Modern Information Retrieval

Web cralwing and search

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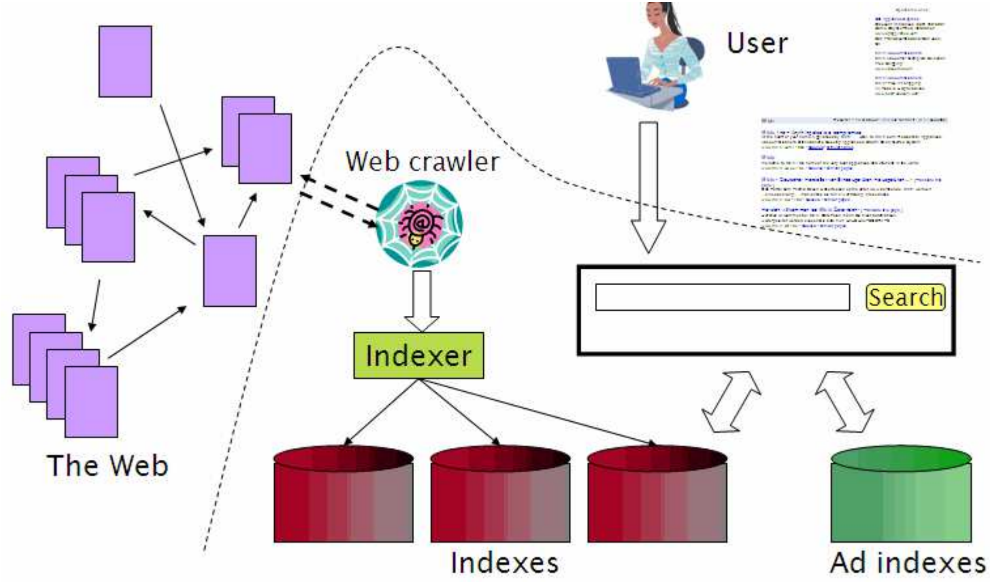
Introduction

Web Search


User
Web crawler
Search
Indexer
The Web
Indexes
Ad indexes

Web Search

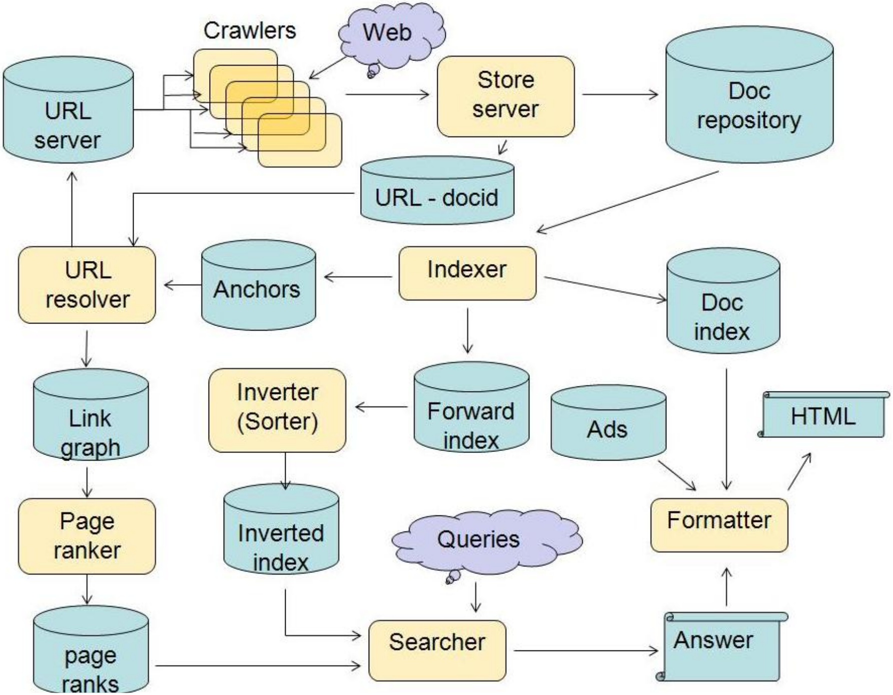
The World Wide Web is huge.

