COMP5425

MULTIMEDIA RETRIEVAL

THE UNIVERSITY OF SYDNEY

Week03 Semester 1, 2014

Web Search

- □ Web Information Retrieval
  - The Web
  - Crawling
  - Ranking: PageRank & HITS

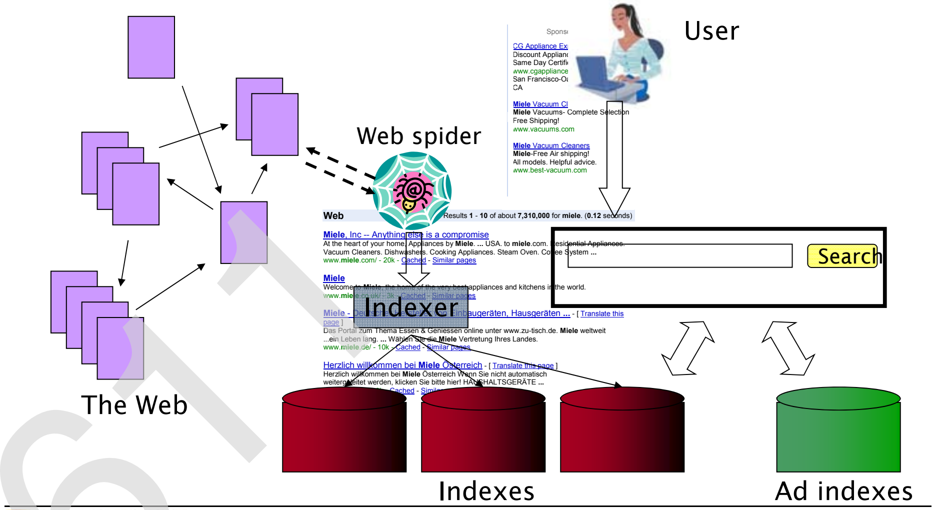
Web Search

- □ Historically, IR was mainly motivated by text search (libraries, etc.). Today: Various other areas and data, e.g. multi media (images, video, etc.), WWW, etc.
- □ Web search: perfect example for an IR system
  - Goal: Find best possible results (web pages) based on
a) Unstructured, heterogeneous, semistructured data
b) Imprecise, ambiguous, short queries
  - Note: ‘Best possible results‘ is also a very vague specification of the ultimate goal
  - But: Very different from traditional IR tasks!

Web Search

- □ Web search is an active research area with high economical impact
- □ Many open questions & challenges for research
  - ◘ Improving existing systems
  - ◘ adapting to new scenarios (more data, spam, …)
  - ◘ new challenges (diverse data formats, multimedia, …),
  - ◘ new tasks (desktop search, personalization, …), etc.
- □ Many other approaches & techniques exist, e.g.
  - ◘ Clustering
  - ◘ Specialized search engines, meta search engines, etc.

Web search basics



Sponsored

CG Appliance Ex
Discount Applianc
Same Day Certifi
www.cgappliance
San Francisco-Oa
CA

Miele Vacuum Cl
Miele Vacuums- Complete Selection
Free Shipping!
www.vacuums.com

Miele Vacuum Cleaners
Miele-Free Air shipping!
All models. Helpful advice.
www.best-vacuum.com

Web Results 1 - 10 of about 7,310,000 for miele. (0.12 seconds)

Miele, Inc -- Anything else is a compromise
At the heart of your home, Appliances by Miele. ... USA. to miele.com. Residential Appliances. Vacuum Cleaners. Dishwashers. Cooking Appliances. Steam Oven. Coffee System ...
www.miele.com/ - 20k - Cached - Similar pages

Miele
Welcome to Miele, the home of the very best appliances and kitchens in the world.
www.miele.co.uk/ - 3k - Cached - Similar pages

Miele - Deutsche Hersteller von Einbaugeräten, Hausgeräten ... - [Translate this page]
Das Portal zum Thema Essen & Geniessen online unter www.zu-tisch.de. Miele weltweit ...ein Leben lang. ... Wählen Sie die Miele Vertretung Ihres Landes.
www.miele.de/ - 10k - Cached - Similar pages

Herzlich willkommen bei Miele Österreich - [Translate this page]
Herzlich willkommen bei Miele Österreich Wenn Sie nicht automatisch weitergeleitet werden, klicken Sie bitte hier! HAUSHALTSGERÄTE ...
Cached - Similar

Characteristics of the Web

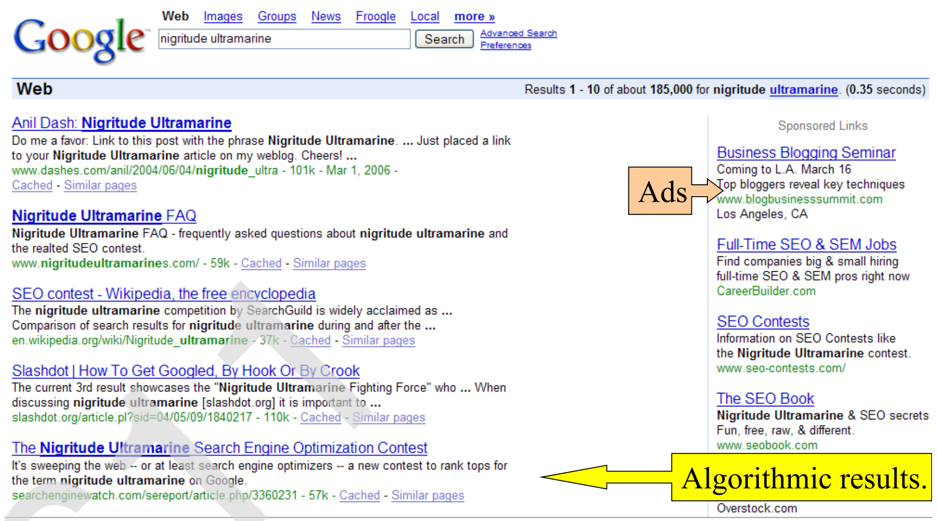
- □ Size: The web is huge! An there are lots of users!
- □ Documents
  - ◘ Extreme variety regarding formats, structure, quality, content (duplicate/near-duplicate) etc.
- □ Users: Very different skills & intensions, e.g.
  - ◘ *Find all information about related patents*
  - ◘ *Find some good tourist inform. about Paris*
  - ◘ *Find the phone no. of the tourist office*
- □ Space: The web is a distributed system
- □ Spam: Expect manipulation instead of cooperation from the document providers
- □ Dynamic: The web keeps growing & changing

Brief (non-technical) History

- □ Early keyword-based engines
  - ◘ Altavista, Excite, Infoseek, Inktomi, 1995-1997
  - ◘ Extension of traditional IR
- □ Sponsored search ranking: Goto.com (morphed into Overture.com → Yahoo!)
  - ◘ Your search ranking depended on how much you paid
  - ◘ Auction for keywords: ***casino*** was expensive!

