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Ranking Models

Search Architecture

Rodrygo L. T. Santos
rodrygo@dcc.ufmg.br

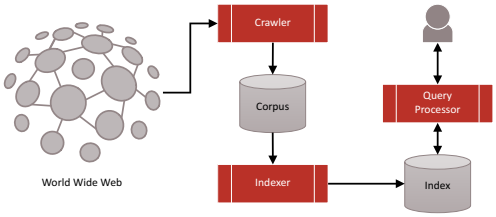
Search architecture

A software architecture consists of software components, the interfaces provided by those components, and the relationships between them

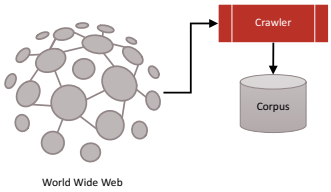
For search, we are concerned about

- Effectiveness (quality of results)
- Efficiency (response time and throughput)

Search components



Search components



Crawling overview

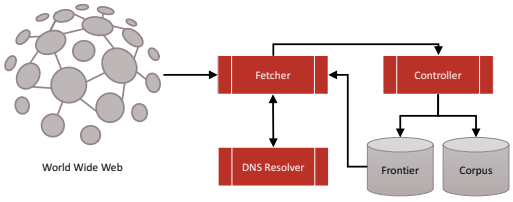
Document acquisition

- Builds a local corpus for searching
- Many types – Web, enterprise, desktop

Web crawlers follow links to find documents

- Must efficiently find huge numbers of web pages (coverage) and keep them up-to-date (freshness)

Crawling overview



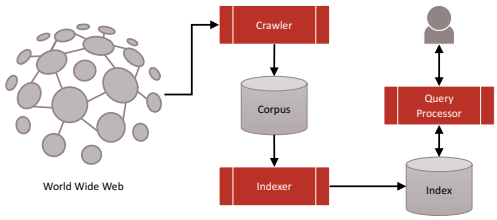
Key challenges

Web is huge and constantly changing
- Not under the control of search providers

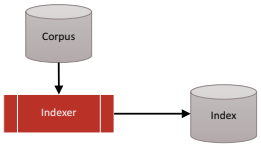
A lot of time is spent waiting for responses
- Parallel crawling is essential

Could potentially flood sites with requests
- To avoid this problem, use politeness policies

Search components



Search components



Indexing overview

Document representation
- From raw text to index terms
- Plus annotations (e.g., entities, categories)

Off-document evidence
- Anchor text, link analysis
- Social network signals

Document representation

Fred's Tropical Fish Shop is the best place to find tropical fish at low, low prices. Whether you're looking for a little fish or a big fish, we've got what you need. We even have fake seaweed for your fishtank (and little surfboards too).

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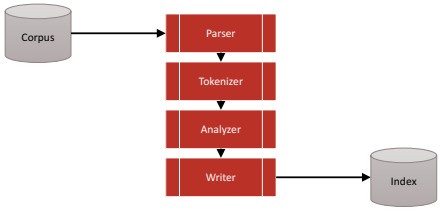
Topical features

9.7 fish
4.2 tropical
22.1 tropical fish
8.2 seaweed
4.2 surfboards

Quality features

14 incoming links
3 days since last update

Indexing overview



Key challenges

Support effective retrieval
- Extract meaningful document features
- Both topical and quality features

Support efficient retrieval
- Quick scoring of matched documents

Index structures

Indexes are designed to make search faster
- Unique requirements, unique data structures

Most common structure is the inverted index
- General name for a class of structures
- "Inverted" because documents are associated with words, rather than words with documents

Example "corpus"

d_1	Tropical fish include fish found in tropical environments around the world, including both freshwater and salt water species.
d_2	Fish keepers often use the term tropical fish to refer only those requiring fresh water, with saltwater tropical fish referred to as marine fish.
d_3	Tropical fish are popular aquarium fish, due to their often bright coloration.
d_4	In freshwater fish, this coloration typically derives from iridescence, while salt water fish are generally pigmented.

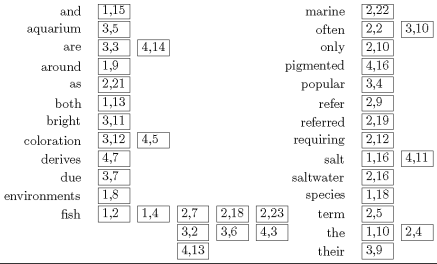
Inverted index: occurrences

and	1	only	2
aquarium	3	pigmented	4
are	3 4	popular	3
around	1	refer	2
as	2	referred	2
both	1	requiring	2
bright	3	salt	1 4
coloration	3 4	saltwater	2
derives	4	species	1
due	3	term	2
environments	1	the	1 2
fish	1 2 3 4	their	3
fishkeepers	2	this	4
found	1	those	2

Inverted index: counts

and	1:1	only	2:1
aquarium	3:1	pigmented	4:1
are	3:1 4:1	popular	3:1
around	1:1	refer	2:1
as	2:1	referred	2:1
both	1:1	requiring	2:1
bright	3:1	salt	1:1 4:1
coloration	3:1 4:1	saltwater	2:1
derives	4:1	species	1:1
due	3:1	term	2:1
environments	1:1	the	1:1 2:1
fish	1:2 2:3 3:2 4:2	their	3:1
fishkeepers	2:1	this	4:1
found	1:1	those	2:1