1. 100,000 indexed pages in1994.
2. 10,000,000,000's indexed pages in 2013.
3. 30 trillion pages in the Google Index in 2022 (100 million gigabytes).
4. Most queries will return millions of pages with high similarity.
5. Content(text) alone cannot discriminate.
6. Use the structure of the Web(a graph).
7. Gives indications of usefulness of each page.

Without web search engines

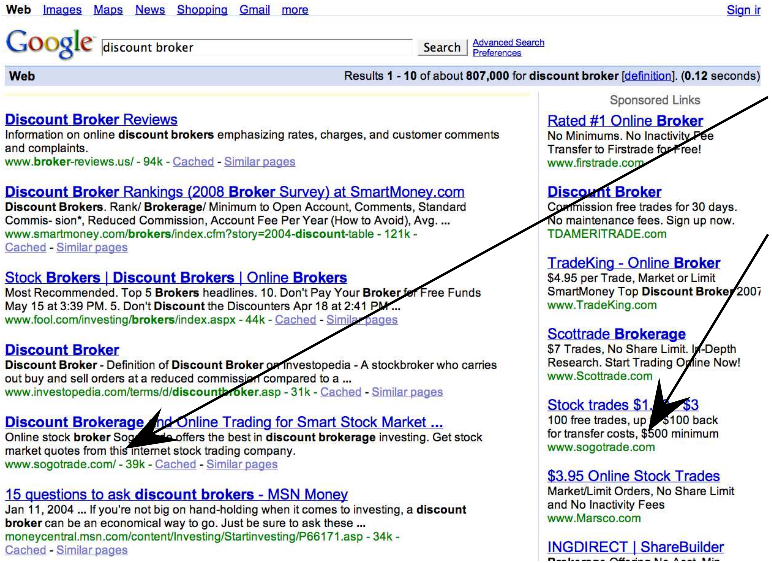
1. Without search, content is hard to find.
2. Without search, there is no incentive to create content.
    - Why publish something if nobody will read it?
    - Why publish something if I don't get ad revenue from it?
3. Somebody needs to pay for the web.
    - Servers, web infrastructure, content creation
    - A large part today is paid by search ads.
    - Search pays for the web.
4. On the web, search is not just a nice feature, search is a key enabler of the web.

Google (1998)


Crawlers
Web
URL server
Store server
Doc repository
URL - docid
URL resolver
Anchors
Indexer
Doc index
Link graph
Inverter (Sorter)
Forward index
Ads
HTML
Page ranker
Inverted index
Queries
Formatter
page ranks
Searcher
Answer

Results of a query

Web pages (left) and ads (right)



Web Results **1** - **10** of about **807,000** for **discount broker** [definition]. (**0.12** seconds)

Discount Broker Reviews
Information on online **discount brokers** emphasizing rates, charges, and customer comments and complaints.
www.**broker**-reviews.us/ - 94k - Cached - Similar pages

Discount Broker Rankings (2008 **Broker** Survey) at SmartMoney.com
Discount Brokers. Rank/ **Brokerage**/ Minimum to Open Account, Comments, Standard Commis- sion*, Reduced Commission, Account Fee Per Year (How to Avoid), Avg. **...**
www.smartmoney.com/**brokers**/index.cfm?story=2004-**discount**-table - 121k - Cached - Similar pages

Stock **Brokers** | **Discount Brokers** | Online **Brokers**
Most Recommended. Top 5 **Brokers** headlines. 10. Don't Pay Your **Broker** for Free Funds May 15 at 3:39 PM. 5. Don't **Discount** the Discounters Apr 18 at 2:41 PM **...**
www.fool.com/investing/**brokers**/index.aspx - 44k - Cached - Similar pages

