Informatics 225
Computer Science 221

Information Retrieval

Lecture 19

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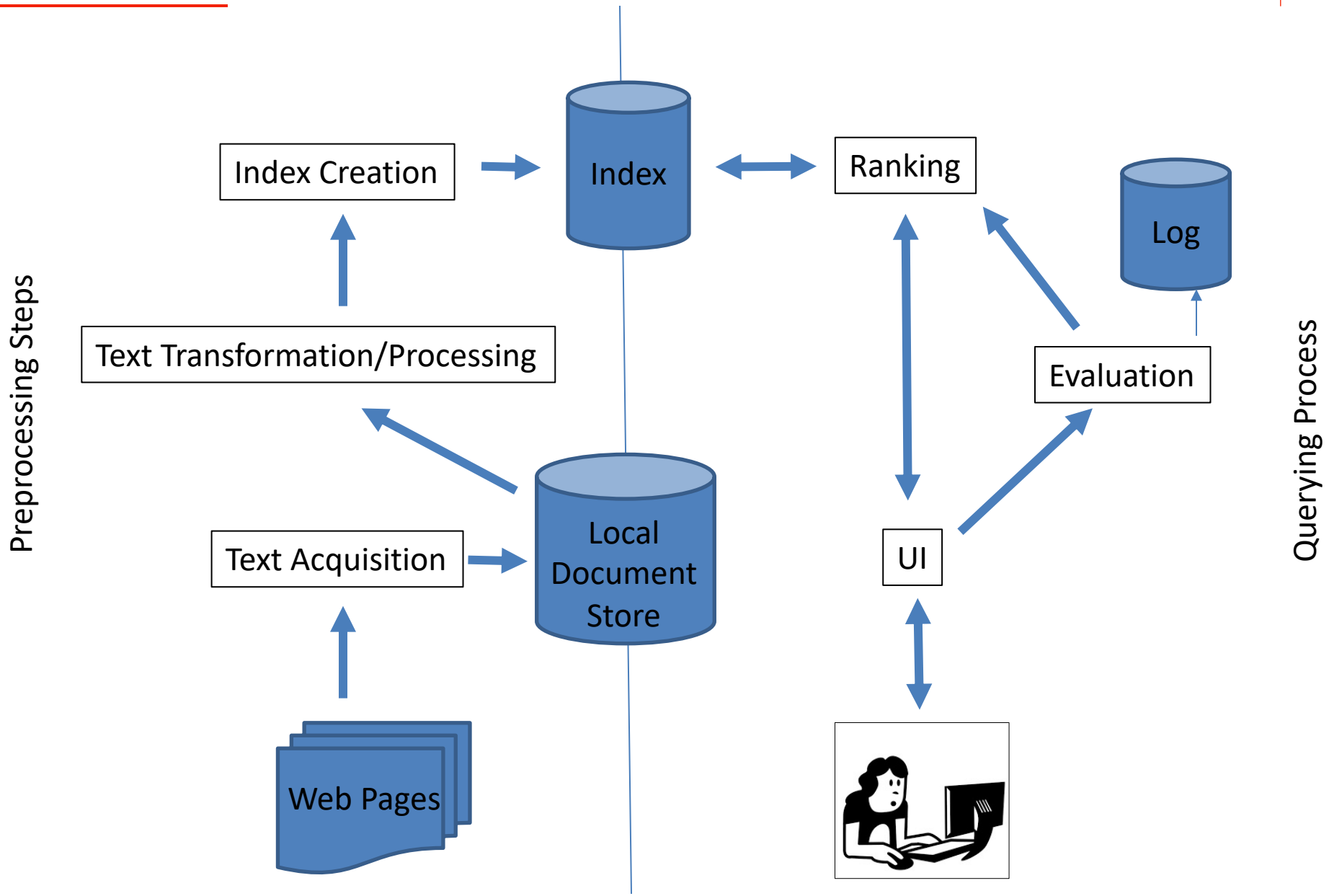
Optimizing Query Evaluation