Brief (non-technical) History

- 1998+: Link-based ranking pioneered by Google
  - Blew away all early engines
  - Great user experience in search of a business model
  - Meanwhile Goto/Overture's annual revenues were nearing $1 billion
- Result: Google added paid-placement "ads" to the side, independent of search results
  - Yahoo followed suit, acquiring Overture (for paid placement) and Inktomi (for search)
- HITS introduced by Kleinberg was used by Teoma



Google

Web Results **1** - **10** of about **185,000** for **nigritude** ultramarine. (**0.35** seconds)

Anil Dash: **Nigritude Ultramarine**
Do me a favor: Link to this post with the phrase **Nigritude Ultramarine**. ... Just placed a link to your **Nigritude Ultramarine** article on my weblog. Cheers! ...
www.dashes.com/anil/2004/06/04/**nigritude**_ultra - 101k - Mar 1, 2006 -
Cached - Similar pages

Nigritude Ultramarine FAQ
Nigritude Ultramarine FAQ - frequently asked questions about **nigritude ultramarine** and the realted SEO contest.
www.**nigritudeultramarine**s.com/ - 59k - Cached - Similar pages

SEO contest - Wikipedia, the free encyclopedia
The **nigritude ultramarine** competition by SearchGuild is widely acclaimed as ...
Comparison of search results for **nigritude ultramarine** during and after the ...
en.wikipedia.org/wiki/Nigritude_**ultramarine** - 37k - Cached - Similar pages

Slashdot | How To Get Googled, By Hook Or By Crook
The current 3rd result showcases the "**Nigritude Ultramarine** Fighting Force" who ... When discussing **nigritude ultramarine** [slashdot.org] it is important to ...
slashdot.org/article.pl?sid=04/05/09/1840217 - 110k - Cached - Similar pages

The **Nigritude Ultramarine** Search Engine Optimization Contest
It's sweeping the web -- or at least search engine optimizers -- a new contest to rank tops for the term **nigritude ultramarine** on Google.
searchenginewatch.com/sereport/article.php/3360231 - 57k - Cached - Similar pages

Sponsored Links

Business Blogging Seminar
Coming to L.A. March 16
Top bloggers reveal key techniques
www.blogbusinesssummit.com
Los Angeles, CA

Full-Time SEO & SEM Jobs
Find companies big & small hiring
full-time SEO & SEM pros right now
CareerBuilder.com

SEO Contests
Information on SEO Contests like
the **Nigritude Ultramarine** contest.
www.seo-contests.com/

The SEO Book
Nigritude Ultramarine & SEO secrets
Fun, free, raw, & different.
www.seobook.com

Overstock.com

Ads

Algorithmic results.

User Needs

- Need
  - **Informational** – want to learn about something (~40% / 65%)

    `Low hemoglobin`
  - **Navigational** – want to go to that page (~25% / 15%)

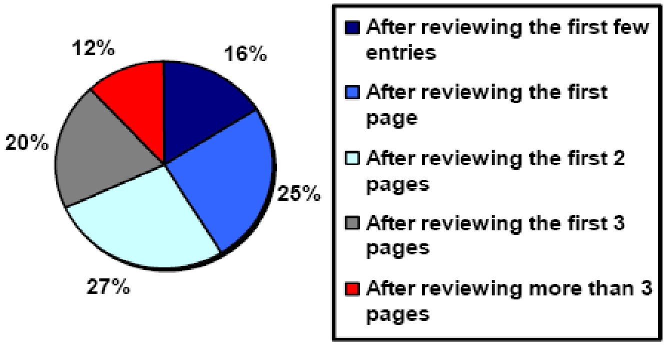
    `United Airlines`
  - **Transactional** – want to do something (web-mediated) (~35% / 20%)
    - Access a service
    - Downloads
    - Shop

    `Seattle weather`
    `Mars surface images`
    `Canon S410`
  - **Gray areas**
    - Find a good hub
    - Exploratory search "see what's there"

    `Car rental Brasil`

How far do people look for results?

"When you perform a search on a search engine and don't find what you are looking for, at what point do you typically either revise your search, or move on to another search engine? (Select one)"



(Source: iprospect.com WhitePaper_2006_SearchEngineUserBehavior.pdf)

Users' empirical evaluation of results

- Quality of pages varies widely
  - Relevance is not enough
  - Other desirable qualities (non IR!!)
    - Content: Trustworthy, diverse, non-duplicated, well maintained
    - Web readability: display correctly & fast
    - No annoyances: pop-ups, etc
- Precision vs. recall
  - On the web, recall seldom matters
- What matters
  - Precision at 1? Precision above the fold?
  - Comprehensiveness – must be able to deal with obscure queries
    - Recall matters when the number of matches is very small
- User perceptions may be unscientific, but are significant over a large aggregate

Users' empirical evaluation of engines

- Relevance and validity of results
- UI – Simple, no clutter, error tolerant
- Trust – Results are objective
- Coverage of topics for polysemic queries
- Pre/Post process tools provided
  - Mitigate user errors (auto spell check, search assist,…)
  - Explicit: Search within results, more like this, refine ...
  - Anticipative: related searches
- Deal with idiosyncrasies
  - Web specific vocabulary
    - Impact on stemming, spell-check, etc
  - Web addresses typed in the search box
  - …

