CS276B

Text Retrieval and Mining

Winter 2005

Lecture 9

Plan for today

- Web size estimation
- Mirror/duplication detection
- Pagerank

Size of the web

What is the size of the web ?

- Issues
  - The web is really infinite
    - Dynamic content, e.g., calendar
    - Soft 404: www.yahoo.com/anything is a valid page
  - Static web contains syntactic duplication, mostly due to mirroring (~20-30%)
  - Some servers are seldom connected
- Who cares?
  - Media, and consequently the user
  - Engine design
  - Engine crawl policy. Impact on recall

What can we attempt to measure?

- The relative size of search engines
  - The notion of a page being indexed is ***still*** reasonably well defined.
  - Already there are problems
    - Document extension: e.g. Google indexes pages not yet crawled by indexing anchortext.
    - Document restriction: Some engines restrict what is indexed (first *n* words, only relevant words, etc.)
- The coverage of a search engine relative to another particular crawling process.

Statistical methods

- Random queries
- Random searches
- Random IP addresses
- Random walks

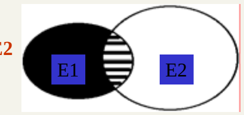
URL sampling via Random Queries

- Ideal strategy: Generate a random URL and check for containment in each index.
- Problem: Random URLs are hard to find!

Random queries [Bhar98a]

- Sample URLs randomly from each engine
  - 20,000 random URLs from each engine
    - Issue random conjunctive query with <200 results
    - Select a random URL from the top 200 results
- Test if present in other engines.
  - Query with 8 rarest words. Look for URL match
- Compute intersection & size ratio

Intersection = x% of E1 = y% of E2
E1/E2 = y/x



- Issues
  - Random narrow queries may bias towards long documents (Verify with disjunctive queries)
  - Other biases induced by process

Random searches

- Choose random searches extracted from a local log [Lawr97] or build "random searches" [Note02]
  - Use only queries with small results sets.
  - Count normalized URLs in result sets.
  - Use ratio statistics
- Advantage:
  - Might be a good reflection of the human perception of coverage

Random searches [Lawr98, Lawr99]

- 575 & 1050 queries from the NEC RI employee logs
- 6 Engines in 1998, 11 in 1999
- Implementation:
  - Restricted to queries with < 600 results in total
  - Counted URLs from each engine after verifying query match
  - Computed size ratio & overlap for individual queries
  - Estimated index size ratio & overlap by averaging over all queries
- Issues
  - Samples are correlated with source of log
  - Duplicates
  - Technical statistical problems (must have non-zero results, ratio average, use harmonic mean?)

Queries from Lawrence and Giles study

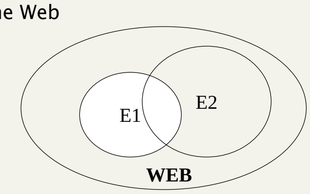
- adaptive access control
- neighborhood preservation topographic
- hamiltonian structures
- right linear grammar
- pulse width modulation neural
- unbalanced prior probabilities
- ranked assignment method
- internet explorer favourites importing
- karvel thornber
- zili liu
- softmax activation function
- bose multidimensional system theory
- gamma mlp
- dvi2pdf
- john oliensis
- rieke spikes exploring neural
- video watermarking
- counterpropagation network
- fat shattering dimension
- abelson amorphous computing

Size of the Web Estimation [Lawr98, Bhar98a]

- Capture – Recapture technique
  - Assumes engines get independent random subsets of the Web

E2 contains x% of E1.
Assume, E2 contains x% of the Web as well

Knowing size of E2 compute size of the Web
Size of the Web = 100*E2/x



Bharat & Broder: 200 M (Nov 97), 275 M (Mar 98)
Lawrence & Giles: 320 M (Dec 97)

Random IP addresses [Lawr99]

- Generate random IP addresses
- Find, if possible, a web server at the given address
- Collect all pages from server
- Advantages
  - Clean statistics, independent of any crawling strategy

Random IP addresses [ONei97, Lawr99]