Architecture



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- Basic process
  - All queries sent to a *director machine*
  - Director then sends messages to many *index servers*
  - Each index server does some portion of the query processing
  - Director organizes the results and returns them to the user
- Two main approaches on how to distribute the query
  - Document distribution
  - Term distribution

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  - each index server acts as a search engine for a small fraction of the total collection
  - director sends a copy of the query to each of the index servers, each of which returns the top-*k* results
  - results are merged into a single ranked list by the director
- Collection statistics should be shared for effective ranking

Distributed Query Evaluation

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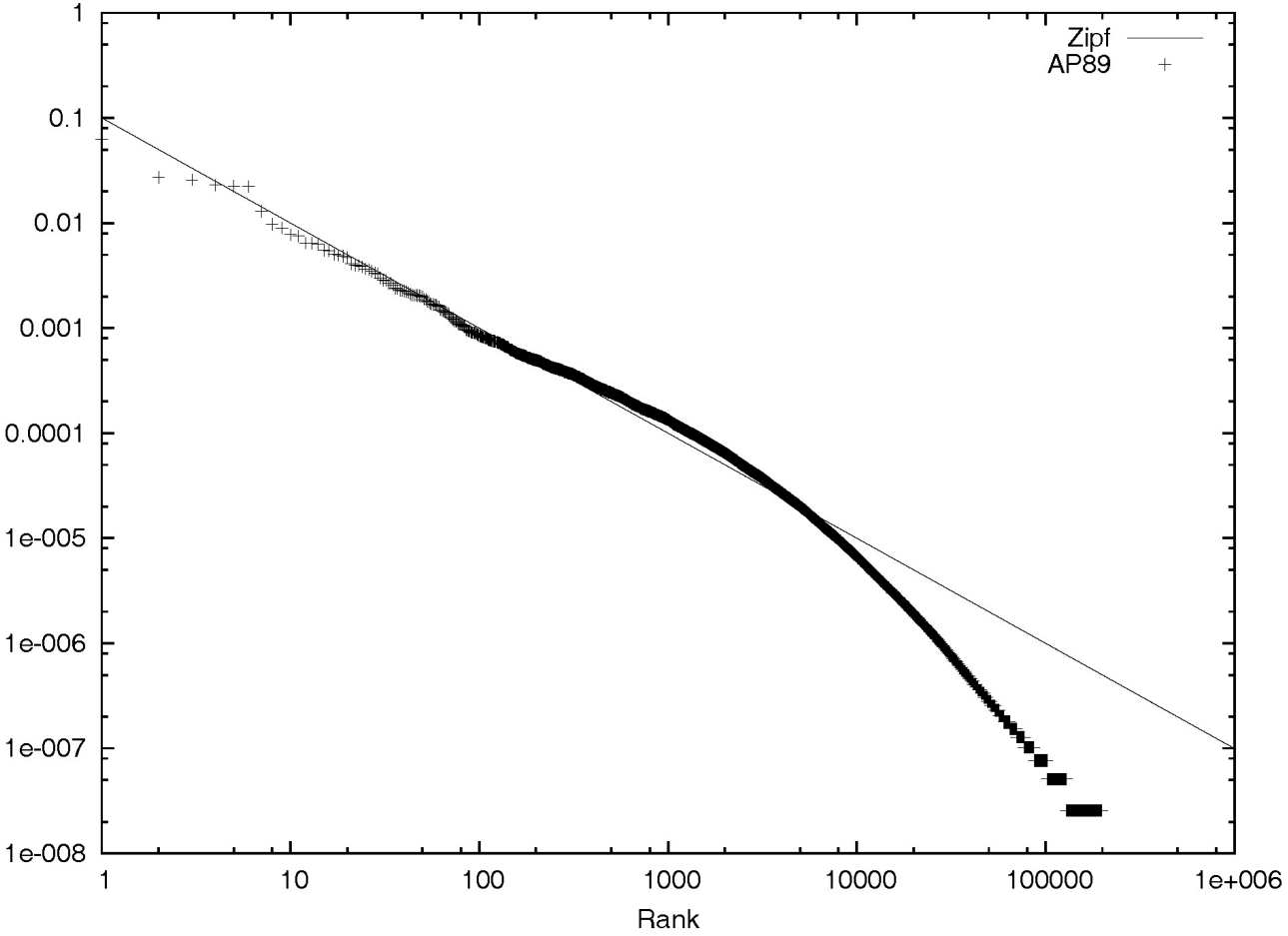
    - usually the one holding the longest inverted list
  - Other index servers send information to that server
  - Final results sent to director