Discount Broker
Discount Broker - Definition of **Discount Broker** on Investopedia - A stockbroker who carries out buy and sell orders at a reduced commission compared to a **...**
www.investopedia.com/terms/d/**discountbroker**.asp - 31k - Cached - Similar pages

Discount Brokerage and Online Trading for Smart Stock Market **...**
Online stock **broker** SogoTrade offers the best in **discount brokerage** investing. Get stock market quotes from this internet stock trading company.
www.sogotrade.com/ - 39k - Cached - Similar pages

15 questions to ask **discount brokers** - MSN Money
Jan 11, 2004 **...** If you're not big on hand-holding when it comes to investing, a **discount broker** can be an economical way to go. Just be sure to ask these **...**
moneycentral.msn.com/content/Investing/Startinvesting/P66171.asp - 34k - Cached - Similar pages

Sponsored Links

Rated #1 Online **Broker**
No Minimums. No Inactivity Fee Transfer to Firstrade for Free!
www.firstrade.com

Discount Broker
Commission free trades for 30 days. No maintenance fees. Sign up now.
TDAMERITRADE.com

TradeKing - Online **Broker**
$4.95 per Trade, Market or Limit SmartMoney Top **Discount Broker** 2007
www.TradeKing.com

Scottrade **Brokerage**
$7 Trades, No Share Limit. In-Depth Research. Start Trading Online Now!
www.Scottrade.com

Stock trades $1.[illegible] $3
100 free trades, up to $100 back for transfer costs, $500 minimum
www.sogotrade.com

$3.95 Online Stock Trades
Market/Limit Orders, No Share Limit and No Inactivity Fees
www.Marsco.com

INGDIRECT | ShareBuilder

SogoTrade appears in search results.

SogoTrade appears in ads.

Do search engines rank advertisers higher than non-advertisers?

All major search engines claim no.

Duplicate detection

Duplicate detection

1. The web is full of duplicated content (30%–40%).
2. More so than many other collections
3. Exact duplicates (easy to eliminate by using hash/fingerprint)
4. Near-duplicates (difficult to eliminate)
5. For the user, it's annoying to get a search result with near-identical documents.
6. We need to eliminate near-duplicates.

Detecting near-duplicates

1. Computing similarity with an edit-distance measure
2. We want syntactic (as opposed to semantic) similarity.

   True semantic similarity (similarity in content) is too difficult to compute.
3. We do not consider documents near-duplicates if they have the same content, but express it with different words.
4. Use similarity threshold θ to make the call is/isn't a near-duplicate.

   For example, two documents are near-duplicates if similarity $> \theta = 80\%$.

Represent each document as set of shingles

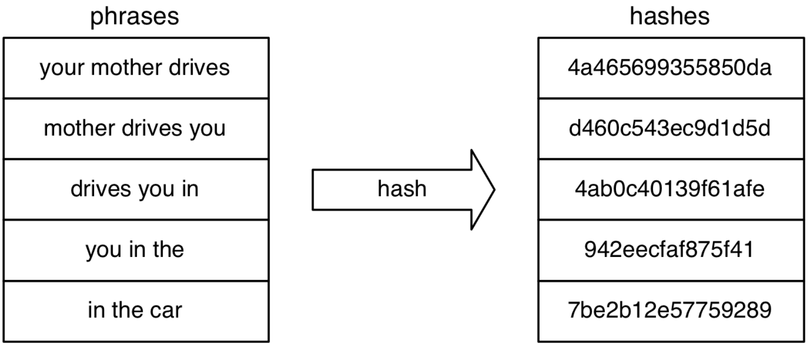
- A shingle is simply a word n-gram.
- Shingles are used as features to measure syntactic similarity of documents.
- For example, for $n = 3$, a rose is a rose is a rose would be represented as this set of shingles:

  { a-rose-is, rose-is-a, is-a-rose }
- Let U be a set and A and B be subsets of U, then the Jaccard coefficient is defined as

$$J(A, B) = \frac{|A \cap B|}{|A \cup B|}$$

- Computing the Jaccard coefficient for two documents needs high computation time.
- We define the similarity of two documents as the Jaccard coefficient of their shingle sets.
- To avoid this, we use a form of hashing.
- We map every shingle into a hash value over large space (for example 64-bits).

