Introduction to

Information Retrieval

CS276

Information Retrieval and Web Search

Chris Manning and Pandu Nayak

Efficient scoring

Today's focus

- Retrieval – get docs matching query from inverted index
- Scoring+ranking
  - Assign a score to each doc
  - Pick *K* highest scoring docs
- Our emphasis today will be on doing this efficiently, rather than on the quality of the ranking

Background

- Score computation is a large (10s of %) fraction of the CPU work on a query
  - Generally, we have a tight budget on latency (say, 250ms)
  - CPU provisioning doesn't permit exhaustively scoring every document on every query
- Today we'll look at ways of cutting CPU usage for scoring, without compromising the quality of results (much)
- Basic idea: avoid scoring docs that won't make it into the top *K*

Recap: Queries as vectors

- Vector space scoring
  - We have a weight for each term in each doc
  - Represent queries as vectors in the space
  - Rank documents according to their cosine similarity to the query in this space
    - Or something more complex: BM25, proximity, …
- Vector space scoring is
  - Entirely query dependent
  - Additive on term contributions – no conditionals etc.
  - Context insensitive (no interactions between query terms)

TAAT vs DAAT techniques

- TAAT = "Term At A Time"
  - Scores for all docs computed concurrently, one query term at a time
- DAAT = "Document At A Time"
  - Total score for each doc (incl all query terms) computed, before proceeding to the next
- Each has implications for how the retrieval index is structured and stored

Efficient cosine ranking

- Find the *K* docs in the collection "nearest" to the query $\Rightarrow$ *K* largest query-doc cosines.
- Efficient ranking:
  - Choosing the *K* largest cosine values efficiently.
    - Can we do this without computing all *N* cosines?

Safe vs non-safe ranking

- The terminology "safe ranking" is used for methods that guarantee that the *K* docs returned are the *K* absolute highest scoring documents
  - (Not necessarily just under cosine similarity)
- Is it ok to be non-safe?
- If it is – then how do we ensure we don't get too far from the safe solution?
  - How do we measure if we are far?

Non-safe ranking

- Covered in depth in Coursera video (number 7)
- Non-safe ranking may be okay
  - Ranking function is only a proxy for user happiness
  - Documents close to top K may be just fine
- Index elimination
  - Only consider high-idf query terms
  - Only consider docs containing many query terms
- Champion lists
- High/low lists, tiered indexes
- Order postings by *g(d)* (query-indep. quality score)

SAFE RANKING

Safe ranking

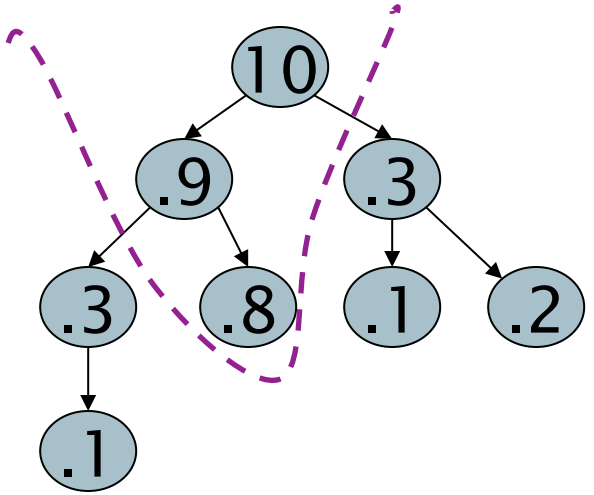
- When we output the top *K* docs, we have a proof that these are indeed the top *K*
- Does this imply we always have to compute all *N* cosines?
  - We'll look at pruning methods
  - So we only fully score some *J* documents
- Do we have to sort the *J* cosine scores?

Computing the *K* largest cosines: selection vs. sorting

- Typically we want to retrieve the top *K* docs (in the cosine ranking for the query)
  - not to totally order all docs in the collection
- Can we pick off docs with *K* highest cosines?
- Let *J* = number of docs with nonzero cosines
  - We seek the *K* best of these *J*

Use heap for selecting top *K*

- Binary tree in which each node's value > the values of children
- Takes *2J* operations to construct, then each of *K* "winners" read off in O(log *J*) steps.
- For *J*=1M, *K*=100, this is about 10% of the cost of sorting.