Query Caching

- Query distributions similar to Zipf
  - About ½ each day are unique, but some are very popular

Reminder: Zipf's Law for AP89



- Note problems at high and low frequencies
- Words that occur once : *Hapax Legomena*.

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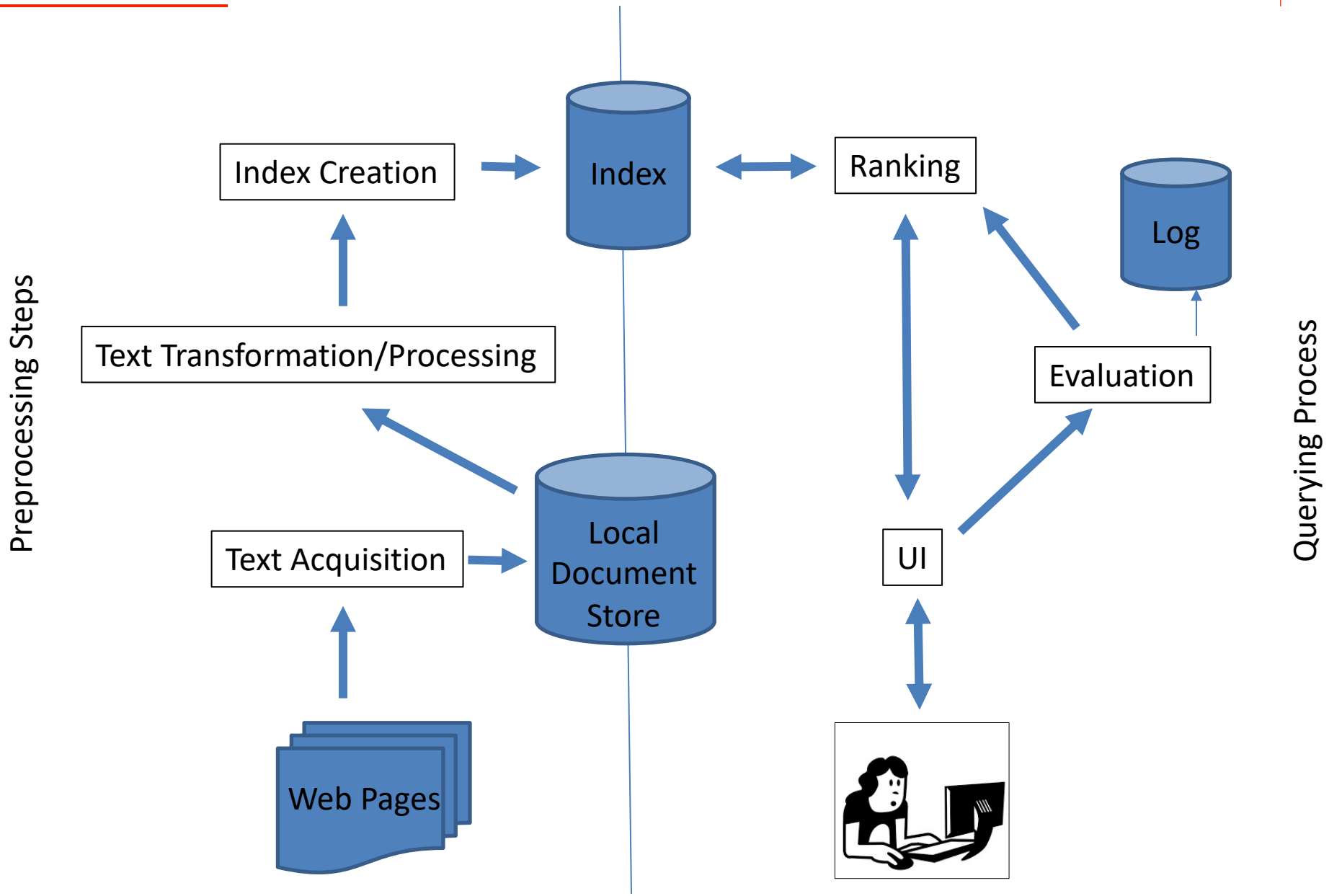
- Inverted list caching can help even with unique queries
- Cache must be refreshed to prevent stale data

