Introduction to Information Retrieval
http://informationretrieval.org

IIR 20: Crawling

Hinrich Schütze

Institute for Natural Language Processing, Universität Stuttgart

2008.07.08

Magnitude of the crawling problem

- To fetch 1,000,000,000 pages in one month . . .

Magnitude of the crawling problem

- To fetch 1,000,000,000 pages in one month . . .
- . . . we need to fetch almost 400 pages per second!

Magnitude of the crawling problem

- To fetch 1,000,000,000 pages in one month . . .
- . . . we need to fetch almost 400 pages per second!
- Actually: many more since many of the pages we attempt to crawl will be duplicates, unfetchable, spam etc.

Basic crawler operation

- Initialize queue with URLs of known seed pages

Basic crawler operation

- Initialize queue with URLs of known seed pages
- Repeat

Basic crawler operation

- Initialize queue with URLs of known seed pages
- Repeat
  - Take URL from queue

Basic crawler operation

- Initialize queue with URLs of known seed pages
- Repeat
  - Take URL from queue
  - Fetch and parse page

Basic crawler operation

- Initialize queue with URLs of known seed pages
- Repeat
  - Take URL from queue
  - Fetch and parse page
  - Extract URLs from page

Basic crawler operation

- Initialize queue with URLs of known seed pages
- Repeat
  - Take URL from queue
  - Fetch and parse page
  - Extract URLs from page
  - Add URLs to queue

Basic crawler operation

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

Complications in crawling

- We need many machines – how do we distribute?

Complications in crawling

- We need many machines – how do we distribute?
- Latency/bandwidth

Complications in crawling

- We need many machines – how do we distribute?
- Latency/bandwidth
- How deep should we crawl sites?

Complications in crawling

- We need many machines – how do we distribute?
- Latency/bandwidth
- How deep should we crawl sites?
- Duplicates

Complications in crawling

- We need many machines – how do we distribute?
- Latency/bandwidth
- How deep should we crawl sites?
- Duplicates
- Spam and spider traps

Complications in crawling

- We need many machines – how do we distribute?
- Latency/bandwidth
- How deep should we crawl sites?
- Duplicates
- Spam and spider traps
- Politeness – don't hit a server too often

Spider trap

- Malicious server that generates an infinite sequence of linked pages

Spider trap

- Malicious server that generates an infinite sequence of linked pages
- Sophisticated spider traps generate pages that are not easily identified as dynamic.

What a crawler must do

- Be polite

What a crawler must do

- Be polite
  - Don't hit a each site too often

What a crawler must do

- Be polite
  - Don’t hit a each site too often
  - Only crawl pages you are allowed to crawl: robots.txt

What a crawler must do

- Be polite
  - Don't hit a each site too often
  - Only crawl pages you are allowed to crawl: robots.txt
- Be robust

What a crawler must do

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

Robots.txt

- Protocol for giving crawlers ("robots") limited access to a website, originally from 1994

Robots.txt

- Protocol for giving crawlers ("robots") limited access to a website, originally from 1994
- Examples:

Robots.txt

- Protocol for giving crawlers ("robots") limited access to a website, originally from 1994
- Examples:
  - User-agent: *
    Disallow: /yoursite/temp/

Robots.txt

- Protocol for giving crawlers ("robots") limited access to a website, originally from 1994
- Examples:
  - User-agent: *
    Disallow: /yoursite/temp/
  - User-agent: searchengine
    Disallow:

Robots.txt

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

What any crawler should do

- Be capable of distributed operation

What any crawler should do

- Be capable of distributed operation
- Be scalable: need to be able to increase crawl rate by adding more machines

What any crawler should do

- Be capable of distributed operation
- Be scalable: need to be able to increase crawl rate by adding more machines
- Fetch pages of higher quality first

What any crawler should do

- Be capable of distributed operation
- Be scalable: need to be able to increase crawl rate by adding more machines
- Fetch pages of higher quality first
- Continuous operation: get fresh version of already crawled pages

URL frontier

URL frontier

- Can include multiple pages from the same host

URL frontier

- Can include multiple pages from the same host
- Must avoid trying to fetch them all at the same time