Search engine optimization (Spam)

- Motives
  - Commercial, political, religious, lobbies
  - Promotion funded by advertising budget
- Operators
  - Contractors (Search Engine Optimizers) for lobbies, companies
  - Web masters
  - Hosting services
- Forums
  - E.g., Web master world (www.webmasterworld.com)
    - Search engine specific tricks
    - Discussions about academic papers ☺

Simplest forms

- First generation engines relied heavily on *tf/idf*
  - The top-ranked pages for the query `maui resort` were the ones containing the most `maui'`s and `resort'`s
- SEOs responded with dense repetitions of chosen terms
  - e.g., `maui resort maui resort maui resort`
  - Often, the repetitions would be in the same color as the background of the web page
    - Repeated terms got indexed by crawlers
    - But not visible to humans on browsers

Pure word density cannot be trusted as an IR signal

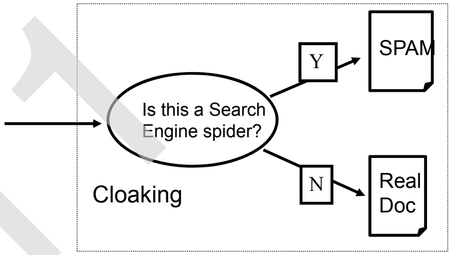
Variants of keyword stuffing

- □ Misleading meta-tags, excessive repetition
- □ Hidden text with colors, style sheet tricks, etc.

Meta-Tags =
"… London hotels, hotel, holiday inn, hilton, discount, booking, reservation, sex, mp3, britney spears, viagra, …"

Cloaking

- □ Serve fake content to search engine spider
- □ DNS cloaking: Switch IP address. Impersonate



More spam techniques

- □ **Doorway pages**
  - Pages optimized for a single keyword that re-direct to the real target page
- □ **Link spamming**
  - Mutual admiration societies, hidden links, awards – more on these later
  - *Domain flooding:* numerous domains that point or re-direct to a target page
- □ **Robots**
  - Fake query stream – rank checking programs
    - "Curve-fit" ranking programs of search engines
  - Millions of submissions via Add-Url

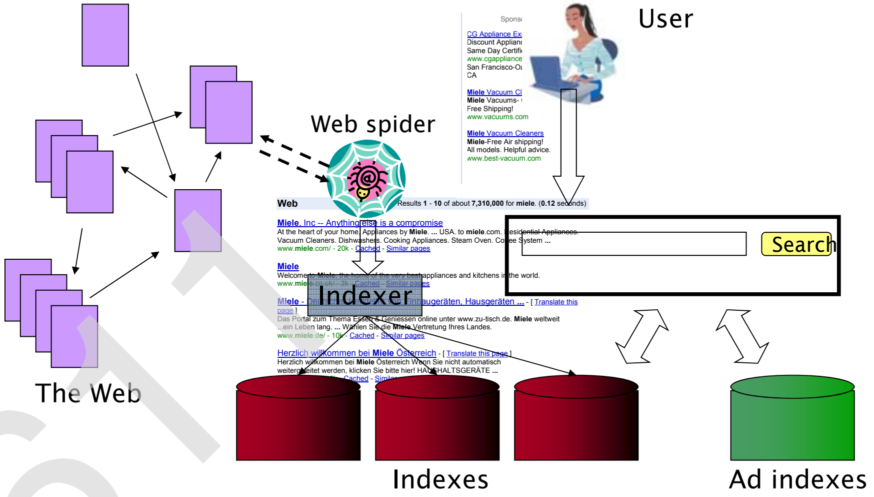
The war against spam

- □ Quality signals - Prefer authoritative pages based on:
  - Votes from authors (linkage signals)
  - Votes from users (usage signals)
- □ Policing of URL submissions
  - Anti robot test
- □ Limits on meta-keywords
- □ Robust link analysis
  - Ignore statistically implausible linkage (or text)
  - Use link analysis to detect spammers (guilt by association)
- □ Spam recognition by machine learning
  - Training set based on known spam
- □ Family friendly filters
  - Linguistic analysis, general classification techniques, etc.
  - For images: flesh tone detectors, source text analysis, etc.
- □ Editorial intervention
  - Blacklists
  - Top queries audited
  - Complaints addressed
  - Suspect pattern detection

More on spam

- □ Web search engines have policies on SEO practices they tolerate/block
  - http://help.yahoo.com/help/us/ysearch/index.html
  - http://www.google.com/intl/en/webmasters/
- □ Adversarial IR: the unending (technical) battle between SEO's and web search engines
- □ Research http://airweb.cse.lehigh.edu/

Web search basics

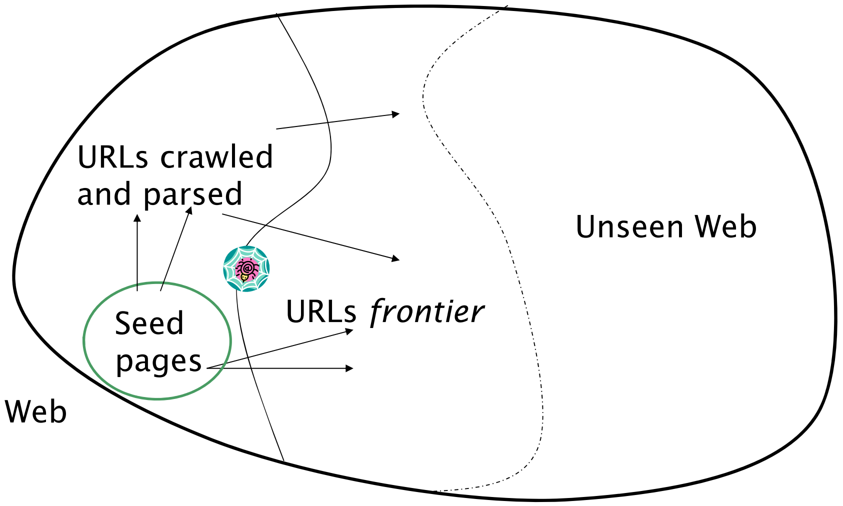


Basic crawler operation

- □ Begin with known "seed" pages
- □ Fetch and parse them
  - Extract URLs they point to
  - Place the extracted URLs on a queue
- □ Fetch each URL on the queue and repeat