Architecture



Query Processing

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Query Processing

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- Term-at-a-time
  - Accumulates scores for documents by processing term lists one at a time
- Both approaches have optimization techniques that significantly reduce time required to generate scores

Document-At-A-Time

Query : salt water tropical

Postings (x:y) – document number and word count

salt	1:1
water	1:1
tropical	1:2
score	1:4

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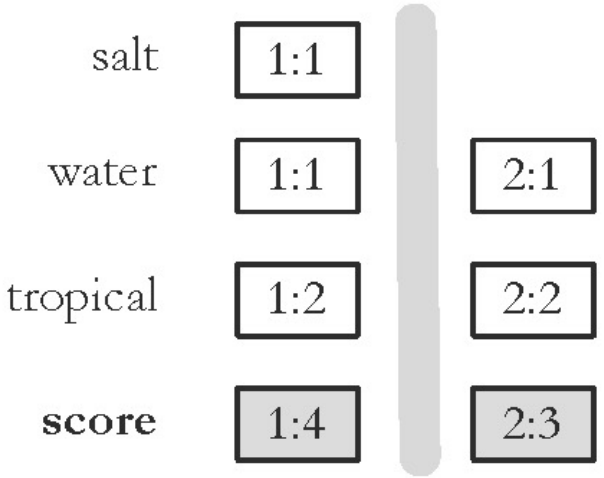

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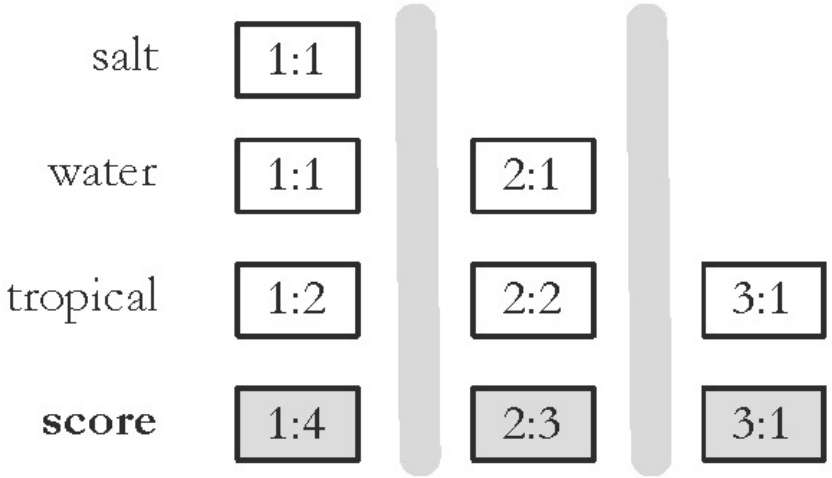

