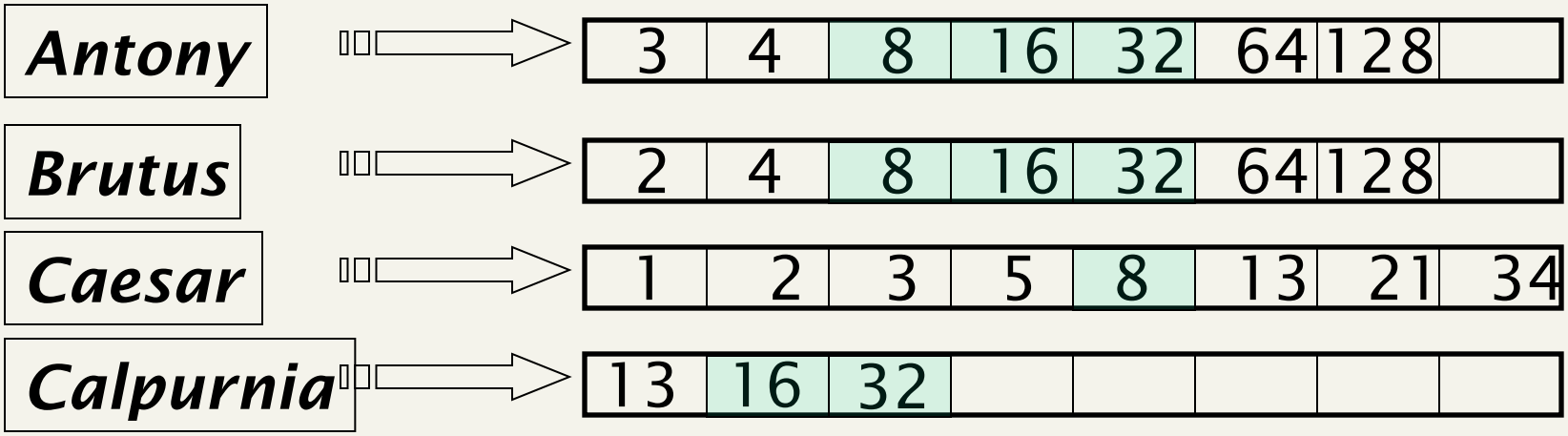
High-idf query terms only

- For a query such as *catcher in the rye*
- Only accumulate scores from *catcher* and *rye*
- Intuition: *in* and *the* contribute little to the scores and don't alter rank-ordering much
- Benefit:
  - Postings of low-idf terms have many docs → these (many) docs get eliminated from *A*

Docs containing many query terms

- Any doc with at least one query term is a candidate for the top *K* output list
- For multi-term queries, only compute scores for docs containing several of the query terms
  - Say, at least 3 out of 4
  - Imposes a "soft conjunction" on queries seen on web search engines (early Google)
- Easy to implement in postings traversal

3 of 4 query terms



Scores only computed for 8, 16 and 32.

Champion lists

- Precompute for each dictionary term *t,* the *r* docs of highest weight in *t*'s postings
  - Call this the champion list for *t*
  - (aka fancy list or top docs for *t*)
- **Note: postings are sorted by docID, a common order**
- Note that *r* has to be chosen at index time
  - r not necessarily the same for different terms
- At query time, only compute scores for docs in the champion list of some query term
  - Pick the *K* top-scoring docs from amongst these

Static quality scores

- We want top-ranking documents to be both *relevant* and *authoritative*
- *Relevance* is being modeled by cosine scores
- *Authority* is typically a query-independent property of a document
- Examples of authority signals
  - Wikipedia among websites
  - Articles in certain newspapers
  - A paper with many citations
  - Many diggs, Y!buzzes or del.icio.us marks
  - (Pagerank)

Modeling authority

- Assign to each document a *query-independent* quality score in [0,1] to each document *d*
  - Denote this by *g(d)*
- Thus, a quantity like the number of citations is scaled into [0,1]

Net score

- Consider a simple total score combining cosine relevance and authority
- net-score(q,d) = $g(d)$ + cosine(q,d)
  - Can use some other linear combination than an equal weighting
- Now we seek the top K docs by net score