URL frontier

- 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

Processing steps in crawling

- Pick a URL from the frontier

Processing steps in crawling

- Pick a URL from the frontier
- Fetch the document at the URL

Processing steps in crawling

- Pick a URL from the frontier
- Fetch the document at the URL
- Check if the document has content already seen (if yes: skip following steps)

Processing steps in crawling

- Pick a URL from the frontier
- Fetch the document at the URL
- Check if the document has content already seen (if yes: skip following steps)
- Index document

Processing steps in crawling

- Pick a URL from the frontier
- Fetch the document at the URL
- Check if the document has content already seen (if yes: skip following steps)
- Index document
- Parse the document and extract URLs to other docs

Processing steps in crawling

- Pick a URL from the frontier
- Fetch the document at the URL
- Check if the document has content already seen (if yes: skip following steps)
- Index document
- Parse the document and extract URLs to other docs
- For each extracted URL:

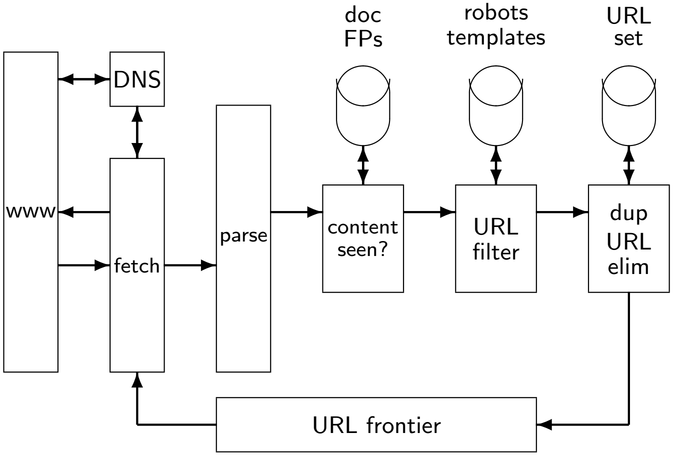
Processing steps in crawling

- Pick a URL from the frontier
- Fetch the document at the URL
- Check if the document has content already seen (if yes: skip following steps)
- Index document
- Parse the document and extract URLs to other docs
- For each extracted URL:
  - Does it fail certain tests (e.g., spam)? Yes: skip

Processing steps in crawling

- Pick a URL from the frontier
- Fetch the document at the URL
- Check if the document has content already seen (if yes: skip following steps)
- Index document
- Parse the document and extract URLs to other docs
- For each extracted URL:
  - Does it fail certain tests (e.g., spam)? Yes: skip
  - Already in the frontier? Yes: skip

Basic crawl architecture



URL normalization

- Some URLs extracted from a document are relative URLs.

URL normalization

- Some URLs extracted from a document are relative URLs.
- E.g., at http://mit.edu, we may have /aboutsite.html

URL normalization

- Some URLs extracted from a document are relative URLs.
- E.g., at http://mit.edu, we may have /aboutsite.html
  - This is the same as: http://mit.edu/aboutsite.html

URL normalization

- Some URLs extracted from a document are relative URLs.
- E.g., at http://mit.edu, we may have /aboutsite.html
  - This is the same as: http://mit.edu/aboutsite.html
- During parsing, we must normalize (expand) all relative URLs.

Content seen

- For each page fetched: check if the content is already in the index

Content seen

- For each page fetched: check if the content is already in the index
- Check this using document fingerprints or shingles

Content seen

- For each page fetched: check if the content is already in the index
- Check this using document fingerprints or shingles
- Skip documents whose content has already been indexed