Web spider

Crawling picture



Simple picture – complications

- Web crawling isn't feasible with one machine
  - All of the above steps distributed
- Even non-malicious pages pose challenges
  - Latency/bandwidth to remote servers vary
  - Webmasters' stipulations
    - How "deep" should you crawl a site's URL hierarchy?
  - Site mirrors and duplicate pages
- Malicious pages
  - Spam pages
  - Spider traps – incl dynamically generated
- Politeness – don't hit a server too often

What any crawler *must* do

- Be Polite: Respect implicit and explicit politeness considerations
  - Only crawl allowed pages
  - Respect *robots.txt* (more on this shortly)
- Be Robust: Be immune to spider traps and other malicious behavior from web servers

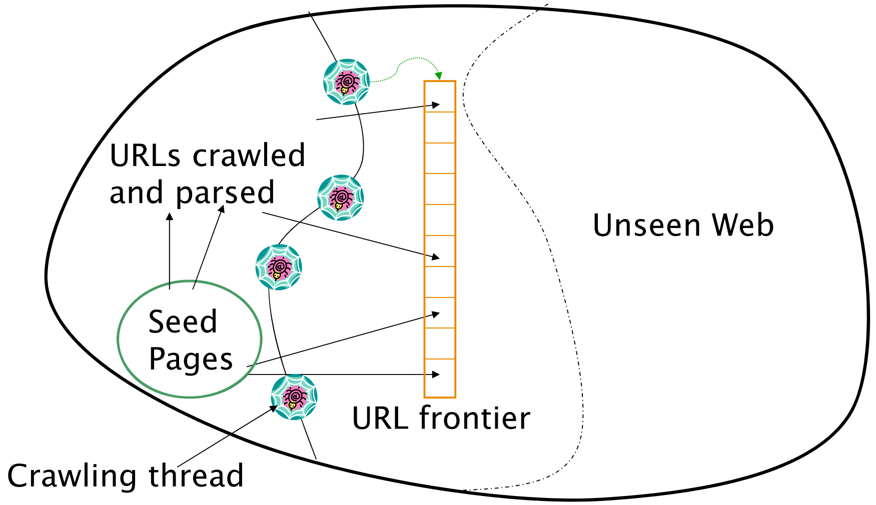
What any crawler *should* do

- Be capable of distributed operation: designed to run on multiple distributed machines
- Be scalable: designed to increase the crawl rate by adding more machines
- Performance/efficiency: permit full use of available processing and network resources

What any crawler *should* do

- Fetch pages of "higher quality" first
- Continuous operation: Continue fetching fresh copies of a previously fetched page
- Extensible: Adapt to new data formats, protocols

Updated crawling picture



URL frontier: two main considerations

- □ Politeness: do not hit a web server too frequently
- □ Freshness: crawl some pages more often than others
  - E.g., pages (such as News sites) whose content changes often

These goals may conflict each other.

(E.g., simple priority queue fails – many links out of a page go to its own site, creating a burst of accesses to that site.)

URL frontier

- □ Can include multiple pages from the same host
- □ Must avoid trying to fetch them all at the same time
- □ Must try to keep all crawling threads busy

Explicit and implicit politeness

- □ Explicit politeness: specifications from webmasters on what portions of site can be crawled
  - robots.txt
- □ Implicit politeness: even with no specification, avoid hitting any site too often

Robots.txt

- □ Protocol for giving spiders (“robots”) limited access to a website, originally from 1994
  - www.robotstxt.org/wc/norobots.html
- □ Website announces its request on what can(not) be crawled
  - For a URL, create a file `URL/robots.txt`
  - This file specifies access restrictions

Robots.txt example

- □ No robot should visit any URL starting with "/yoursite/temp/", except the robot called “searchengine":

```
User-agent: *
Disallow: /yoursite/temp/

User-agent: searchengine
Disallow:
```

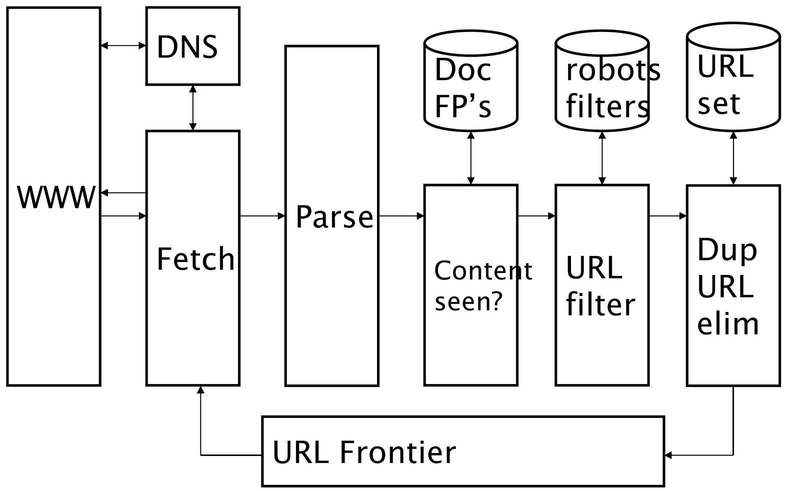
Processing steps in crawling

- □ Pick a URL from the frontier
- □ Fetch the document at the URL
- □ Parse the URL
  - Extract links from it to other docs (URLs)
- □ Check if URL has content already seen
  - If not, add to indexes
- □ For each extracted URL
  - Ensure it passes certain URL filter tests
  - Check if it is already in the frontier (duplicate URL elimination)

Which one?

E.g., only crawl .edu, obey robots.txt, etc.