Detecting near-duplicates (Hashing)



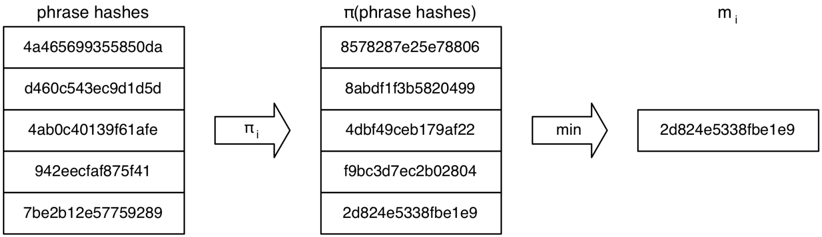
phrases	hashes
your mother drives	4a465699355850da
mother drives you	d460c543ec9d1d5d
drives you in	4ab0c40139f61afe
you in the	942eecfaf875f41
in the car	7be2b12e57759289

hash

This needs long time to compute, because it needs to hash all shingles.

MinHash

1. MinHash uses constant storage independent of the document length and producing a good estimate of our similarity measure.
2. This approach maps each document to a fixed-size set of hashes as a rough signature of this document.
3. This is accomplished by using a set of k randomizing hash functions.
4. For each randomizing hash function π_i, we pass the entire document's phrase hashes through to get a minimum hash denoted m_i.



phrase hashes

4a465699355850da

d460c543ec9d1d5d

4ab0c40139f61afe

942eecfaf875f41

7be2b12e57759289

π_i

π(phrase hashes)

8578287e25e78806

8abdf1f3b5820499

4dbf49ceb179af22

f9bc3d7ec2b02804

2d824e5338fbe1e9

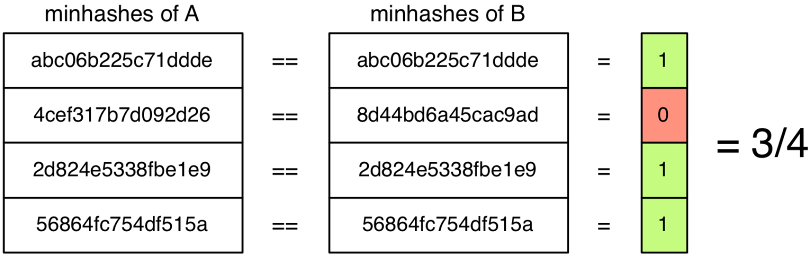
min

m_i

2d824e5338fbe1e9

MinHash

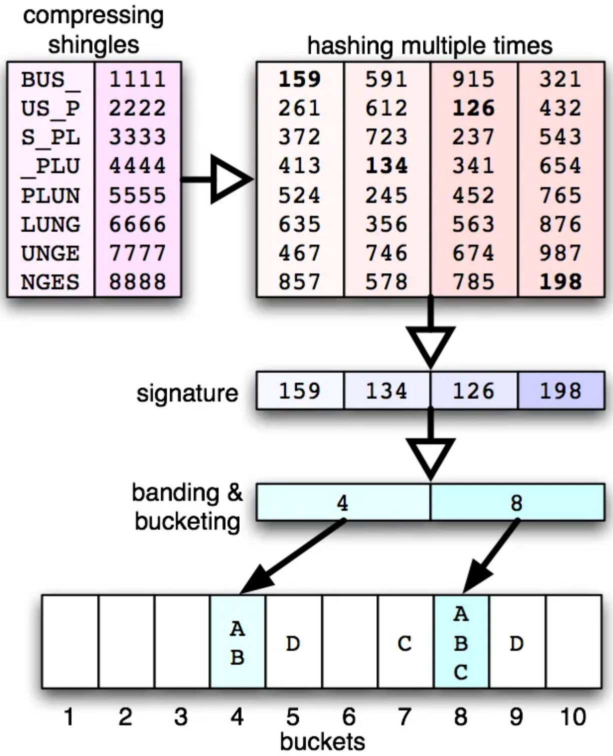
1. The signature of the document is now the ordered list of these minimum hashes m_0 through m_{k-1}.
2. This method achieves an approximation to Jaccard similarity (the given probability).