Top *K* by net score – idea 1

- Order all postings by *g(d)*
  - Key: this is a common ordering for all postings
- Thus, can concurrently traverse query terms' postings for
  - Postings intersection
  - Cosine score computation
- Under *g(d)*-ordering, top-scoring docs likely to appear early in postings traversal
  - In time-bound applications (say, we have to return whatever search results we can in 50 ms), this allows us to stop postings traversal early

Top *K* by net score – idea 2

- Can combine champion lists with *g(d)*-ordering
- Maintain for each term a champion list of the *r* docs with highest *g(d)* + tf-idf$_{td}$
- Seek top-*K* results from only the docs in these champion lists
- **Note: postings are sorted by g(d), a common order**

Top *K* by net score – idea 3

- For each term, we maintain two postings lists called *high* and *low*
  - Think of *high* as the champion list
- When traversing postings on a query, only traverse *high* lists first
  - If we get more than *K* docs, select the top *K* and stop
  - Else proceed to get docs from the *low* lists
- Can be used even for simple cosine scores, without global quality *g(d)*
- A means for segmenting index into two tiers
  - Tiered indexes (later)

Impact-ordered postings

- We only want to compute scores for docs for which $wf_{t,d}$ is high enough
- We sort each postings list by $tf_{t,d}$ *or* $wf_{t,d}$
- Now: not all postings in a common order!
  - If common order (docID, g(d)), supports concurrent traversal of all query terms' posting lists. Computing scores in this manner is referred to as "document-at-a-time scoring"
  - Otherwise, "term-at-a-time"
- How do we compute scores in order to pick off top *K?*
  - Two ideas follow

1. Early termination

- When traversing *t*'s postings, stop early after either
  - a fixed number of *r* docs
  - $wf_{t,d}$ drops below some threshold
- Take the union of the resulting sets of docs
  - One from the postings of each query term
- Compute only the scores for docs in this union

2. idf-ordered terms

- When considering the postings of query terms
- Look at them in order of decreasing idf
  - High idf terms likely to contribute most to score
- As we update score contribution from each query term
  - Stop if doc scores relatively unchanged
- Can apply to cosine or some other net scores

Cluster pruning: preprocessing

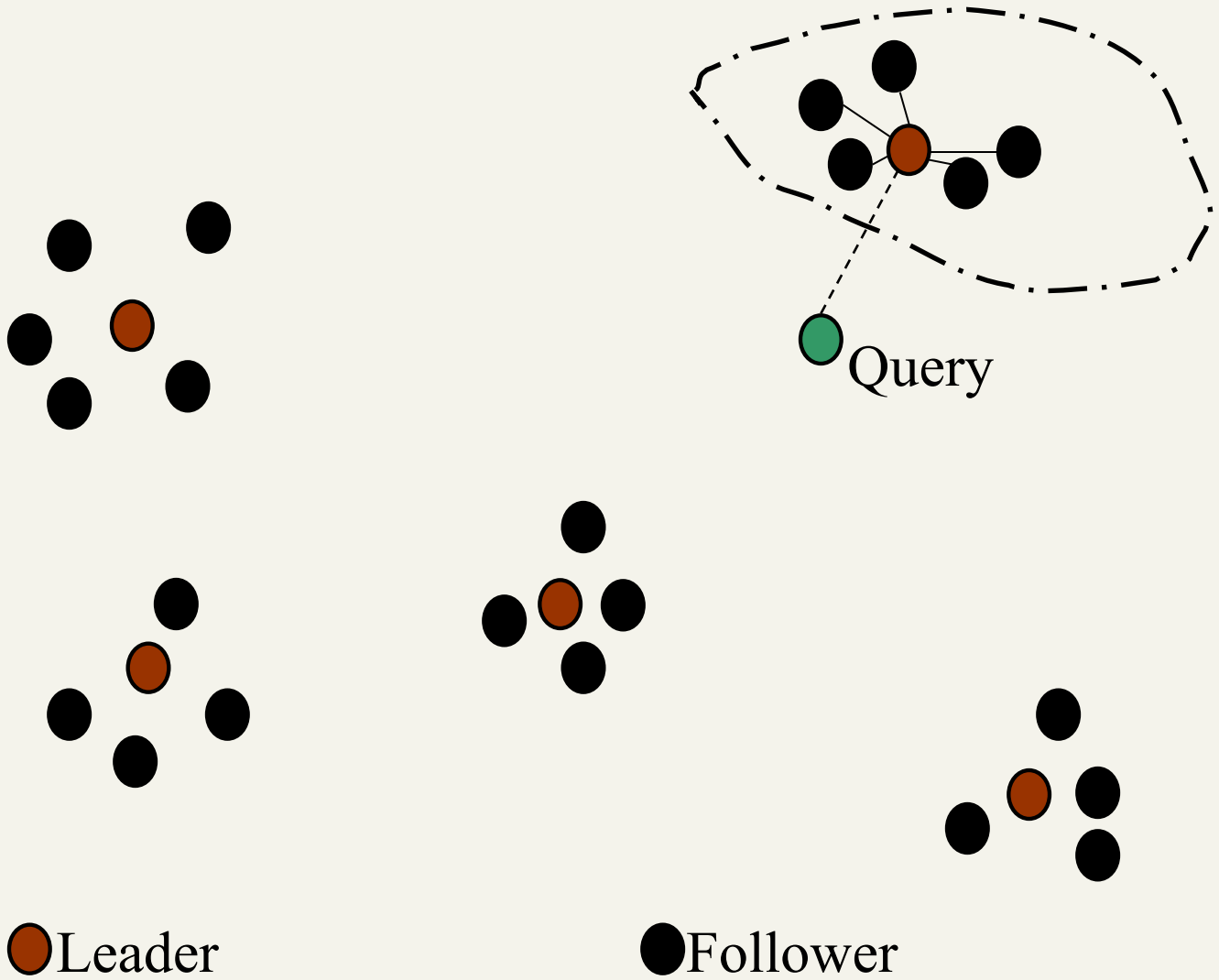
- Pick √N *docs* at random: call these *leaders*
  - Why random?
  - Fast; leaders reflect data distribution