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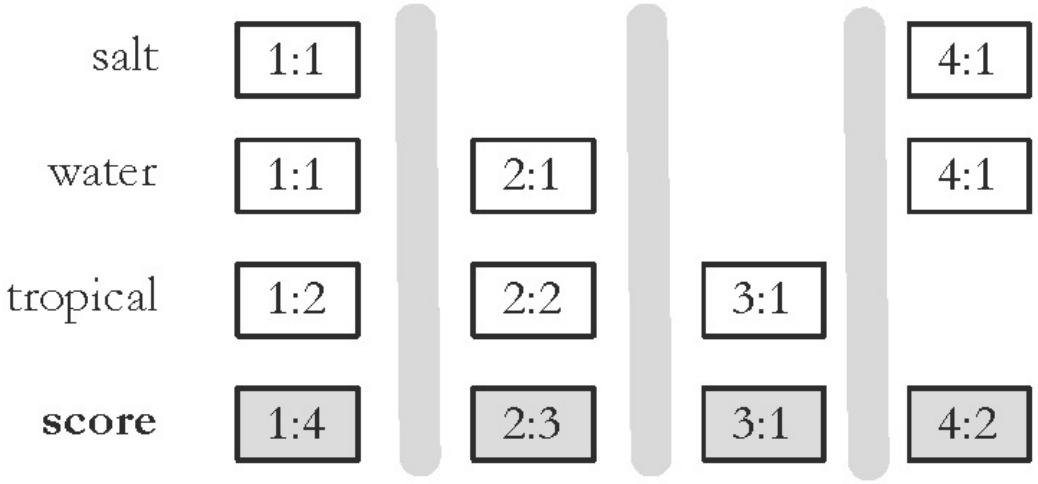

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Document-At-A-Time

```
procedure DocumentAtATimeRetrieval(Q, I, f, g, k)
    L ← Array()
    R ← PriorityQueue(k)
    for all terms w_i in Q do
        l_i ← InvertedList(w_i, I)
        L.add( l_i )
    end for
    for all documents d ∈ I do
        s_d ← 0
        for all inverted lists l_i in L do
            if l_i.getCurrentDocument() = d then
                s_d ← s_d + g_i(Q) f_i(l_i)          ▷ Update the document score
            end if
            l_i.movePastDocument( d )
        end for
        R.add( s_d, d )
    end for
    return the top k results from R
end procedure
```

Pseudocode Function Descriptions

- getCurrentDocument()
  - Returns the document number of the current posting of the inverted list.
- skipForwardToDocument(d)
  - Moves forward in the inverted list until getCurrentDocument() <= d. This function may read to the end of the list.
- movePastDocument(d)
  - Moves forward in the inverted list until getCurrentDocument() < d.
- moveToNextDocument()
  - Moves to the next document in the list. Equivalent to movePastDocument(getCurrentDocument()).
- getNextAccumulator(d)
  - returns the first document number d' >= d that has already has an accumulator.
- removeAccumulatorsBetween(a, b)
  - Removes all accumulators for documents numbers between a and b. A_d will be removed iff a < d < b.

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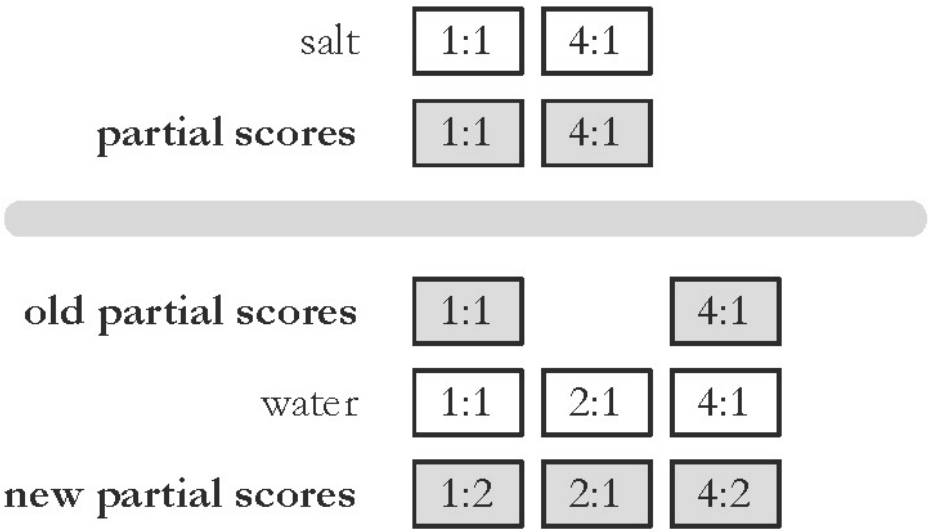