minhashes of A		minhashes of B		
abc06b225c71ddde	==	abc06b225c71ddde	=	🟩 1
4cef317b7d092d26	==	8d44bd6a45cac9ad	=	🟥 0
2d824e5338fbe1e9	==	2d824e5338fbe1e9	=	🟩 1
56864fc754df515a	==	56864fc754df515a	=	🟩 1

= 3/4

MinHash



compressing shingles

BUS_	1111
US_P	2222
S_PL	3333
_PLU	4444
PLUN	5555
LUNG	6666
UNGE	7777
NGES	8888

hashing multiple times

159	591	915	321
261	612	**126**	432
372	723	237	543
413	**134**	341	654
524	245	452	765
635	356	563	876
467	746	674	987
857	578	785	**198**

signature

159	134	126	198

banding & bucketing

4	8

1	2	3	4	5	6	7	8	9	10
			A B	D		C	A B C	D	

buckets

Spam pages

The goal of spamming on the web

1. You have a page that will generate lots of revenue for you if people visit it.
2. Therefore, you would like to direct visitors to this page.
3. One way of doing this: get your page ranked highly in search results.

Spam technique: Keyword stuffing / Hidden text

1. Misleading meta-tags, excessive repetition
2. Hidden text with colors, style sheet tricks etc.
3. Used to be very effective, most search engines now catch these

Spam technique: Doorway and lander pages

Doorway page optimized for a single keyword, redirects to the real target page.

Lander page optimized for a single keyword or a misspelled domain name, designed to attract surfers who will then click on ads.

Spam technique: Duplication

1. Get good content from somewhere (steal it or produce it yourself)
2. Publish a large number of slight variations of it
3. For example, publish the answer to a tax question with the spelling variations of “tax deferred” on the previous slide

Spam technique: Link spam

1. Create lots of links pointing to the page you want to promote
2. Put these links on pages with high (or at least non-zero) PageRank
    - Newly registered domains (domain flooding)
    - A set of pages that all point to each other to boost each other's PageRank
    - Pay somebody to put your link on their highly ranked page
    - Leave comments that include the link on blogs

SEO: Search engine optimization

1. Promoting a page in the search rankings is not necessarily spam.
2. It can also be a legitimate business – which is called SEO.
3. You can hire an SEO firm to get your page highly ranked.
4. There are many legitimate reasons for doing this.
   - For example, Google bombs like *Who is a failure?*
5. And there are many legitimate ways of achieving this:
   - Restructure your content in a way that makes it easy to index
   - Talk with influential bloggers and have them link to your site
   - Add more interesting and original content

The war against spam

1. Quality indicators
    - Links, statistically analyzed (PageRank etc)
    - Usage (users visiting a page)
    - No adult content (e.g., no pictures with flesh-tone)
    - Distribution and structure of text
2. Combine all of these indicators and use machine learning
3. Editorial intervention
    - Blacklists
    - Top queries audited
    - Complaints addressed
    - Suspect patterns detected

Web IR

Web IR: Differences from traditional IR

Links The web is a hyperlinked document collection.

Queries Web queries are different, more varied and there are a lot of them. How many?

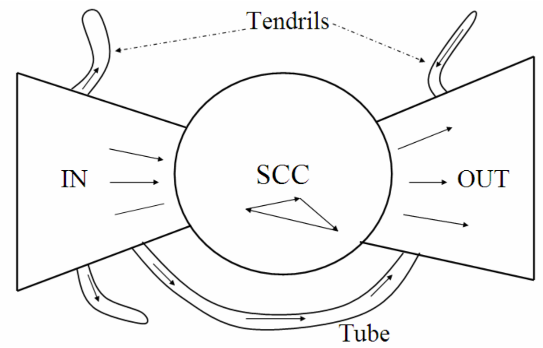
Users Users are different, more varied and there are a lot of them. How many?