Basic crawl architecture



DNS (Domain Name Server)

- A lookup service on the internet
  - Given a URL, retrieve its IP address
  - Service provided by a distributed set of servers – thus, lookup latencies can be high (even seconds)
- Common OS implementations of DNS lookup are *blocking*: only one outstanding request at a time
- Solutions
  - DNS caching
  - Batch DNS resolver – collects requests and sends them out together

Parsing: URL normalization

- When a fetched document is parsed, some of the extracted links are *relative* URLs
- E.g., at http://en.wikipedia.org/wiki/Main_Page

we have a relative link to /wiki/Wikipedia:General_disclaimer which is the same as the absolute URL http://en.wikipedia.org/wiki/Wikipedia:General_disclaimer

- During parsing, must normalize (expand) such relative URLs

Content seen?

- Duplication is widespread on the web
- If the page just fetched is already in the index, do not further process it
- This is verified using document fingerprints or shingles

Filters and robots.txt

- Filters – regular expressions for URL's to be crawled/not
- Once a robots.txt file is fetched from a site, need not fetch it repeatedly
  - Doing so burns bandwidth, hits web server
- Cache robots.txt files

Duplicate URL elimination

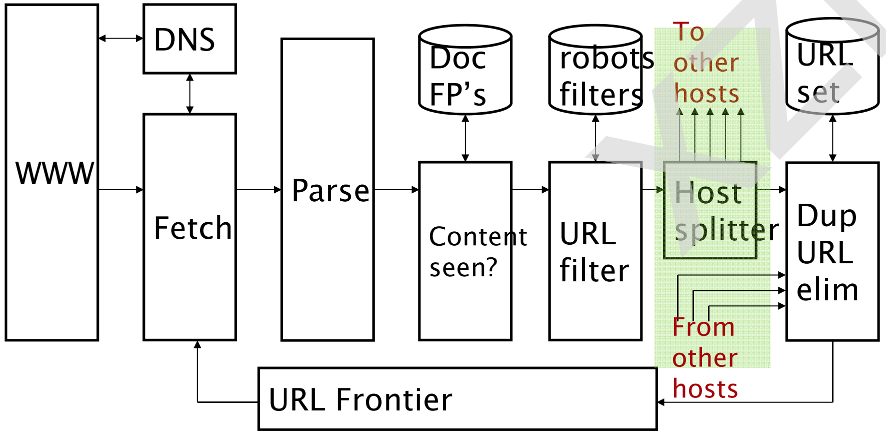
- For a non-continuous (one-shot) crawl, test to see if an extracted+filtered URL has already been passed to the frontier
- For a continuous crawl – see details of frontier implementation

Distributing the crawler

- Run multiple crawl threads, under different processes – potentially at different nodes
  - Geographically distributed nodes
- Partition hosts being crawled into nodes
  - Hash used for partition
- How do these nodes communicate?

Communication between nodes

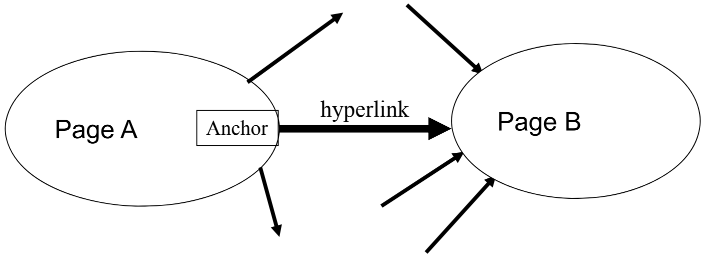
- The output of the URL filter at each node is sent to the Duplicate URL Eliminator at all nodes



Ranking

- Beyond traditional IR ranking
  - Purely focus on content
- Must incorporating the following formation as well
  - Anchor text (peer review)
  - Link analysis (social relationship)
    - PageRank and variants
    - HITS

The Web as a Directed Graph

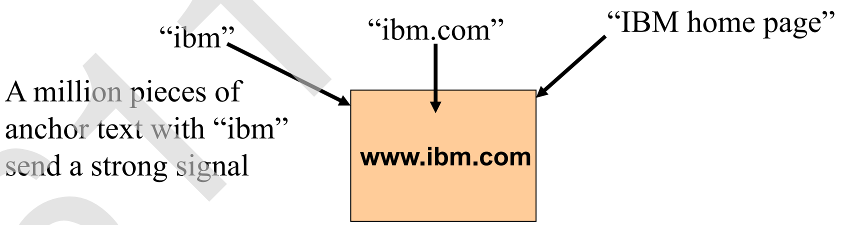


Assumption 1: A hyperlink between pages denotes author perceived relevance (quality signal)

Assumption 2: The anchor of the hyperlink describes the target page (textual context)

Anchor Text

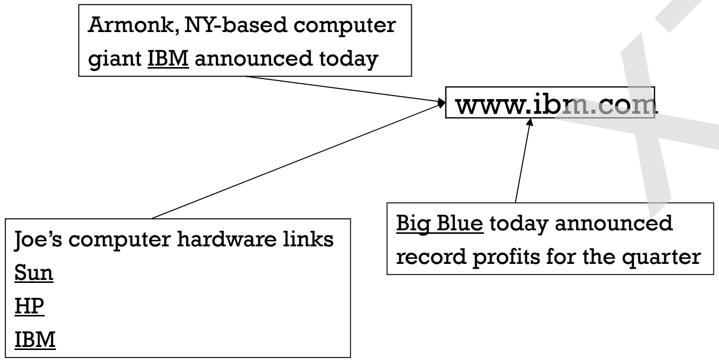
- For ***ibm*** how to distinguish between:
  - IBM's home page (mostly graphical)
  - IBM's copyright page (high term freq. for 'ibm')
  - Rival's spam page (arbitrarily high term freq.)


"ibm"
"ibm.com"
"IBM home page"
A million pieces of anchor text with "ibm" send a strong signal
www.ibm.com

WWW Worm - McBryan [Mcbr94]

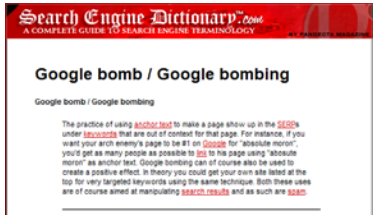
Indexing anchor text

- When indexing a document *D*, include anchor text from links pointing to *D*.