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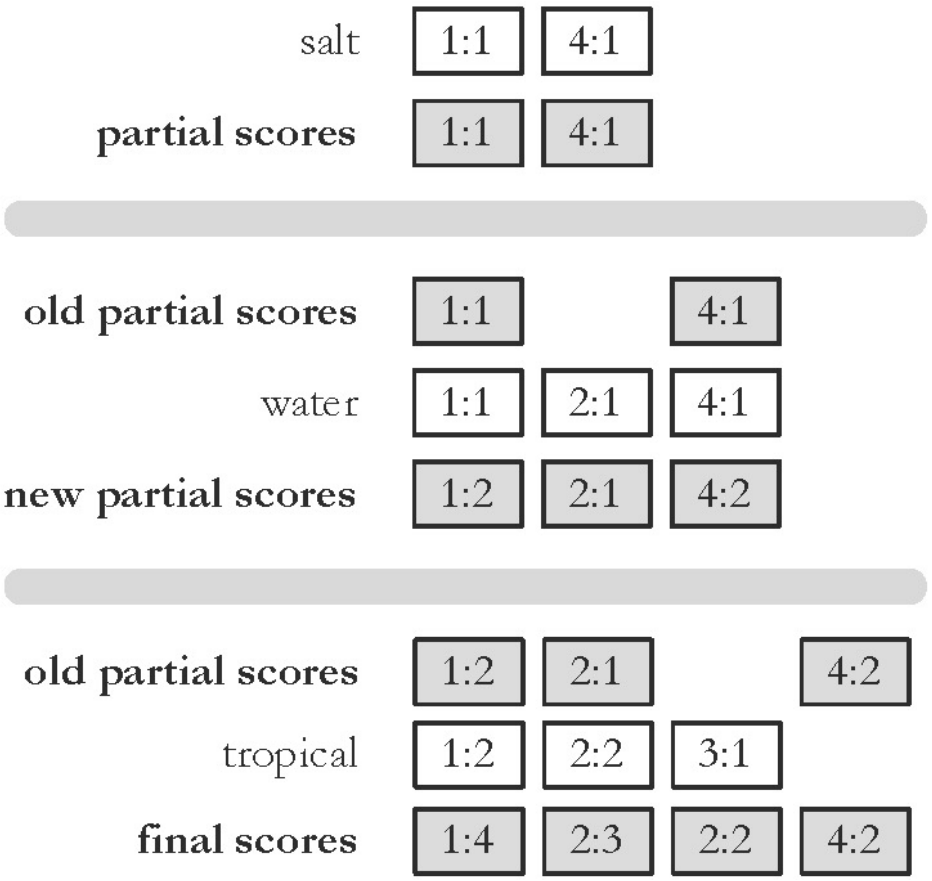

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Term-At-A-Time

```
procedure TermAtATimeRetrieval(Q, I, f, g k)
    A ← HashTable()
    L ← Array()
    R ← PriorityQueue(k)
    for all terms w_i in Q do
        l_i ← InvertedList(w_i, I)
        L.add( l_i )
    end for
    for all lists l_i ∈ L do
        while l_i is not finished do
            d ← l_i.getCurrentDocument()
            A_d ← A_d + g_i(Q) f(l_i)
            l_i.moveToNextDocument()
        end while
    end for
    for all accumulators A_d in A do
        s_d ← A_d                    ▷ Accumulator contains the document score
        R.add( s_d, d )
    end for
    return the top k results from R
end procedure
```

Optimization Techniques

- Term-at-a-time uses more memory for accumulators, but accesses disk more efficiently

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- Two classes of optimization
  - Read less data from inverted lists
    - e.g., skip lists (already covered on previous lectures. e.g. skip pointers), index the index
    - better for simple feature functions

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- Term-at-a-time uses more memory for accumulators, but accesses disk more efficiently