Distributing the crawler

- Run multiple crawl threads, potentially at different nodes

Distributing the crawler

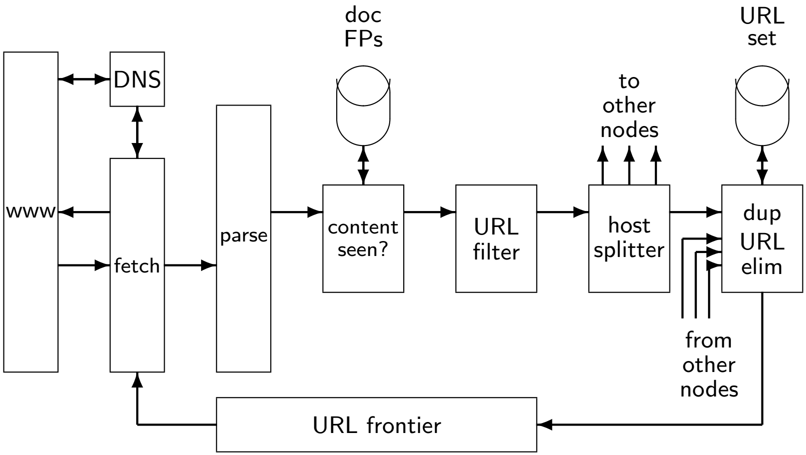
- Run multiple crawl threads, potentially at different nodes
  - Usually geographically distributed nodes

Distributing the crawler

- Run multiple crawl threads, potentially at different nodes
  - Usually geographically distributed nodes
- Partition hosts being crawled into nodes

Google data centers:
http://www.wayfaring.com/maps/show/48030

Distributed crawler



URL frontier: Two main considerations

- Politeness: Don't hit a web server too frequently

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

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

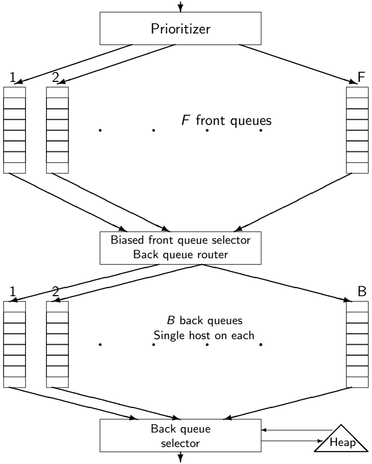
URL frontier: Two main considerations

- 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.

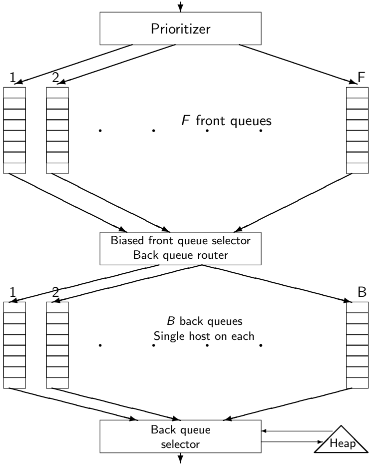
URL frontier: Two main considerations

- 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.
- Why?

Mercator URL frontier

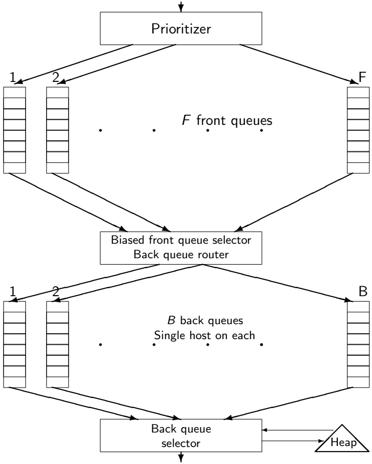


Mercator URL frontier



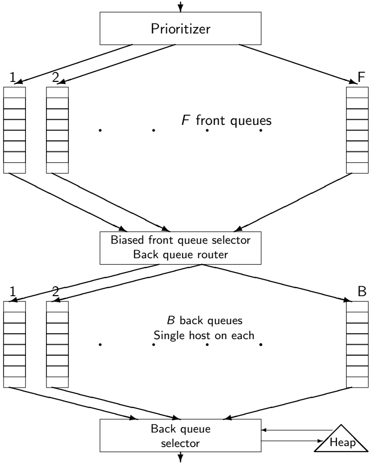
- URLs flow in from the top into the frontier.

