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CS47300: Web Information Search and Management

Web Crawling: Duplicate Detection

Prof. Chris Clifton

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Some slides courtesy Croft et al.

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Detecting Duplicates

- Duplicate and near-duplicate documents occur in many situations
  - Copies, versions, plagiarism, spam, mirror sites
  - 30% of the web pages in a large crawl are exact or near duplicates of pages in the other 70%
- Duplicates consume significant resources during crawling, indexing, and search
  - Little value to most users

Duplicate Detection

- *Exact* duplicate detection is relatively easy
- *Checksum* techniques
  - A checksum is a value that is computed based on the content of the document
    - e.g., sum of the bytes in the document file

T	r	o	p	i	c	a	l		f	i	s	h	*Sum*
54	72	6F	70	69	63	61	6C	20	66	69	73	68	508

  - Possible for files with different text to have same checksum
- Functions such as a *cyclic redundancy check* (CRC), have been developed that consider the positions of the bytes

Near-Duplicate Detection

- More challenging task
  - Are web pages with same text context but different advertising or format near-duplicates?
- A near-duplicate document is defined using a threshold value for some similarity measure between pairs of documents
  - e.g., document *D1* is a near-duplicate of document *D2* if more than 90% of the words in the documents are the same

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Computing Similarity

- Features:
  - Segments of a document (natural or artificial breakpoints)
  - Shingles (Word N-Grams)
  - ***a rose is a rose is a rose*** → 4-grams are

    a_rose_is_a

    rose_is_a_rose

    is_a_rose_is

    a_rose_is_a
- Similarity Measure between two docs (= sets of shingles)
  - Jaccard coefficient: (Size_of_Intersection / Size_of_Union)

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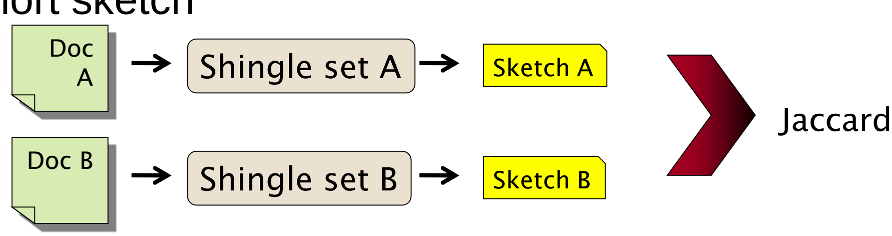
Shingles + Set Intersection

- Computing exact set intersection of shingles between all pairs of documents is expensive
- Approximate using a cleverly chosen subset of shingles from each (a *sketch*)
- Estimate (size_of_intersection / size_of_union) based on a short sketch



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Sketch of a document

- Create a "sketch vector" (of size ~200) for each document
  - Documents that share ≥ *t* (say 80%) corresponding vector elements are deemed near duplicates
  - For doc *D*, $\text{sketch}_D[\,i\,]$ is as follows:
    - Let f map all shingles in the universe to $1..2^m$ (e.g., f = fingerprinting)
    - Let π_i be a *random permutation* on $1..2^m$
    - Pick MIN $\{\pi_i(f(s))\}$ over all shingles *s* in *D*