- Two classes of optimization
  - Read less data from inverted lists
    - e.g., skip lists (already covered on previous lectures. e.g. skip pointers), index the index
    - better for simple feature functions
  - Calculate scores for fewer documents
    - E.g., conjunctive processing
    - better for complex feature functions

Conjunctive processing

- Among the simplest types of query optimization.
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- Default mode of many engines.
- Every returned document must contain all query terms.
- Works best when one of the query terms is rare.
  - By first selecting the documents containing the rare term(s), you can skip a large fraction of the documents
- Can be used in Term-at-a-time and Document-at-a-time approaches

```
1: procedure TermAtATimeRetrieval(Q, I, f, g, k)
2:     A ← Map()
3:     L ← Array()
4:     R ← PriorityQueue(k)
5:     for all terms w_i in Q do
6:         l_i ← InvertedList(w_i, I)
7:         L.add( l_i )
8:     end for
9:     for all lists l_i ∈ L do
10:        d_0 ← −1
11:        while l_i is not finished do
12:            if i = 0 then
13:                d ← l_i.getCurrentDocument()
14:                A_d ← A_d + g_i(Q) f(l_i)
15:                l_i.moveToNextDocument()
16:            else
17:                d ← l_i.getCurrentDocument()
18:                d′ ← A.getNextAccumulator(d)
19:                A.removeAccumulatorsBetween(d_0, d′)
20:                if d = d′ then
21:                    A_d ← A_d + g_i(Q) f(l_i)
22:                    l_i.moveToNextDocument()
23:                else
24:                    l_i.skipForwardToDocument(d′)
25:                end if
26:                d_0 ← d′
27:            end if
28:        end while
29:    end for
30:    for all accumulators A_d in A do
31:        s_d ← A_d                ▷ Accumulator contains the document score
32:        R.add( s_d, d )
33:    end for
34:    return the top k results from R
35: end procedure
```

Conjunctive Term-at-a-Time

Check the accumulator for the next document containing all previously seen terms and skip the list of postings to that document.

```
1: procedure DocumentAtATimeRetrieval(Q, I, f, g, k)
2:     L ← Array()
3:     R ← PriorityQueue(k)
4:     for all terms w_i in Q do
5:         l_i ← InvertedList(w_i, I)
6:         L.add( l_i )
7:     end for
8:     d ← −1
9:     while all lists in L are not finished do
10:        s_d ← 0
11:        for all inverted lists l_i in L do
12:            if l_i.getCurrentDocument() > d then
13:                d ← l_i.getCurrentDocument()
14:            end if
15:        end for
16:        for all inverted lists l_i in L do
17:            l_i.skipForwardToDocument(d)
18:            if l_i.getCurrentDocument() = d then
19:                s_d ← s_d + g_i(Q) f_i(l_i)        ▷ Update the document score
20:                l_i.movePastDocument( d )
21:            else
22:                d ← −1
23:                break
24:            end if
25:        end for
26:        if d > −1 then R.add( s_d, d )
27:        end if
28:    end while
29:    return the top k results from R
30: end procedure
```

Conjunctive Document-at-a-Time

Finds the largest document pointed by an inverted list

Try to skip all lists to point to the document

If it can, score, otherwise break.

Threshold Methods

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  - for most applications, *k* is small

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Threshold Methods

- Threshold methods use number of top-ranked documents needed (*k*) to optimize query processing
  - for most applications, *k* is small

- For any query, there is a *minimum score* that each document needs to reach before it can be shown to the user
  - score of the *k*th-highest scoring document
  - gives *threshold* τ
  - Unfortunately, we don't know τ…
  - optimization methods estimate τ' to ignore documents