Inverted index: positions



Inverted index: fields

Document structure is useful in search
- Field restrictions (e.g., date, from:)
- Some fields more important (e.g., title, h1)

A couple of options
- Separate inverted lists for each field type
- Add information about fields to postings

Auxiliary structures

Vocabulary, dictionary, or lexicon
- Lookup table from term to inverted list
- Either hash table in memory or B-tree for disk

Additional structures for document data
- Basic statistics, static features, metadata

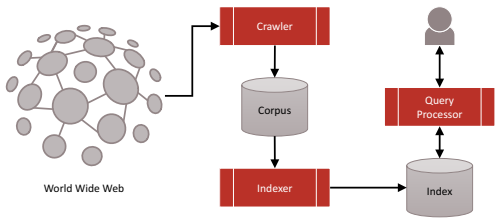
Additional structure for corpus statistics

Index compression

Inverted indexes are very large
- Typically 25-50% of corpus size
- Much higher if n-grams are indexed

Compression saves disk and/or memory space
- Typically have to decompress lists to use them
- Best techniques have good trade-offs

Search components



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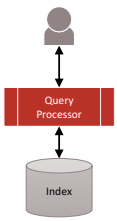


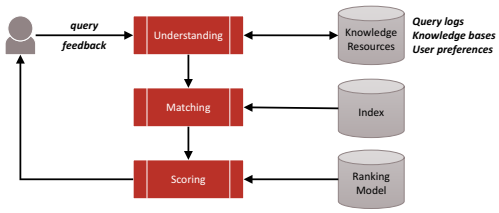
Query processing overview

Query representation
- Infers user's need from a keyword query

Document ranking
- Matches and scores indexed documents

Feedback handling
- Both explicit and implicit signals

Query processing overview



Key challenges

Queries are typically short, ill-specified
- Long queries tend to be difficult

Finding matching documents can be expensive
- Particularly for common terms or long queries

Ranking is a tough business
- Different queries, different requirements

Query understanding: expand matches

Query relaxation

[information about tropical fish]

↳ [tropical fish]

Query expansion

[tropical fish]

↳ [tropical fish aquarium]

Query understanding: narrow results

Query segmentation

[tropical fish captive breeding]

↳ [”tropical fish” AND ”captive breeding”]

Query scoping

[tropical fish hawaii]

↳ [category:”tropical fish” place:hawaii]

Document matching

Scan posting lists for all query terms

fish	1:2	2:3	3:2	4:2
tropical	1:2	2:2	3:1	

Score matching documents

$$f(q,d) = \sum_{t \in q} f(t,d)$$

Matching semantics

Disjunctive matching
- Documents must contain at least one query term
- More matches, lower precision

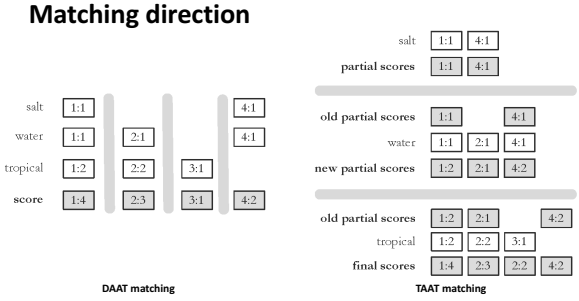
Conjunctive matching
- Documents must contain all query terms
- Fewer matches, higher precision

Matching direction

Document-at-a-time (DAAT)
- Inverted lists processed in parallel
- One document scored at a time

Term-at-a-time (TAAT)
- Inverted lists processed in sequence
- Partial document scores accumulated

Matching direction



Optimization techniques

No clear winner
- DAAT uses less memory (no accumulators)
- TAAT is more memory efficient (sequential access)

Both can be improved
- Read less data from inverted lists (skipping)
- Calculate scores for fewer documents (thresholding)

Other approaches

Unsafe early termination
- Ignore high-frequency word lists in TAAT
- Ignore documents at end of lists in DAAT

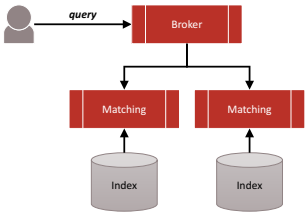
Can be improved with index tiering
- Postings ordered by quality (e.g., PageRank)
- Postings ordered by score (e.g., BM25)

Distributed matching

Indexes are often distributed in a cluster
- Too large to fit in one machine
- Replication helps load balancing

Two main approaches
- Document partitioning (most common)
- Term partitioning

Distributed matching



Distributed matching

Problem
- Ranking models typically leverage global statistics (e.g., number of documents where a term appears)
- Shards only have local statistics

Solution
- Share or approximate global statistics

Multi-stage ranking

Some ranking models can be expensive
- Infeasible to score billions of documents

Ranking as a multi-stage cascade
- Stage #1: Boolean matching (billions)
- Stage #2: Unsupervised scoring (millions)
- Stage #3: Supervised scoring (thousands)

Caching

Query distributions similar to Zipf
- About 15% of never seen queries each day
- Popular queries account for majority of traffic

Caching can significantly improve effectiveness
- For popular queries, cache search results
- For unpopular queries, cache inverted lists

References

Search Engines: Information Retrieval in Practice, Ch. 5
Croft et al., 2009

Scalability Challenges in Web Search Engines
Cambazoglu and Baeza-Yates, 2015

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Coming next…

Document Understanding

Rodrygo L. T. Santos
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