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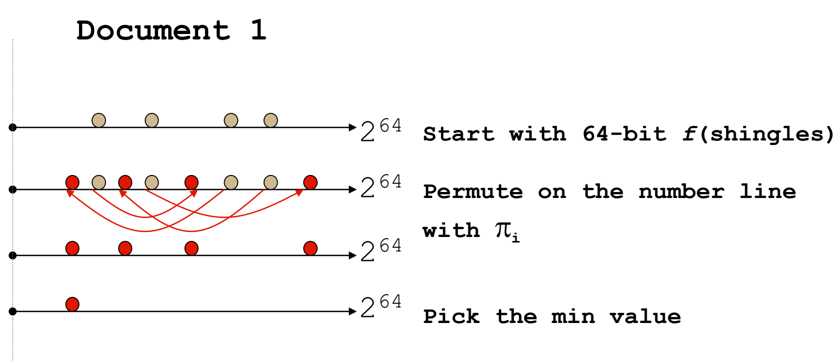
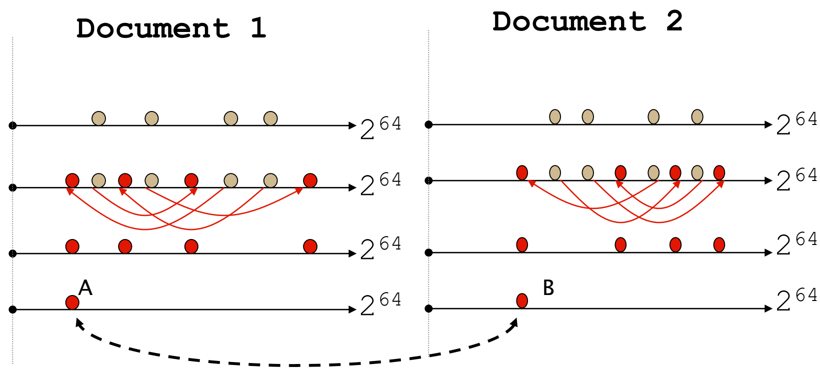
Computing Sketch[i] for Doc1



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



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

Final notes

- Shingling is a *randomized algorithm*
  - Our analysis did not presume any probability model on the inputs
  - It will give us the right (wrong) answer with some probability on *any input*
- We've described how to detect near duplication in a pair of documents
- In "real life" we'll have to concurrently look at many pairs
  - See text book for details

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Removing Noise

- Many web pages contain text, links, and pictures that are not directly related to the main content of the page
- This additional material is mostly *noise* that could negatively affect the ranking of the page
- Techniques have been developed to detect the content blocks in a web page
  - Non-content material is either ignored or reduced in importance in the indexing process

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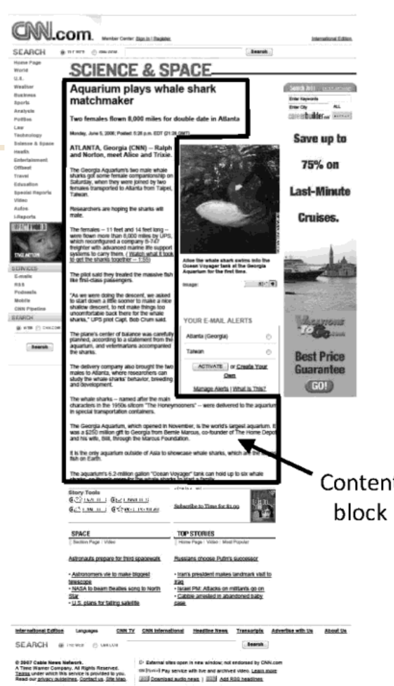
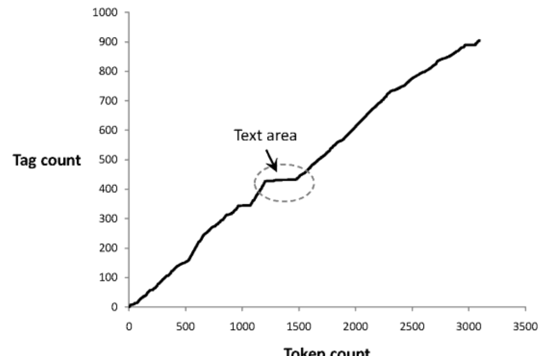
Noise Example



Finding Content Blocks

- Cumulative distribution of tags in the example web page



  – Main text content of the page corresponds to the "plateau" in the middle of the distribution

Finding Content Blocks

- Represent a web page as a sequence of bits, where b_n = *1* indicates that the *n*th token is a tag
- Optimization problem where we find values of *i* and *j* to maximize both the number of tags below *i* and above *j* and the number of non-tag tokens between *i* and *j*
- i.e., maximize