Armonk, NY-based computer giant IBM announced today
www.ibm.com
Joe's computer hardware links
Sun
HP
IBM
Big Blue today announced record profits for the quarter

Indexing anchor text

- Can sometimes have unexpected side effects - *e.g.*, ***evil empire***.
  - Google Bomb
- Can score anchor text with weight depending on the authority of the anchor page's website
  - E.g., if we were to assume that content from cnn.com or yahoo.com is authoritative, then trust their anchor text



Search Engine Dictionary™.com
A COMPLETE GUIDE TO SEARCH ENGINE TERMINOLOGY
BY PANDECTA MAGAZINE

Google bomb / Google bombing

Google bomb / Google bombing

The practice of using anchor text to make a page show up in the SERPs under keywords that are out of context for that page. For instance, if you want your arch enemy's page to be #1 on Google for "absolute moron", you'd get as many people as possible to link to his page using "abosute moron" as anchor text. Google bombing can of course also be used to create a positive effect. In theory you could get your own site listed at the top for very targeted keywords using the same technique. Both these uses are of course aimed at manipulating search results and as such are spam.

众口铄金
To describe the force of public opinion, and even be able to melt metal. Unanimously to confuse right and wrong analogy.

http://www.searchenginedictionary.com/terms-google-bomb.shtml

Citation Analysis

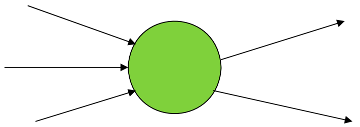
- Citation frequency
- Co-citation coupling frequency
  - Cocitations with a given author measures “impact”
  - Cocitation analysis
- Bibliographic coupling frequency
  - Articles that co-cite the same articles are related
- Citation indexing
  - Who is author cited by? (Garfield 1972)
- PageRank preview: Pinsker and Narin ’60s

Query processing

- First retrieve all pages meeting the text query (say ***venture capital***).
- Order these by their link popularity (either variant on the previous page).

Query-independent ordering

- First generation: using link counts as simple measures of popularity.
- Two basic suggestions:
  - Undirected popularity:
    - Each page gets a score = the number of in-links plus the number of out-links (3+2=5).
  - Directed popularity:
    - Score of a page = number of its in-links (3).

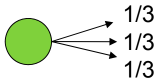


Spamming simple popularity

- *Exercise*: How do you spam each of the following heuristics so your page gets a high score?
- Each page gets a static score = the number of in-links plus the number of out-links.
- Static score of a page = number of its in-links.

PageRank Scoring

- Imagine a browser doing a random walk on web pages:
  - Start at a random page
  - At each step, go out of the current page along one of the links on that page, equiprobably
- "In the steady state" each page has a long-term visit rate - use this as the page's score.



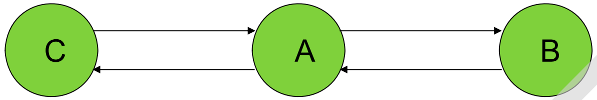
Mathematically … …

- Assume that there are *n* web pages and the *i*-th page is simply noted with *i*.
- The web pages form a directed graph and the graph can be represented with adjacent matrix *P*
  - Element $p_{i,j}$ represents the connection between the *i*-th web page and the *j*-th web page
    - 1: if page *i* refers to page *j*; 0, otherwise.
- PageRank of the *i*-th web page is denoted with a_i

$$a_j = \sum_{i=1}^{n} \frac{a_i}{OutLinks(i)} \times p_{i,j} = \sum_{i=1}^{n} a_i \times \frac{p_{i,j}}{OutLinks(i)}$$

$$\sum_{i=1}^{n} a_i = 1.$$

A sample



$$\begin{bmatrix} 0 & 1 & 1 \\ 1 & 0 & 0 \\ 1 & 0 & 0 \end{bmatrix} \qquad \begin{bmatrix} 0 & 0.5 & 0.5 \\ 1 & 0 & 0 \\ 1 & 0 & 0 \end{bmatrix}$$

$$p_{i,j} \qquad \frac{p_{i,j}}{OutLinks(i)}$$

$$\sum_{j=1}^{n} p_{ij} = 1.$$

More Mathematically … …

$$a_j = \sum_{i=1}^{n} a_i \times p_{i,j}$$

$$a = aP$$

$$a(t) = a(t-1)P$$

How do we compute this vector?

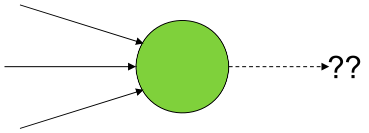
- Let **a** = [a_1, a_n] denote the row vector of steady-state probabilities.
- If we our current position is described by **a**, then the next step is distributed as **aP**.
- But **a** is the steady state, so **a**=**aP**.
- Solving this matrix equation gives us **a**.
  - So **a** is the (left) eigenvector for **P**.
  - (Corresponds to the "principal" eigenvector of **P** with the largest eigenvalue.)
  - Transition probability matrices always have larges eigenvalue 1.

One way of computing a

- Recall, regardless of where we start, we eventually reach the steady state **a**.
- Start with any distribution (say **x**=(*10 0*)).
- After one step, we're at **xP**;
- after two steps at $\mathbf{xP}^2$, then $\mathbf{xP}^3$ and so on.
- "Eventually" means for "large" *k*, $\mathbf{xP}^k$ = **a**.
- Algorithm: multiply **x** by increasing powers of **P** until the product looks stable.

Not quite enough

- The web is full of dead-ends.
  - Random walk can get stuck in dead-ends.
    - No through road
  - Makes no sense to talk about long-term visit rates.



Random Surfer / Random Walker

- At a dead end, jump to a random web page.
- At any non-dead end, with probability (1-γ), jump to a random web page.
  - With 90% (*i.e.* γ=90%)to follow P if there are outbound links.
  - Different names for this parameter, such as damping factor.
  - Teleporter probability is (1- γ).