Documents Documents are different, more varied and there are a lot of them. How many?

Context Context is more important on the web than in many other IR applications.

Ads and spam

Bowtie structure of the web



1. Strongly connected component (SCC) in the center
2. Lots of pages that get linked to, but don't link (OUT)
3. Lots of pages that link to other pages, but don't get linked to (IN)
4. Tendrils, tubes, islands

How do users evaluate search engines?

1. Classic IR relevance (as measured by F) can also be used for web IR.
2. Equally important: Trust, duplicate elimination, readability, loads fast, no pop-ups
3. On the web, precision is more important than recall.
    - Precision at 1, precision at 10, precision on the first 2-3 pages
    - But there is a subset of queries where recall matters.

Search in a hyperlinked collection

- Web search in most cases is interleaved with navigation (with following links).
- Different from most other IR collections
- Distributed content creation: no design, no coordination
- Unstructured (text, html), semistructured (html, xml), structured/relational (databases)
- Dynamically generated content

Size of the web

Size of the web

1. What is size? Number of web servers? Number of pages? Terabytes of data available?
2. Some servers are seldom connected (such as your laptop running a web server)
3. The dynamic web is infinite.

Sampling methods

1. Random queries
2. Random searches
3. Random IP addresses
4. Random walks

Variant: Estimate relative sizes of indexes

1. There are significant differences between indexes of different search engines (max url depth, max count/host, anti-spam rules, priority rules etc.).
2. Different engines have different preferences.
3. Different engines index different things under the same URL (anchor text, frames, meta-keywords, size of prefix etc.).

Sampling URLs

- Generate a random URL
- Problem: Random URLs are hard to find (and sampling distribution should reflect user interest)
- Approach 1: Random walks / IP addresses : In theory: might give us a true estimate of the size of the web (as opposed to just relative sizes of index)
- Approach 2: Generate a random URL contained in a given engine: Suffices for accurate estimation of relative size

Random URLs from random queries

- Use vocabulary of the web for query generation
- Vocabulary can be generated from web crawl
- Use conjunctive queries w_1 AND w_2 (such as vocalists AND rsi)
- Get result set of one hundred URLs from the source engine
- Choose a random URL from the result set
- This sampling method induces a weight $W(p)$ for each page p.

Checking if a page is in the index

1. Search for URL if the engine supports this or create a query that will find doc *d* with high probability.
    - Download doc, extract words
    - Use 8 low frequency word as AND query
    - Call this a strong query for *d*
    - Run query
    - Check if *d* is in result set
2. Problems
    - Near duplicates
    - Redirects
    - Engine time-outs

Random searches

- Choose random searches extracted from a search engine log.
- Use only queries with small result sets.
- For each random query: compute ratio size(r_1)/size(r_2) of the two result sets
- Average over random searches

Summary

1. Many different approaches to web size estimation.
2. None is perfect.
3. The problem has gotten much harder.
4. There hasn't been a good study for a couple of years.
5. Great topic for a thesis!

Web crawler

Basic crawler operation

1. Initialize queue with URLs of known seed pages
2. Repeat
    - Take URL from queue
    - Fetch and parse page
    - Extract URLs from page
    - Add URLs to queue
3. Fundamental assumption: The web is well linked.

What's wrong with the simple crawler

1. Scale: we need to distribute.
2. We can't index everything: we need to subselect. How?
3. Duplicates: need to integrate duplicate detection
4. Spam: need to integrate spam detection
5. Politeness: Web servers have policies (implicit/explicit) for regulating the rate at which a crawler can visit them. These policies must be respected.
6. Freshness: we need to recrawl periodically.
    - Because of the size of the web, we can do frequent recrawls only for a small subset.
    - Again, subselection problem or prioritization

What a crawler must do?