$$\sum_{n=0}^{i-1} b_n + \sum_{n=i}^{j} (1 - b_n) + \sum_{n=j+1}^{N-1} b_n$$

Finding Content Blocks

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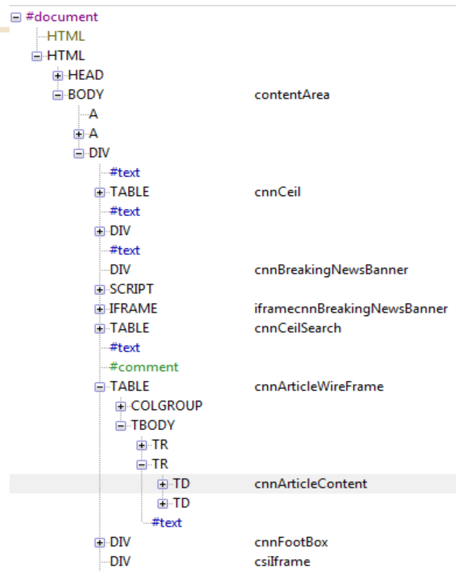
- Other approaches use DOM structure and visual (layout) features



Deep Web

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- Sites that are difficult for a crawler to find are collectively referred to as the *deep* (or *hidden*) *Web*
  – much larger than conventional Web
- Three broad categories:
  – private sites
    - no incoming links, or may require log in with a valid account
  – form results
    - sites that can be reached only after entering some data into a form
  – scripted pages
    - pages that use JavaScript, Flash, or another client-side language to generate links

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Sitemaps

- Sitemaps contain lists of URLs and data about those URLs, such as modification time and modification frequency
- Generated by web server administrators
- Tells crawler about pages it might not otherwise find
- Gives crawler a hint about when to check a page for changes

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Sitemap Example

```
<?xml version="1.0" encoding="UTF-8"?>
<urlset xmlns="http://www.sitemaps.org/schemas/sitemap/0.9">
  <url>
    <loc>http://www.company.com/</loc>
    <lastmod>2008-01-15</lastmod>
    <changefreq>monthly</changefreq>
    <priority>0.7</priority>
  </url>
  <url>
    <loc>http://www.company.com/items?item=truck</loc>
    <changefreq>weekly</changefreq>
  </url>
  <url>
    <loc>http://www.company.com/items?item=bicycle</loc>
    <changefreq>daily</changefreq>
  </url>
</urlset>
```

Distributed Crawling

- Three reasons to use multiple computers for crawling
  - Helps to put the crawler closer to the sites it crawls
  - Reduces the number of sites the crawler has to remember
  - Reduces computing resources required
- Distributed crawler uses a hash function to assign URLs to crawling computers
  - hash function should be computed on the host part of each URL

Desktop Crawls

- Used for desktop search and enterprise search
- Differences to web crawling:
  - Much easier to find the data
  - Responding quickly to updates is more important
  - Must be conservative in terms of disk and CPU usage
  - Many different document formats
  - Data privacy very important

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Document Feeds

- Many documents are *published*
  - created at a fixed time and rarely updated again
  - e.g., news articles, blog posts, press releases, email
- Published documents from a single source can be ordered in a sequence called a *document feed*
  - new documents found by examining the end of the feed

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Document Feeds

- Two types:
  - A *push feed* alerts the subscriber to new documents
  - A *pull feed* requires the subscriber to check periodically for new documents
- Most common format for pull feeds is called *RSS*
  - Really Simple Syndication, RDF Site Summary, Rich Site Summary, or ...

RSS Example

```
<?xml version="1.0"?>
<rss version="2.0">
  <channel>
    <title>Search Engine News</title>
    <link>http://www.search-engine-news.org/</link>
    <description>News about search engines.</description>
    <language>en-us</language>
    <pubDate>Tue, 19 Jun 2008 05:17:00 GMT</pubDate>
    <ttl>60</ttl>

    <item>
      <title>Upcoming SIGIR Conference</title>
      <link>http://www.sigir.org/conference</link>
      <description>The annual SIGIR conference is coming!
        Mark your calendars and check for cheap
        flights.</description>
      <pubDate>Tue, 05 Jun 2008 09:50:11 GMT</pubDate>
      <guid>http://search-engine-news.org#500</guid>
    </item>
```

RSS Example

```
...
    <item>
      <title>New Search Engine Textbook</title>
      <link>http://www.cs.umass.edu/search-book</link>
      <description>A new textbook about search engines
        will be published soon.</description>
      <pubDate>Tue, 05 Jun 2008 09:33:01 GMT</pubDate>
      <guid>http://search-engine-news.org#499</guid>
    </item>
  </channel>
</rss>
```