- HTTP requests to random IP addresses
  - Ignored: empty or authorization required or excluded
  - [Lawr99] Estimated 2.8 million IP addresses running crawlable web servers (16 million total) from observing 2500 servers.
  - OCLC using IP sampling found 8.7 M hosts in 2001
    - Netcraft [Netc02] accessed 37.2 million hosts in July 2002
- [Lawr99] exhaustively crawled 2500 servers and extrapolated
  - Estimated size of the web to be 800 million
  - Estimated use of metadata descriptors:
    - Meta tags (keywords, description) in 34% of home pages, Dublin core metadata in 0.3%

Issues

- Virtual hosting
- Server might not accept http://102.93.22.15
- No guarantee all pages are linked to root page
- Power law for # pages/hosts generates bias

Random walks [Henz99, BarY00, Rusm01]

- View the Web as a directed graph from a given list of seeds.
- Build a random walk on this graph
  - Includes various "jump" rules back to visited sites
  - Converges to a stationary distribution
    - Time to convergence not really known
  - Sample from stationary distribution of walk
  - Use the "small results set query" method to check coverage by SE
  - "Statistically clean" method, at least in theory!

Issues

- List of seeds is a problem.
- Practical approximation might not be valid: Non-uniform distribution, subject to link spamming
- Still has all the problems associated with "strong queries"

Conclusions

- No sampling solution is perfect.
- Lots of new ideas ...
- ....but the problem is getting harder
- Quantitative studies are fascinating and a good research problem

Duplicates and mirrors

Duplicate/Near-Duplicate Detection

- *Duplication*: Exact match with fingerprints
- *Near-Duplication*: Approximate match
  - Overview
    - Compute syntactic similarity with an edit-distance measure
    - Use similarity threshold to detect near-duplicates
      - E.g., Similarity > 80% => Documents are "near duplicates"
      - Not transitive though sometimes used transitively

Computing Similarity

- Features:
  - Segments of a document (natural or artificial breakpoints) [Brin95]
  - Shingles (Word N-Grams) [Brin95, Brod98]
    "a rose is a rose is a rose" =>
    a_rose_is_a
    rose_is_a_rose
    is_a_rose_is
- Similarity Measure
  - TFIDF [Shiv95]
  - Set intersection [Brod98]
    (Specifically, Size_of_Intersection / Size_of_Union)

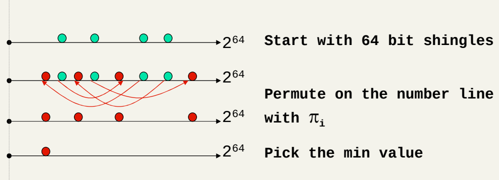
Jaccard measure

Shingles + Set Intersection

- Computing <u>exact</u> set intersection of shingles between all pairs of documents is expensive/intractable
  - Approximate using a cleverly chosen subset of shingles from each (a *sketch*)
- Estimate size_of_intersection / size_of_union based on a short sketch ([Brod97, Brod98])
  - Create a "sketch vector" (e.g., of size 200) for each document
  - Documents which share more than t (say 80%) corresponding vector elements are similar
  - For doc D, sketch[i] is computed as follows:
    - Let f map all shingles in the universe to $0..2^m$ (e.g., f = fingerprinting)
    - Let π_i be a specific random permutation on $0..2^m$
    - Pick MIN π_i (f(s)) over all shingles s in D

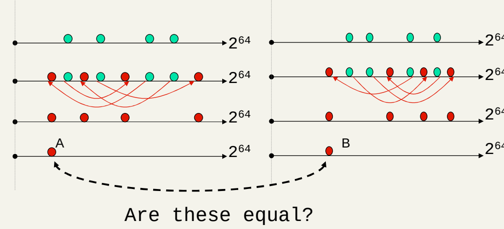
Computing Sketch[i] for Doc1

Document 1



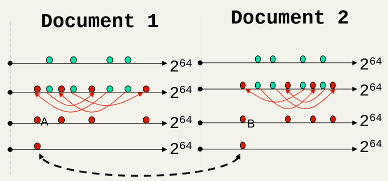
Test if Doc1.Sketch[i] = Doc2.Sketch[i]

Document 1
Document 2



Test for 200 random permutations: π_1, π_2,… π_{200}

However…



A = B iff the shingle with the MIN value in the union of Doc1 and Doc2 is common to both (I.e., lies in the intersection)

This happens with probability:
Size_of_intersection / Size_of_union

Why? See minhash slides on class website.