- For every other doc, pre-compute nearest leader
  - Docs attached to a leader: its *followers;*
  - Likely: each leader has ~ √*N* followers.

Cluster pruning: query processing

- Process a query as follows:
  - Given query *Q*, find its nearest *leader L.*
  - Seek *K* nearest docs from among *L*'s followers.

Visualization



Content

- Speeding up vector space ranking
- **Putting together a complete search system**
  - Components of an IR system

Parametric indexes (p102)

- Thus far, a doc has been a sequence of terms
- In fact documents have multiple parts, some with special semantics:
  - Author, Date of publication, Language, Format, Title
- These constitute the metadata about a document
- This metadata would generally include *fields* such as the date of creation and the format of the document, as well the author and possibly the title of the document.
- The possible values of a field should be thought of as finite - for instance, the set of all dates of authorship.

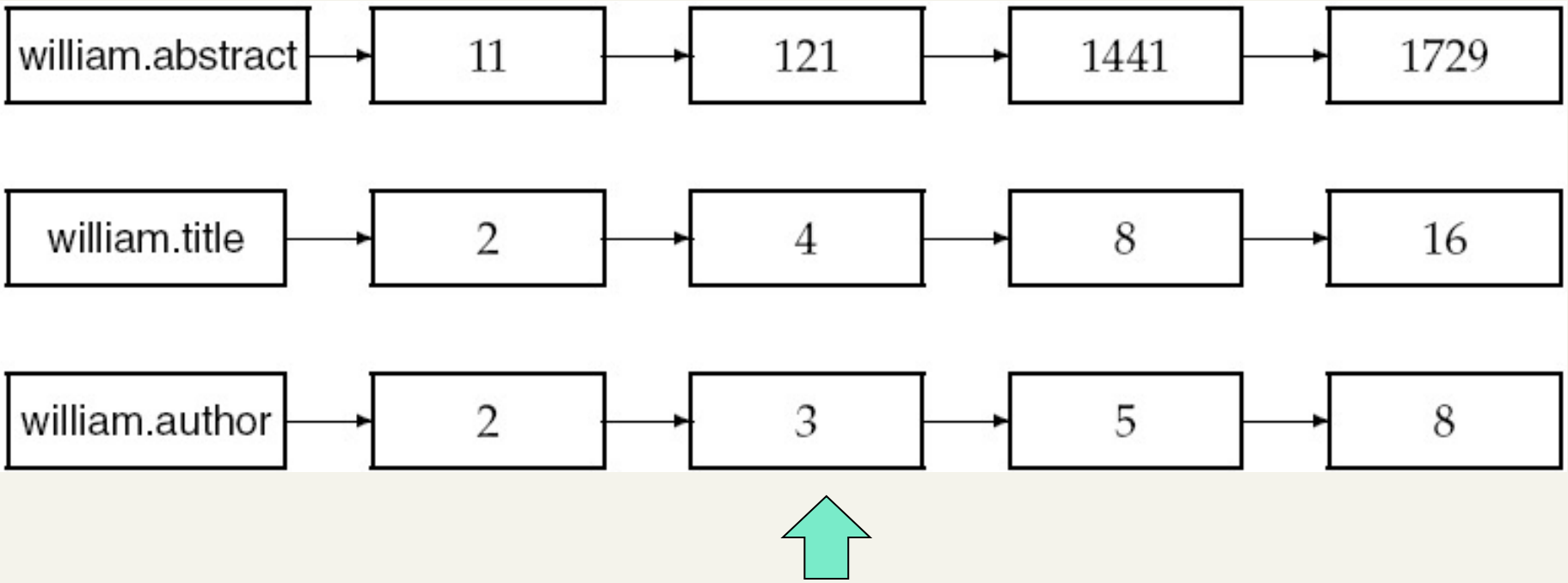
Parametric indexes

- We sometimes wish to search by these metadata
  - E.g., find docs authored by William Shakespeare in the year 1601, containing *alas poor Yorick*
- Parametric (or field) index: there is one parametric index for each field (say, date of creation)
- Parametric search typically treated as conjunction
  - doc *must* be authored by shakespeare

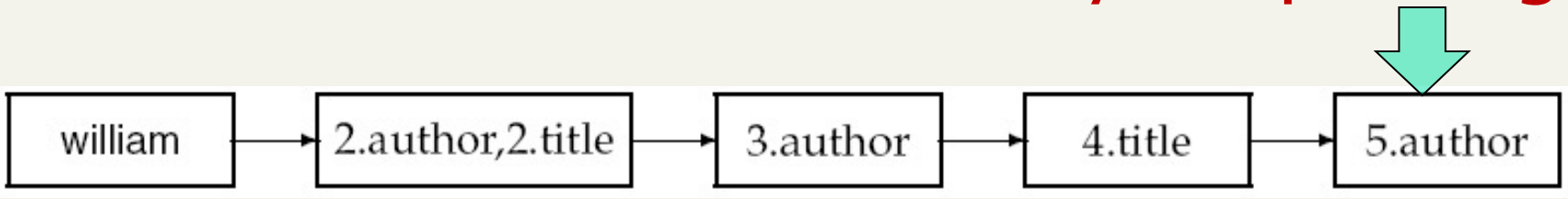
Zone indexes

- *Zones* are similar to fields, except the contents of a zone can be arbitrary free text, whereas a field may take on a relatively small set of values. For instance, document titles and abstracts are generally treated as zones.
  - Title, Abstract, References …
- Build inverted indexes on zones as well to permit querying, e.g.,
  - find documents with merchant in the title and the phrase gentle rain in the body