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RSS

- `ttl` tag (time to live)
  - amount of time (in minutes) contents should be cached
- RSS feeds are accessed like web pages
  - using HTTP GET requests to web servers that host them
- Easy for crawlers to parse
- Easy to find new information

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Conversion

- Text is stored in hundreds of incompatible file formats
  - e.g., raw text, RTF, HTML, XML, Microsoft Word, ODF, PDF
- Other types of files also important
  - e.g., PowerPoint, Excel
- Typically use a conversion tool
  - converts the document content into a tagged text format such as HTML or XML
  - retains some of the important formatting information

Character Encoding

- A character encoding is a mapping between bits and glyphs
  - i.e., getting from bits in a file to characters on a screen
  - Can be a major source of incompatibility
- ASCII is basic character encoding scheme for English
  - encodes 128 letters, numbers, special characters, and control characters in 7 bits, extended with an extra bit for storage in bytes

Character Encoding

- Other languages can have many more glyphs
  - e.g., Chinese has more than 40,000 characters, with over 3,000 in common use
- Many languages have multiple encoding schemes
  - e.g., CJK (Chinese-Japanese-Korean) family of East Asian languages, Hindi, Arabic
  - must specify encoding
  - can't have multiple languages in one file
- Unicode developed to address encoding problems

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Unicode

- Single mapping from numbers to glyphs that attempts to include all glyphs in common use in all known languages
- Unicode is a mapping between numbers and glyphs
  - does not uniquely specify bits to glyph mapping!
  - e.g., UTF-8, UTF-16, UTF-32

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Unicode

- Proliferation of encodings comes from a need for compatibility and to save space
  - UTF-8 uses one byte for English (ASCII), as many as 4 bytes for some traditional Chinese characters
  - variable length encoding, more difficult to do string operations
  - UTF-32 uses 4 bytes for every character
- Many applications use UTF-32 for internal text encoding (fast random lookup) and UTF-8 for disk storage (less space)

Unicode

Decimal	Hexadecimal	Encoding			
0–127	0–7F	0xxxxxxx			
128–2047	80–7FF	110xxxxx	10xxxxxx		
2048–55295	800–D7FF	1110xxxx	10xxxxxx	10xxxxxx	
55296–57343	D800–DFFF	Undefined			
57344–65535	E000–FFFF	1110xxxx	10xxxxxx	10xxxxxx	
65536–1114111	10000–10FFFF	11110xxx	10xxxxxx	10xxxxxx	10xxxxxx

- e.g., Greek letter pi (π) is Unicode symbol number 960
- In binary, 00000011 11000000 (3C0 in hexadecimal)
- Final encoding is **110**01111 **10**000000 (CF80 in hexadecimal)

Storing the Documents

- Many reasons to store converted document text
  - saves crawling time when page is not updated
  - provides efficient access to text for snippet generation, information extraction, etc.
- Database systems can provide document storage for some applications
  - web search engines use customized document storage systems

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Storing the Documents

- Requirements for document storage system:
  - Random access
    - request the content of a document based on its URL
    - hash function based on URL is typical
  - Compression and large files
    - reducing storage requirements and efficient access
  - Update
    - handling large volumes of new and modified documents
    - adding new anchor text

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Compression

- Text is highly redundant (or predictable)
- Compression techniques exploit this redundancy to make files smaller without losing any of the content
- Compression of indexes covered later
- Popular algorithms can compress HTML and XML text by 80%
  - e.g., DEFLATE (zip, gzip) and LZW (UNIX compress, PDF)
  - may compress large files in blocks to make access faster

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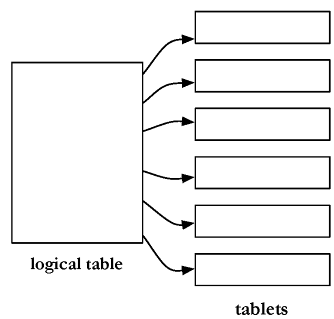
BigTable