Mirror Detection

- Mirroring is systematic replication of web pages across hosts.
  - Single largest cause of duplication on the web
- **Host1**/α and **Host2**/β are mirrors iff
  For all (or most) paths p such that when
  http://**Host1**/ α / p exists
  http://**Host2**/ β / p exists as well
  with identical (or near identical) content, and vice versa.
- E.g.,
  - http://**www.elsevier.com**/ and http://**www.elsevier.nl**/
  - Structural Classification of Proteins
    - http://**scop.mrc-lmb.cam.ac.uk**/scop
    - http://**scop.berkeley.edu**/
    - http://**scop.wehi.edu.au**/scop
    - http://**pdb.weizmann.ac.il**/scop
    - http://**scop.protres.ru**/

Repackaged Mirrors

Auctions.msn.com
Auctions.lycos.com

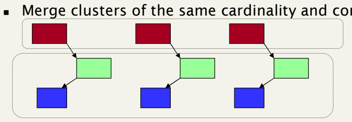
Aug 2001

Motivation

- Why detect mirrors?
  - Smart crawling
    - Fetch from the fastest or freshest server
    - Avoid duplication
  - Better connectivity analysis
    - Combine inlinks
    - Avoid double counting outlinks
  - Redundancy in result listings
    - "If that fails you can try: <mirror>/samepath"
  - Proxy caching

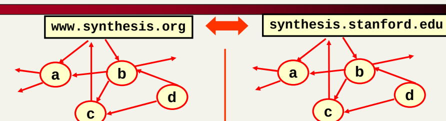
Bottom Up Mirror Detection
[Cho00]

- Maintain clusters of subgraphs
- Initialize clusters of trivial subgraphs
  - Group near-duplicate single documents into a cluster
- Subsequent passes
  - Merge clusters of the same cardinality and corresponding linkage



  - Avoid decreasing cluster cardinality
- To detect mirrors we need:
  - Adequate path overlap
  - Contents of corresponding pages within a small time range

Can we use URLs to find mirrors?



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www.synthesis.org/Docs/yr5ar/cicee/comp-integ-analysis.h	synthesis.stanford.edu/Docs/myr5/cicee/comp-integ-analysis.html

Top Down Mirror Detection
[Bhar99, Bhar00c]

- E.g.,
  `www.synthesis.org/Docs/ProjAbs/synsys/synalysis.html`
  `synthesis.stanford.edu/Docs/ProjAbs/synsys/quant-dev-new-teach.html`
- What features could indicate mirroring?
  - Hostname similarity:
    - word unigrams and bigrams: { www, www.synthesis, synthesis, …}
  - Directory similarity:
    - Positional path bigrams { 0:Docs/ProjAbs, 1:ProjAbs/synsys, … }
  - IP address similarity:
    - 3 or 4 octet overlap
    - Many hosts sharing an IP address => virtual hosting by an ISP
  - Host outlink overlap
  - Path overlap
    - Potentially, path + sketch overlap

Implementation

- Phase I - Candidate Pair Detection
  - Find features that pairs of hosts have in common
  - Compute a list of host pairs which might be mirrors
- Phase II - Host Pair Validation
  - Test each host pair and determine extent of mirroring
    - Check if 20 paths sampled from Host1 have near-duplicates on Host2 and vice versa
    - Use transitive inferences:
      IF Mirror(A,x) AND Mirror(x,B) THEN Mirror(A,B)
      IF Mirror(A,x) AND !Mirror(x,B) THEN !Mirror(A,B)
- Evaluation
  - 140 million URLs on 230,000 hosts (1999)
  - Best approach combined 5 sets of features
    - Top 100,000 host pairs had precision = 0.57 and recall = 0.86