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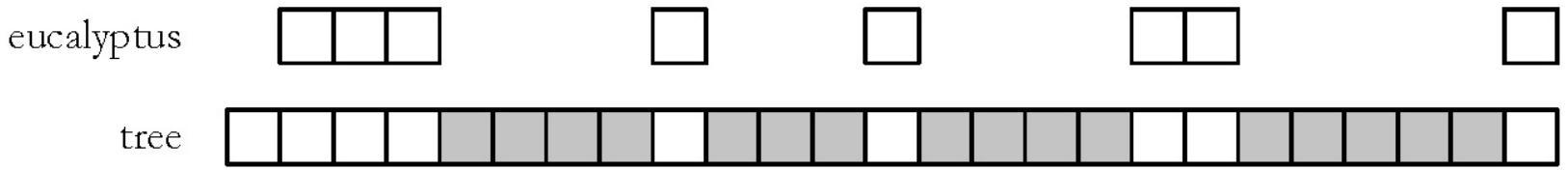
- After you have some estimate:
  - *MaxScore* method compares the maximum score that remaining documents could have to τ'
    - Ignore parts of the inverted lists that will not generate document scores above τ'
    - *safe* optimization in that ranking will be the same without optimization

MaxScore Example



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  - maximum score for any document containing just “tree”

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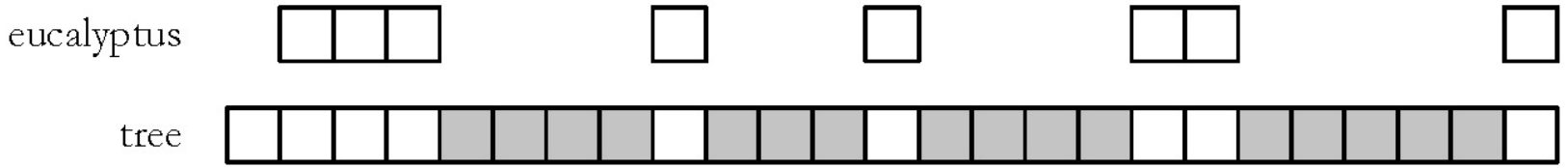

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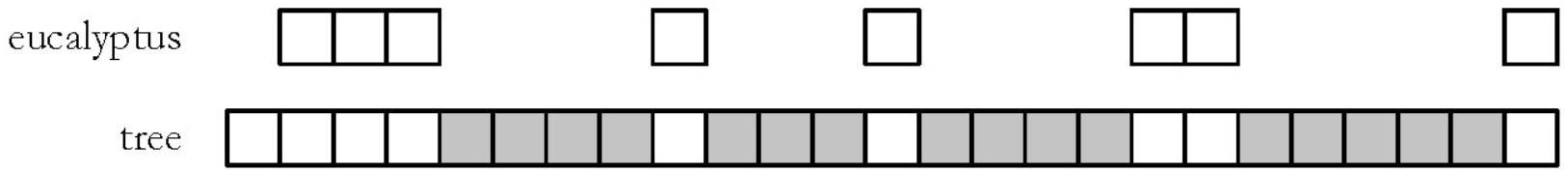

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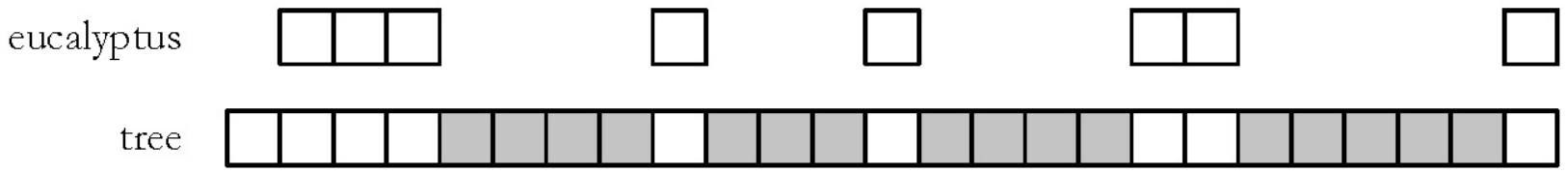

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- Can safely skip over all gray postings

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  - *unsafe* optimization

- List ordering
  - order inverted lists by quality metric (e.g. PageRank) or by partial score
  - makes unsafe (and fast) optimizations more likely to retrieve good documents