- Google’s document storage system
  - Customized for storing, finding, and updating web pages
  - Handles large collection sizes using inexpensive computers



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BigTable

- No query language, no complex queries to optimize
- Only row-level transactions
- Tablets are stored in a replicated file system that is accessible by all BigTable servers
- Any changes to a BigTable tablet are recorded to a transaction log, which is also stored in a shared file system
- If any tablet server crashes, another server can immediately read the tablet data and transaction log from the file system and take over

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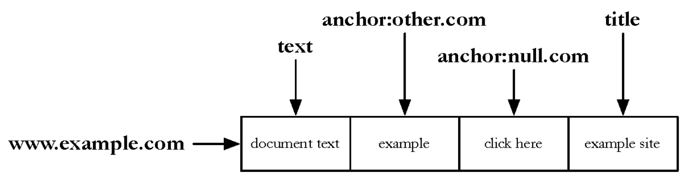
BigTable

- Logically organized into rows
- A row stores data for a single web page



- Combination of a row key, a column key, and a timestamp point to a single *cell* in the row

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BigTable

- BigTable can have a huge number of columns per row
  – all rows have the same column groups
  – not all rows have the same columns
  – important for reducing disk reads to access document data
- Rows are partitioned into tablets based on their row keys
  – simplifies determining which server is appropriate

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Size of the web

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How big is the web ?

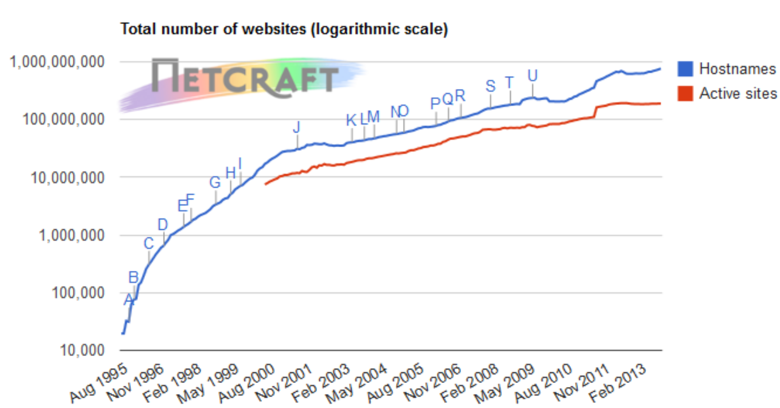
- Issues
  - The web might as well be infinite
    - Dynamic content, e.g., calendar
  - Static web contains syntactic duplication, mostly due to mirroring (~30%)
  - Some servers are seldom connected
- Who cares?
  - Engine design
  - Engine crawl policy. Impact on recall.
  - Media, and consequently the user

The web: size

- What is being measured?
  - Number of hosts
  - Number of (static) html pages
    - Volume of data
- Number of hosts – netcraft survey
  - http://news.netcraft.com/archives/web_server_survey.html
  - Monthly report on how many web hosts & servers are out there
- Number of pages – numerous estimates (will discuss later)

Netcraft Web Server Survey

http://news.netcraft.com/archives/web_server_survey.html



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The web: evolution

- All of these numbers keep changing
- Relatively few scientific studies of the evolution of the web [Fetterly & al, 2003]
  - http://research.microsoft.com/research/sv/sv-pubs/p97-fetterly/p97-fetterly.pdf
- Sometimes possible to extrapolate from small samples (fractal models) [Dill & al, 2001]
  - http://www.vldb.org/conf/2001/P069.pdf

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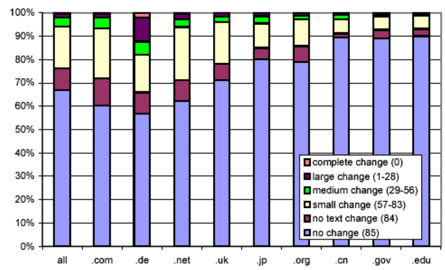
Rate of change

- [Cho00] 720K pages from 270 popular sites sampled daily from Feb 17 – Jun 14, 1999
  - Any changes: 40% weekly, 23% daily
- [Fett02] Massive study 151M pages checked over few months
  - Significant changed -- 7% weekly
  - Small changes – 25% weekly
- [Ntul04] 154 large sites re-crawled from scratch weekly
  - 8% new pages/week
  - 8% die
  - 5% new content
  - 25% new links/week