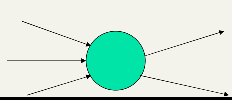
Link Analysis on the Web

Citation Analysis

- Citation frequency
- Co-citation coupling frequency
  - Cocitations with a given author measures “impact”
  - Cocitation analysis [Mcca90]
    - Convert frequencies to correlation coefficients, do multivariate analysis/clustering, validate conclusions
    - E.g., cocitation in the “Geography and GIS” web shows communities [Lars96]
- Bibliographic coupling frequency
  - Articles that co-cite the same articles are related
- Citation indexing
  - Who is a given author cited by? (Garfield [Garf72])
    - E.g., Science Citation Index (*http://www.isinet.com/*)
    - CiteSeer (*http://citeseer.ist.psu.edu*) [Lawr99a]

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).



Query processing

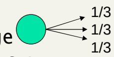
- First retrieve all pages meeting the text query (say ***venture capital***).
- Order these by their link popularity (either variant on the previous page).

Spamming simple popularity

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

Pagerank scoring

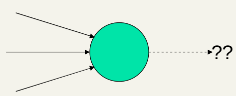
- Imagine a browser doing a random walk on web pages:
  - Start at a random page



  - 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.

Not quite enough

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



Teleporting

- At a dead end, jump to a random web page.
- At any non-dead end, with probability 10%, jump to a random web page.
  - With remaining probability (90%), go out on a random link.
  - 10% - a parameter.

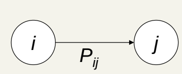
Result of teleporting

- 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?

Markov chains

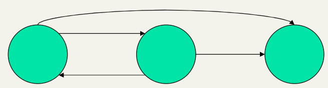
- A Markov chain consists of n states, plus an $n \times n$ transition probability matrix **P**.
- At each step, we are in exactly one of the states.
- For $1 \leq i,j \leq n$, the matrix entry P_{ij} tells us the probability of j being the next state, given we are currently in state i.

$P_{ii}>0$ is OK.



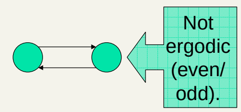
Markov chains

- Clearly, for all i, $\sum_{j=1}^{n} P_{ij} = 1.$
- Markov chains are abstractions of random walks.
- *Exercise*: represent the teleporting random walk from 3 slides ago as a Markov chain, for this case:



Ergodic Markov chains

- A Markov chain is <u>ergodic</u> if
  - you have a path from any state to any other
  - you can be in any state at every time step, with non-zero probability.



Ergodic Markov chains

- For any ergodic Markov chain, there is a unique long-term visit rate for each state.
  - *Steady-state distribution*.
- Over a long time-period, we visit each state in proportion to this rate.
- <u>It doesn't matter where we start.</u>

Probability vectors

- A probability (row) vector **x** = $(x_1, \ldots x_n)$ tells us where the walk is at any point.
- E.g., (000…1…000) means we're in state *i*.

  1 i n

More generally, the vector **x** = $(x_1, \ldots x_n)$ means the walk is in state *i* with probability x_i.

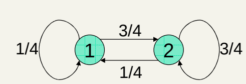
$$\sum_{i=1}^{n} x_i = 1.$$

Change in probability vector

- If the probability vector is **x** = $(x_1, \ldots x_n)$ at this step, what is it at the next step?
- Recall that row *i* of the transition prob. Matrix **P** tells us where we go next from state *i*.
- So from **x**, our next state is distributed as **xP**.

Steady state example

- The steady state looks like a vector of probabilities **a** = $(a_1, \ldots a_n)$:
  - a_i is the probability that we are in state *i*.



For this example, $a_1=1/4$ and $a_2=3/4$.

How do we compute this vector?

- Let **a** = $(a_1, \ldots a_n)$ 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, $\mathbf{xP}^k = \mathbf{a}$.
- Algorithm: multiply **x** by increasing powers of **P** until the product looks stable.

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
  - more on these heuristics later.

Resources

- http://www2004.org/proceedings/docs/1p309.pdf
- http://www2004.org/proceedings/docs/1p595.pdf
- http://www2003.org/cdrom/papers/refereed/p270/kamvar-270-xhtml/index.html
- http://www2003.org/cdrom/papers/refereed/p641/xhtml/p641-mccurley.html