Mercator URL frontier



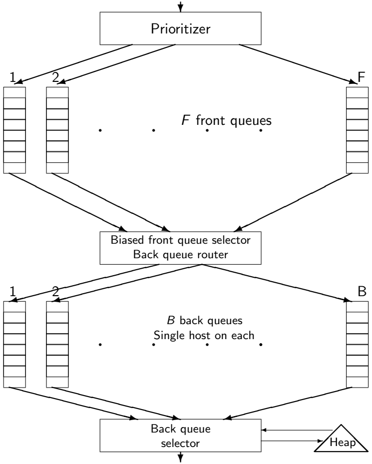
- URLs flow in from the top into the frontier.
- Front queues manage prioritization.

Mercator URL frontier



- URLs flow in from the top into the frontier.
- Front queues manage prioritization.
- Back queues enforce politness.

Mercator URL frontier



- URLs flow in from the top into the frontier.
- Front queues manage prioritization.
- Back queues enforce politness.
- Each queue is FIFO.

Front queues

- Prioritizer assigns to URL an integer priority between 1 and K.

Front queues

- Prioritizer assigns to URL an integer priority between 1 and K.
- Then appends URL to corresponding queue

Front queues

- Prioritizer assigns to URL an integer priority between 1 and K.
- Then appends URL to corresponding queue
- Heuristics for assigning priority: refresh rate, PageRank etc

Biased front queue selector

- Selection from front queues is initiated by back queues (see below)

Biased front queue selector

- Selection from front queues is initiated by back queues (see below)
- Pick a front queue from which to select next URL

Biased front queue selector

- Selection from front queues is initiated by back queues (see below)
- Pick a front queue from which to select next URL
  - Round robin

Biased front queue selector

- Selection from front queues is initiated by back queues (see below)
- Pick a front queue from which to select next URL
  - Round robin
  - Randomly

Biased front queue selector

- Selection from front queues is initiated by back queues (see below)
- Pick a front queue from which to select next URL
    - Round robin
    - Randomly
    - Or more sophisticated variant

Biased front queue selector

- Selection from front queues is initiated by back queues (see below)
- Pick a front queue from which to select next URL
  - Round robin
  - Randomly
  - Or more sophisticated variant
  - But with a bias in favor of high-priority front queues

Back queue invariants

- Each back queue is kept non-empty while the crawl is in progress.

Back queue invariants

- Each back queue is kept non-empty while the crawl is in progress.
- Each back queue only contains URLs from a single host.

Back queue invariants

- Each back queue is kept non-empty while the crawl is in progress.
- Each back queue only contains URLs from a single host.
- Maintain a table from hosts to back queues.

Back queue heap

- One entry for each back queue

Back queue heap

- One entry for each back queue
- The entry is the earliest time t_e at which the host corresponding to the back queue can be hit again.

Back queue heap

- One entry for each back queue
- The entry is the earliest time t_e at which the host corresponding to the back queue can be hit again.
- This earliest time is determined by (i) last access to that host (ii) time gap heuristic

How a crawler thread interacts with back queue

- Extract the root of the back queue heap

How a crawler thread interacts with back queue

- Extract the root of the back queue heap
- Fetch the URL at head of corresponding back queue q

How a crawler thread interacts with back queue

- Extract the root of the back queue heap
- Fetch the URL at head of corresponding back queue q
- Check if q is now empty

How a crawler thread interacts with back queue

- Extract the root of the back queue heap
- Fetch the URL at head of corresponding back queue q
- Check if q is now empty
- If yes: keep (i) pulling URLs from the front queues and (ii) adding them to their corresponding back queues until ...

How a crawler thread interacts with back queue

- Extract the root of the back queue heap
- Fetch the URL at head of corresponding back queue q
- Check if q is now empty
- If yes: keep (i) pulling URLs from the front queues and (ii) adding them to their corresponding back queues until ...
- ... the URL's host does not have a back queue – then put the URL in q and create heap entry for it.

Resources

- Chapter 20 of IIR

Resources

- Chapter 20 of IIR
- Resources at `http://ifnlp.org/ir`

Resources

- Chapter 20 of IIR
- Resources at `http://ifnlp.org/ir`
- Paper on Mercator by Heydon et al.

Resources

- Chapter 20 of IIR
- Resources at `http://ifnlp.org/ir`
- Paper on Mercator by Heydon et al.
- Robot exclusion standard