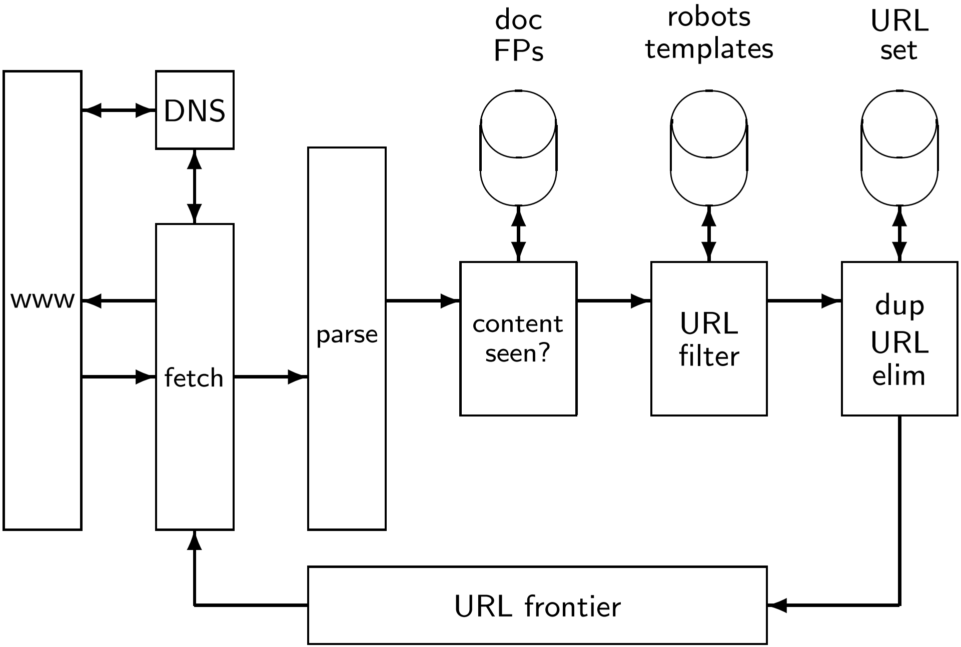
1. Be polite
    - Don’t hit a site too often
    - Only crawl pages you are allowed to crawl: robots.txt
2. Be robust
    - Be immune to duplicates, very large pages, very large websites, dynamic pages etc

Robots.txt

1. Protocol for giving crawlers ("robots") limited access to a website, originally from 1994
2. Examples:
    - User-agent: *
      Disallow: /yoursite/temp/
    - User-agent: searchengine
      Disallow:
3. Important: cache the robots.txt file of each site we are crawling

A real crawler

Basic crawl architecture


doc FPs
robots templates
URL set
DNS
www
fetch
parse
content seen?
URL filter
dup URL elim
URL frontier

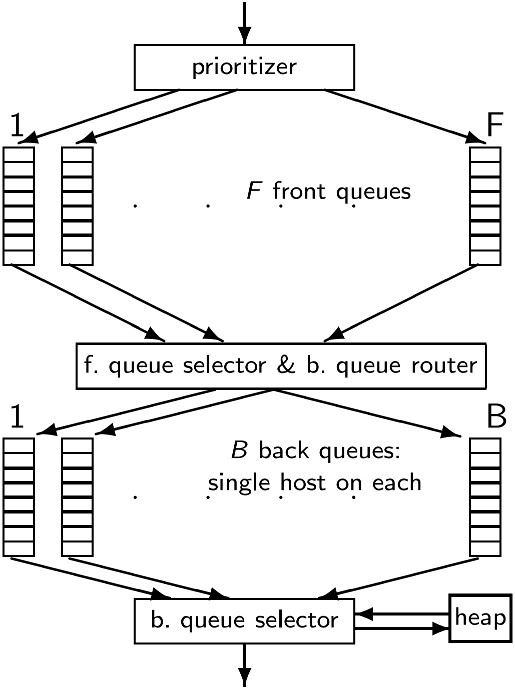
URL frontier

- The URL frontier is the data structure that holds and manages URLs we've seen, but that have not been crawled yet.
- Can include multiple pages from the same host
- Must avoid trying to fetch them all at the same time
- Must keep all crawling threads busy