Result of Random Surfer / Walker

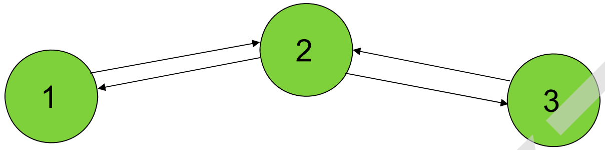
- □ Now cannot get stuck locally.
- □ There is a long-term rate at which any page is visited (not obvious, will show this).
- □ How do we compute this visit rate?
  - How to revise matrix P?

Revise P

$$a_j = \gamma \times \sum_{i=1}^{n} a_i \times p_{i,j} + (1-\gamma)/n$$

- □ In each row
  - Replace the zero elements with (1-γ)/n;
  - Replace the non-zero elements with p_{ij} × γ + (1-γ)/n

Case study



$$\begin{bmatrix} 0 & 1 & 0 \\ 1 & 0 & 1 \\ 0 & 1 & 0 \end{bmatrix} \quad \begin{bmatrix} 0 & 1 & 0 \\ 1/2 & 0 & 1/2 \\ 0 & 1 & 0 \end{bmatrix} \quad \begin{bmatrix} 1/6 & 2/3 & 1/6 \\ 5/12 & 1/6 & 5/12 \\ 1/6 & 2/3 & 1/6 \end{bmatrix}$$

γ=1/2

Case Study

$$P = \begin{pmatrix} 1/6 & 2/3 & 1/6 \\ 5/12 & 1/6 & 5/12 \\ 1/6 & 2/3 & 1/6 \end{pmatrix}$$

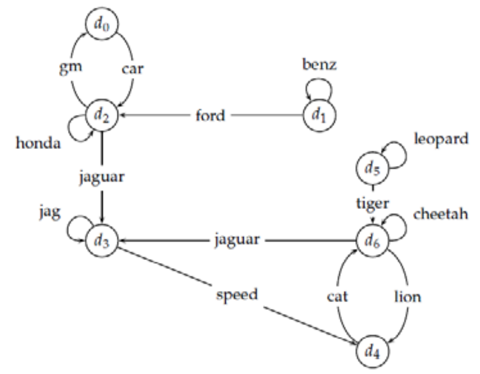
$$\vec{x}_0 P = \begin{pmatrix} 1/6 & 2/3 & 1/6 \end{pmatrix} = \vec{x}_1$$

$$\vec{x}_1 P = \begin{pmatrix} 1/6 & 2/3 & 1/6 \end{pmatrix} \begin{pmatrix} 1/6 & 2/3 & 1/6 \\ 5/12 & 1/6 & 5/12 \\ 1/6 & 2/3 & 1/6 \end{pmatrix} = \begin{pmatrix} 1/3 & 1/3 & 1/3 \end{pmatrix} = \vec{x}_2$$

$\vec{x}_0$	1	0	0
$\vec{x}_1$	1/6	2/3	1/6
$\vec{x}_2$	1/3	1/3	1/3
$\vec{x}_3$	1/4	1/2	1/4
$\vec{x}_4$	7/24	5/12	7/24
...	...	...	...
$\vec{x}$	5/18	4/9	5/18

How about this one?

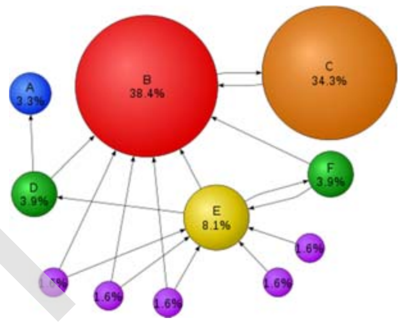
- □ γ=0.86



$$\begin{matrix}
0.02 & 0.02 & 0.88 & 0.02 & 0.02 & 0.02 & 0.02 \\
0.02 & 0.45 & 0.45 & 0.02 & 0.02 & 0.02 & 0.02 \\
0.31 & 0.02 & 0.31 & 0.31 & 0.02 & 0.02 & 0.02 \\
0.02 & 0.02 & 0.02 & 0.45 & 0.45 & 0.02 & 0.02 \\
0.02 & 0.02 & 0.02 & 0.02 & 0.02 & 0.02 & 0.88 \\
0.02 & 0.02 & 0.02 & 0.02 & 0.02 & 0.45 & 0.45 \\
0.02 & 0.02 & 0.02 & 0.31 & 0.31 & 0.02 & 0.31
\end{matrix}$$

$$\vec{x} = (0.05 \quad 0.04 \quad 0.11 \quad 0.25 \quad 0.21 \quad 0.04 \quad 0.31)$$

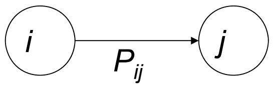
Are the figures correct ?



http://en.wikipedia.org/wiki/PageRank

Markov chains (too mathematical)

- □ A Markov chain consists of *n* <u>states</u>, plus an *n*×*n* <u>transition probability matrix</u> **P**.
- □ At each step, we are in exactly one of the states.
- □ For *1 ≤ i,j ≤ n,* the matrix element p_{ij} tells us the probability of *j* being the next state, given we are currently in state *i*.



$$\sum_{j=1}^{n} p_{ij} = 1, p_{ij} > 0.$$

PageRank summary

- □ Preprocessing:
  - Given graph of links, build matrix **P**.
  - From it compute **a**.
  - The entry a_i is a number between 0 and 1: the PageRank of page *i*.
- □ Query processing:
  - Retrieve pages meeting query.
  - Rank them by their PageRank.
  - Order is query-*independent*.
- □ The reality
  - PageRank is used in Google, but so are many other clever heuristics.