WAND scoring

- An instance of DAAT scoring
- Basic idea reminiscent of branch and bound
  - We maintain a running *threshold* score – e.g., the K^{th} highest score computed so far
  - We prune away all docs whose cosine scores are guaranteed to be below the threshold
  - We compute exact cosine scores for only the un-pruned docs

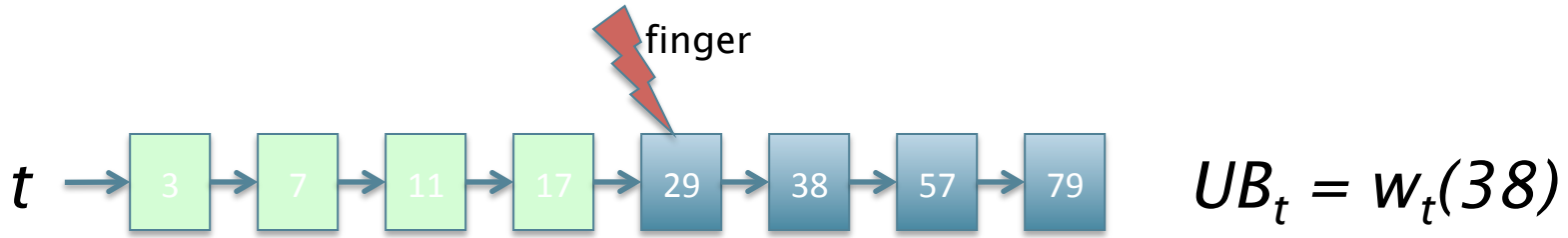
Broder et al. Efficient Query Evaluation using a Two-Level Retrieval Process.

Index structure for WAND

- Postings ordered by docID
- Assume a special iterator on the postings of the form "go to the first docID greater than or equal to *X*"
- Typical state: we have a "finger" at some docID in the postings of each query term
  - Each finger moves only to the right, to larger docIDs
- Invariant – all docIDs lower than any finger have already been *processed,* meaning
  - These docIDs are either pruned away or
  - Their cosine scores have been computed

Upper bounds

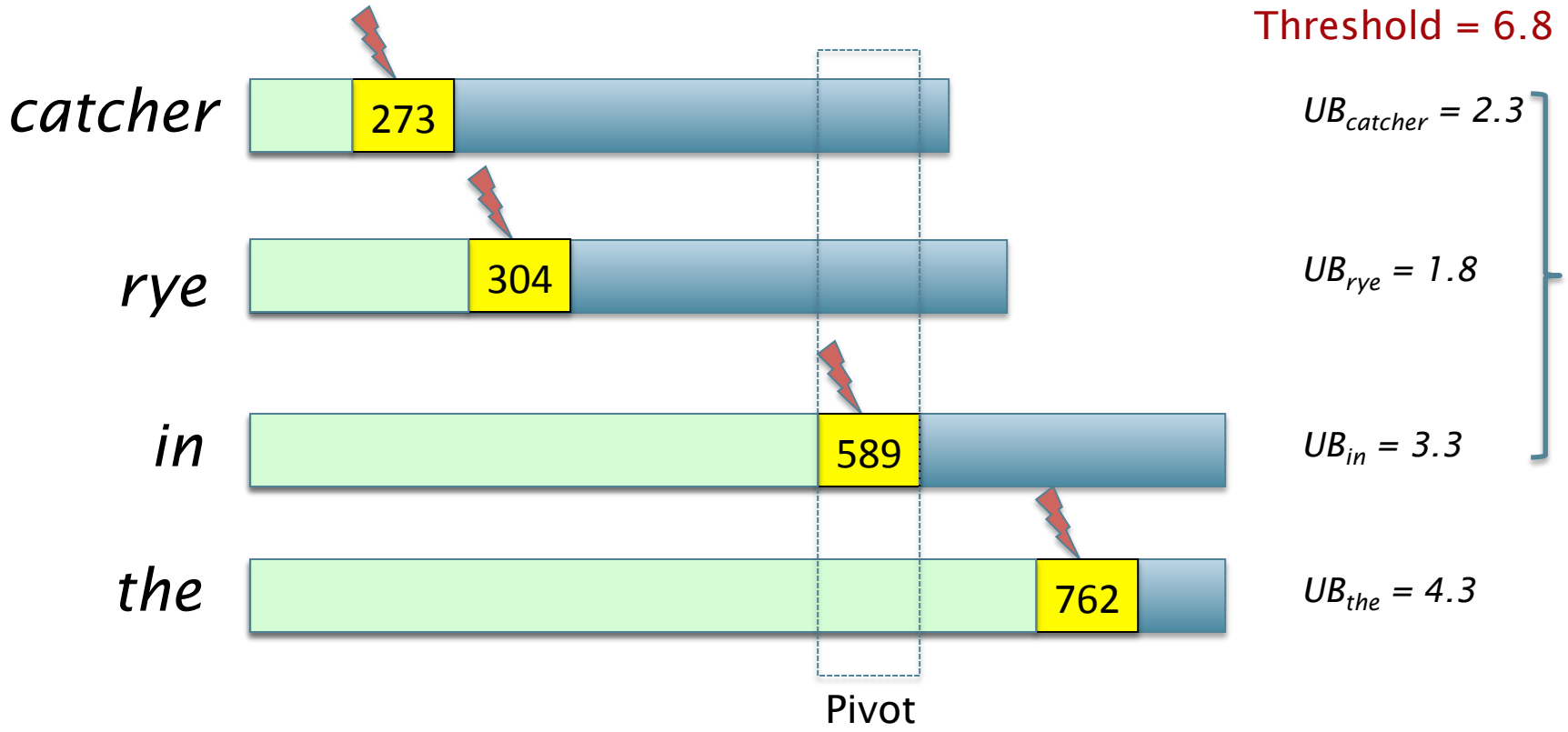
- At all times for each query term *t*, we maintain an *upper bound* UB_t on the score contribution of any doc to the right of the finger
  - Max (over docs remaining in *t*'s postings) of w_t(doc)