URL frontier: Two main considerations

- Politeness: Don't hit a web server too frequently
    - E.g., insert a time gap between successive requests to the same server
- Freshness: Crawl some pages (e.g., news sites) more often than others
- Not an easy problem: simple priority queue fails.

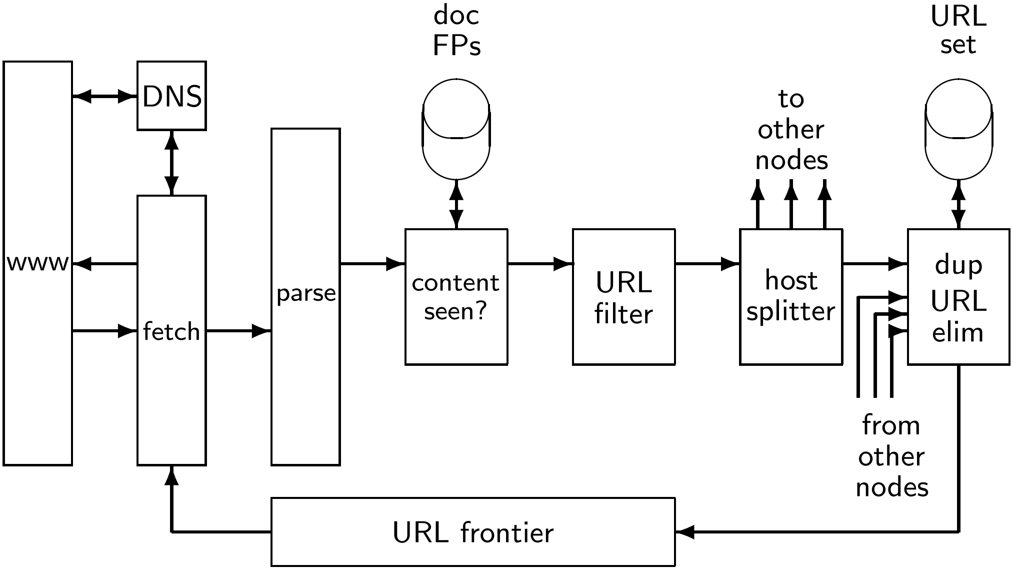
URL frontier


prioritizer
1
F
F front queues
f. queue selector & b. queue router
1
B
B back queues:
single host on each
b. queue selector
heap

Distributing the crawler

1. Run multiple crawl threads, potentially at different nodes
2. Usually geographically distributed nodes
3. Partition hosts being crawled into nodes

Distributed crawl architecture


doc
FPs
URL
set
to
other
nodes
www
DNS
fetch
parse
content
seen?
URL
filter
host
splitter
dup
URL
elim
from
other
nodes
URL frontier

References

Reading

1. Chapters 19 and 20 of Introduction to Information Retrieval[1]
2. Chapter 3 of Search Engines - Information Retrieval in Practice Book[2].

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[1] Christopher D. Manning, Prabhakar Raghavan, and Hinrich Schütze (2008). *Introduction to Information Retrieval*. New York, NY, USA: Cambridge University Press.

[2] W. Bruce Croft, Donald Metzler, and Trevor Strohman (2009). *Search Engines - Information Retrieval in Practice*. Pearson Education.

References

- Croft, W. Bruce, Donald Metzler, and Trevor Strohman (2009). *Search Engines - Information Retrieval in Practice*. Pearson Education.
- Manning, Christopher D., Prabhakar Raghavan, and Hinrich Schütze (2008). *Introduction to Information Retrieval*. New York, NY, USA: Cambridge University Press.

Questions?