PageRank: Issues and Variants

- How realistic is the random surfer model?
  - What if we modeled the back button?
  - Surfer behavior sharply skewed towards short paths
  - Search engines, bookmarks & directories make jumps non-random.
- Biased Surfer Models
  - Topic sensitive (Personalized) PageRank
  - Weight edge traversal probabilities based on match with topic/query (non-uniform edge selection)
  - Bias jumps to pages on topic (e.g., based on personal bookmarks & categories of interest)

Influencing PageRank: *Personalization*

- Input:
  - Web graph P
  - influence vector $\mathbf{v}$

    $\mathbf{v}$: (page → degree of influence)
- Output:
  - Rank vector $\mathbf{a}$: (page → page importance wrt $\mathbf{v}$)
- $\mathbf{a} = \mathrm{PR}(W, \mathbf{v})$

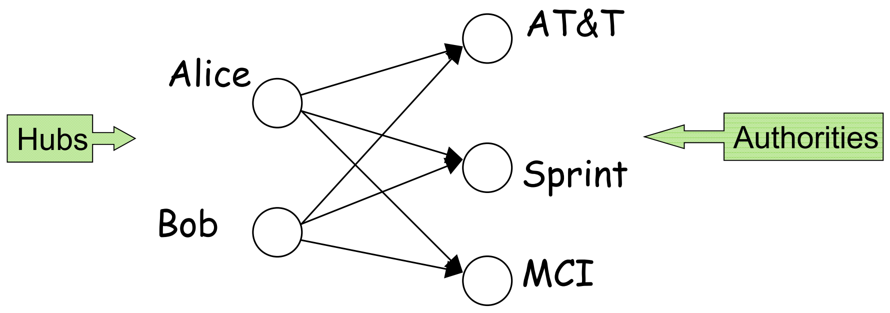
Hyperlink-Induced Topic Search (HITS)

- In response to a query, instead of an ordered list of pages each meeting the query, find two sets of inter-related pages:
  - *Hub pages* are good lists of links on a subject.
    - e.g., “Bob’s list of cancer-related links.”
  - *Authority pages* occur recurrently on good hubs for the subject.
- Best suited for “broad topic” queries rather than for page-finding queries.
- Gets at a broader slice of common *opinion*.

Hubs and Authorities

- Thus, a good hub page for a topic *points* to many authoritative pages for that topic.
- A good authority page for a topic is *pointed* to by many good hubs for that topic.
- Circular definition - will turn this into an iterative computation.

The hope



Long distance telephone companies

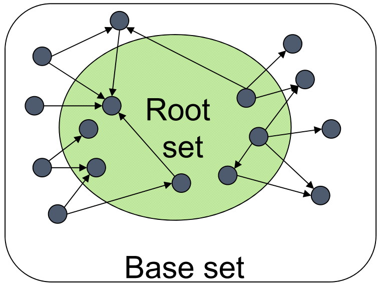
High-level scheme

- □ Extract from the web a <u>base set</u> of pages that *could* be good hubs or authorities.
- □ From these, identify a small set of top hub and authority pages;
  - → iterative algorithm.

Base set

- □ Given text query (say ***browser***), use a text index to get all pages containing ***browser.***
  - ◘ Call this the <u>root set</u> of pages.
- □ Add in any page that either
  - ◘ points to a page in the root set, or
  - ◘ is pointed to by a page in the root set.
- □ Call this the <u>base set</u>.

Visualization



Assembling the base set

- Root set typically 200-1000 nodes.
- Base set may have up to 5000 nodes.
- How do you find the base set nodes?
  - Follow out-links by parsing root set pages.
  - Get in-links (and out-links) from a *connectivity server.*
  - (Actually, suffices to text-index strings of the form ***href="URL"*** to get in-links to *URL*.)

Distilling hubs and authorities

- Compute, for each page *x* in the base set, a hub score *h(x)* and an authority score *a(x).*
- Initialize: for all *x, h(x)←1; a(x) ←1;*
- Iteratively update all *h(x), a(x)*;

Key

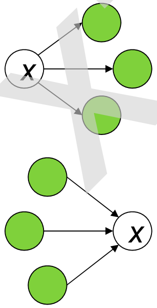
- After iterations
  - output pages with highest *h()* scores as top hubs
  - highest *a()* scores as top authorities.

Iterative update

- Repeat the following updates, for all *x*:

$$h(x) \leftarrow \sum_{x \mapsto y} a(y)$$

$$a(x) \leftarrow \sum_{y \mapsto x} h(y)$$



Scaling

- To prevent the *h()* and *a()* values from getting too big, can scale down after each iteration.
- Scaling factor doesn't really matter:
  - we only care about the *relative* values of the scores.

How many iterations?

- Claim: relative values of scores will converge after a few iterations:
  - in fact, suitably scaled, *h()* and *a()* scores settle into a steady state!
  - proof of this comes later.
- We only require the relative orders of the *h()* and *a()* scores - not their absolute values.
- In practice, ~5 iterations get you close to stability.

Issues

- Topic Drift
  - Off-topic pages can cause off-topic “authorities” to be returned
    - E.g., the neighborhood graph can be about a “super topic”
- Mutually Reinforcing Affiliates
  - Affiliated pages/sites can boost each others’ scores
    - Linkage between affiliated pages is not a useful signal

PageRank	**HITS**
⊕ - Hard to spam - Computes quality signal for all pages	⊕ - Easy to compute, real-time execution is hard - Query specific - Works on small graphs
⊖ - Non-trivial to compute - Not query specific - Does not work on small graphs	⊖ - Local graph structure can be manufactured - Provides a signal only when there is direct connectivity (e.g. home pages)
Proven to be effective for general purpose ranking	Well suited for supervised directory construction

TUTORIAL ON SEARCH FROM THE WEB TO THE ENTERPRISE, SIGIR 2002

More sophisticated *information* retrieval

- Cross-language information retrieval
- Question answering
- Text mining/Knowledge discovery
  - Clustering
- Spamming in Web Search
- More efficient calculation
- Storage, speed, freshness
- Fighting spam
- Make better usage of the structure of the web
- Consider the continuous change of the web's structure
- Better study of its characteristics (practical + theor.):
  - Stability and sensitivity
  - Influence of the linkage
  - Influence of different parameters
- Personalization and specialization
- …

Need To Know

- □ Characteristics of the Web
- □ Architecture of web information retrieval
- □ Crawling issues
- □ Spamming
- □ Principles of PageRank
- □ Principles of HITS

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