As finger moves right, *UB* drops

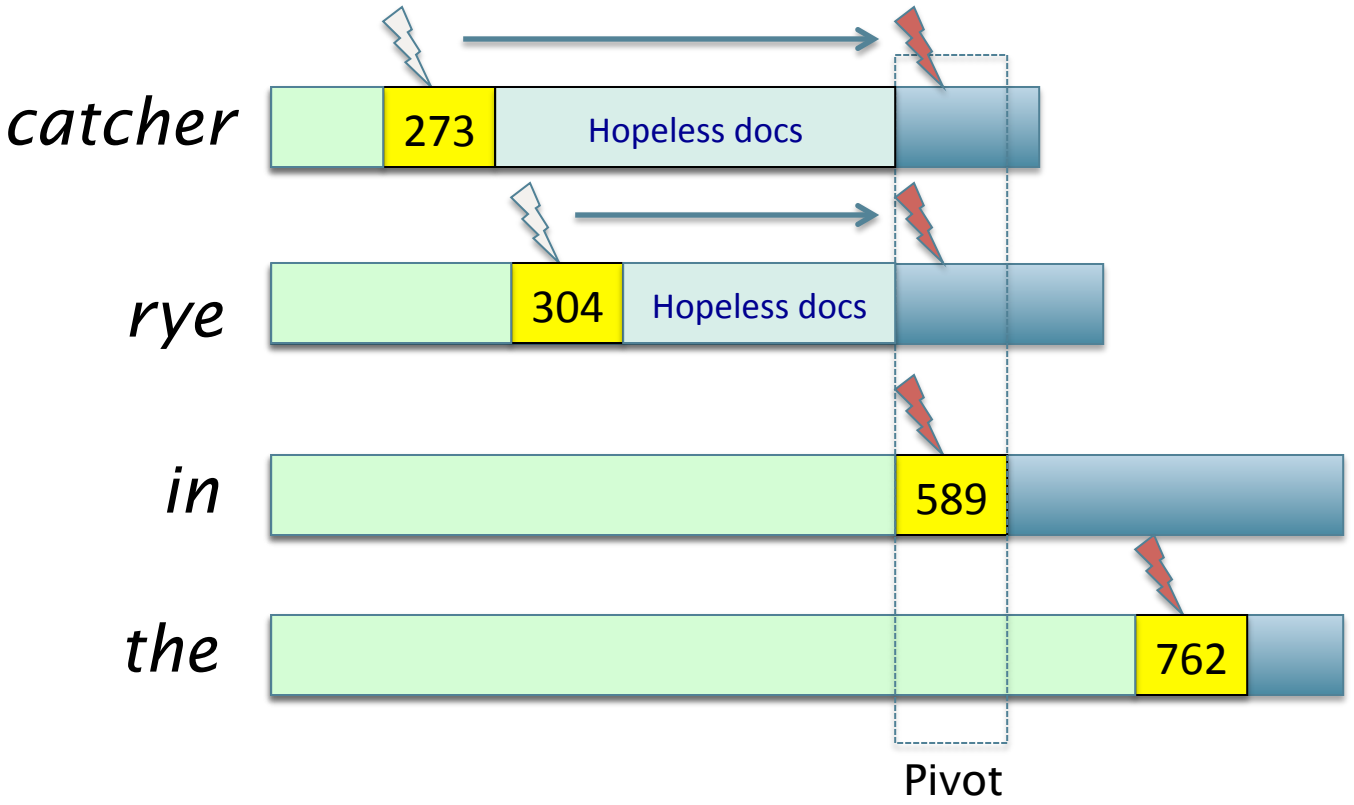
Pivoting

- Query: *catcher in the rye*
- Let's say the current finger positions are as below