Static pages: rate of change

- Fetterly et al. study (2002): several views of data, 150 million pages over 11 weekly crawls
  - Bucketed into 85 groups by extent of change



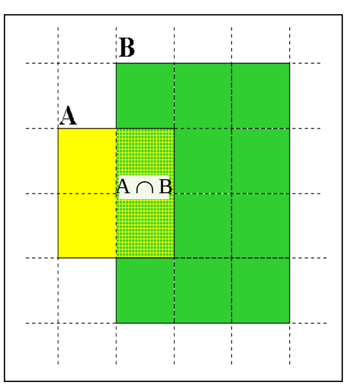
What can we attempt to measure?

- The relative sizes of search engines
  - The notion of a page being indexed is still *reasonably* well defined.
  - Already there are problems
    - Document extension: e.g. engines index pages not yet crawled, by indexing anchortext.
    - Document restriction: All 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

Relative Size from Overlap [Bharat & Broder, 98]



Sample URLs randomly from A

Check if contained in B

and vice versa

$A \cap B = (1/2) * \text{Size } A$
$A \cap B = (1/6) * \text{Size } B$

$(1/2) * \text{Size } A = (1/6) * \text{Size } B$

$\therefore \text{Size } A / \text{Size } B = (1/6)/(1/2) = 1/3$

Each test involves: (i) <u>Sampling</u> (ii) Checking

Sampling URLs

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

Random URLs from random queries [Bharat & B, 98]

- Generate random query: how?
  - **Lexicon:** 400,000+ words from a crawl of Yahoo!
  - **Conjunctive Queries:** w_1 and w_2
    e.g., vocalists AND rsi
- Get 100 result URLs from the source engine
- Choose a random URL as the candidate to check for presence in other engines.

Query Based Checking

- *Strong Query* to check for a document *D*:
  - Download document. Get list of words.
  - Use 8 low frequency words as AND query
- Check if *D* is present in result set.
- Problems:
  - Near duplicates
  - Frames
  - Redirects
  - Engine time-outs
  - Might be better to use e.g. 5 distinct conjunctive queries of 6 words each.

Advantages & disadvantages

- Statistically sound under the induced weight.
- Biases induced by random query
  - Query Bias: Favors content-rich pages in the language(s) of the lexicon
  - Ranking Bias: *Solution:* Use conjunctive queries & fetch all
  - Checking Bias: Duplicates, impoverished pages omitted
  - Document or query restriction bias: engine might not deal properly with 8 words conjunctive query
  - Malicious Bias: Sabotage by engine
  - Operational Problems: Time-outs, failures, engine inconsistencies, index modification.

Random searches

- Choose random searches extracted from a local log [Lawrence & Giles 97] or build “random searches” [Notess]
  - Use only queries with small results sets.
  - Count normalized URLs in result sets.
  - Use ratio statistics

Advantages & disadvantages

- Advantage
  - Might be a better reflection of the human perception of coverage
- Issues
  - Samples are correlated with source of log
  - Duplicates
  - Technical statistical problems (must have non-zero results, etc.)

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

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

Random IP addresses [Lawrence & Giles '99]

- Generate random IP addresses
- Find a web server at the given address
  - If there's one
- Collect all pages from server.
- Method first used by O'Neill, McClain, & Lavoie, **"A Methodology for Sampling the World Wide Web", 1997.** `http://digitalarchive.oclc.org/da/ViewObject.jsp?objid=0000003447`

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. 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%

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Advantages & disadvantages

- Advantages
  - Clean statistics
  - Independent of crawling strategies
- Disadvantages
  - Doesn't deal with duplication
  - Many hosts might share one IP, or not accept requests
  - No guarantee all pages are linked to root page.
    - Eg: employee pages
  - Power law for # pages/hosts generates bias towards sites with few pages.
    - But bias can be accurately quantified IF underlying distribution understood
  - Potentially influenced by spamming (multiple IP's for same server to avoid IP block)

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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