Example zone indexes



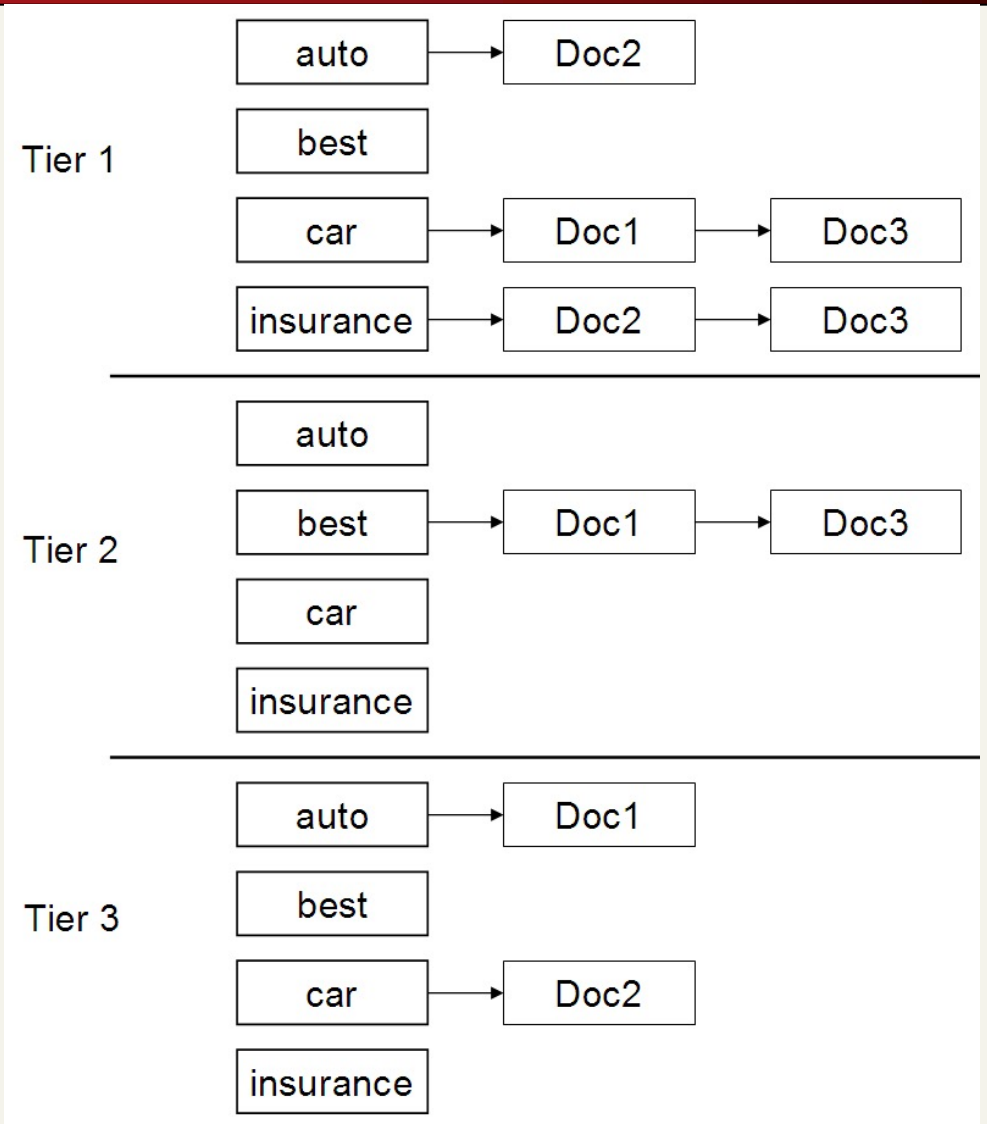
Encode zones in dictionary vs. postings.



Tiered indexes

- Break postings up into a hierarchy of lists
  - Most important
  - …
  - Least important
- Can be done by *g(d)* or another measure
- Inverted index thus broken up into tiers of decreasing importance
- At query time use top tier unless it fails to yield *K* docs
  - If so drop to lower tiers

Example tiered index



Query term proximity

- Free text queries: just a set of terms typed into the query box – common on the web
- Users prefer docs in which query terms occur within close proximity of each other
- Let *w* be the smallest window in a doc containing all query terms, e.g.,
- For the query *strained mercy* the smallest window in the doc *The quality of mercy is not strained* is 4 (words)
- Would like scoring function to take this into account – how?

Query parsers

- Free text query from user may in fact spawn one or more queries to the indexes, e.g. query *rising interest rates*
  - Run the query as a phrase query
  - If <*K* docs contain the phrase *rising interest rates*, run the two phrase queries *rising interest* and *interest rates*
  - If we still have <*K* docs, run the vector space query *rising interest rates*
  - Rank matching docs by vector space scoring
- This sequence is issued by a query parser

Aggregate scores

- We've seen that score functions can combine **cosine, static quality, proximity**, etc.
- How do we know the best combination?
- Some applications – expert-tuned
- Increasingly common: machine-learned

Putting it all together