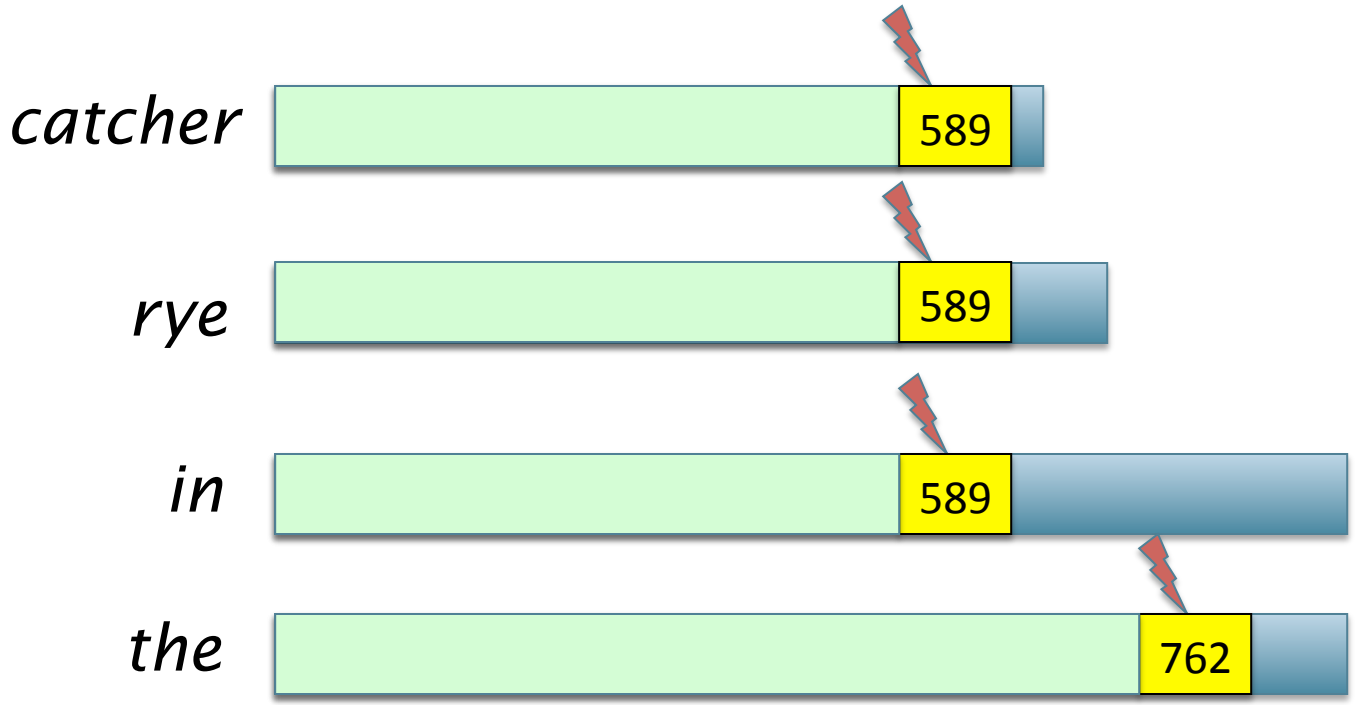
Prune docs that have no hope

- Terms sorted in order of finger positions
- Move fingers to 589 or right



Compute 589's score if need be

- If 589 is present in enough postings, compute its full cosine score – else some fingers to right of 589
- Pivot again …



WAND summary

- In tests, WAND leads to a 90+% reduction in score computation
  - Better gains on longer queries
- Nothing we did was specific to cosine ranking
  - We need scoring to be *additive* by term
- WAND and variants give us safe ranking
  - Possible to devise "careless" variants that are a bit faster but not safe (see summary in Ding+Suel 2011)
  - Ideas combine some of the non-safe scoring we considered