Introduction to Information Retrieval

http://informationretrieval.org

IIR 19: Web Search

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Overview

Outline

Indexing anchor text

- Anchor text is often a better description of a page's content than the page itself.
- Anchor text can be weighted more highly than the text on the page.
- A Google bomb is a search with "bad" results due to maliciously manipulated anchor text.
  - [dangerous cult] on Google, Bing, Yahoo

PageRank

- Model: a web surfer doing a random walk on the web
- Formalization: Markov chain
- PageRank is the long-term visit rate of the random surfer or the steady-state distribution.
- Need teleportation to ensure well-defined PageRank
- Power method to compute PageRank
  - PageRank is the principal left eigenvector of the transition probability matrix.

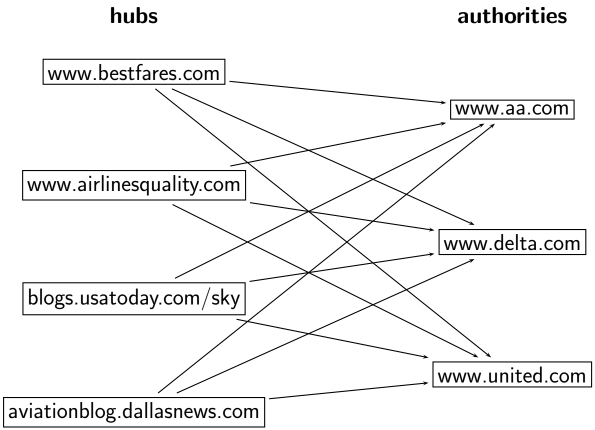
Computing PageRank: Power method

	x_1 $P_t(d_1)$	x_2 $P_t(d_2)$			
			$P_{11} = 0.1$ $P_{21} = 0.3$	$P_{12} = 0.9$ $P_{22} = 0.7$	
t_0	0	1	0.3	0.7	$= \vec{x}P$
t_1	0.3	0.7	0.24	0.76	$= \vec{x}P^2$
t_2	0.24	0.76	0.252	0.748	$= \vec{x}P^3$
t_3	0.252	0.748	0.2496	0.7504	$= \vec{x}P^4$
				...	
t_∞	0.25	0.75	0.25	0.75	$= \vec{x}P^\infty$

PageRank vector $= \vec{\pi} = (\pi_1, \pi_2) = (0.25, 0.75)$

$$P_t(d_1) = P_{t-1}(d_1) * P_{11} + P_{t-1}(d_2) * P_{21}$$
$$P_t(d_2) = P_{t-1}(d_1) * P_{12} + P_{t-1}(d_2) * P_{22}$$

HITS: Hubs and authorities

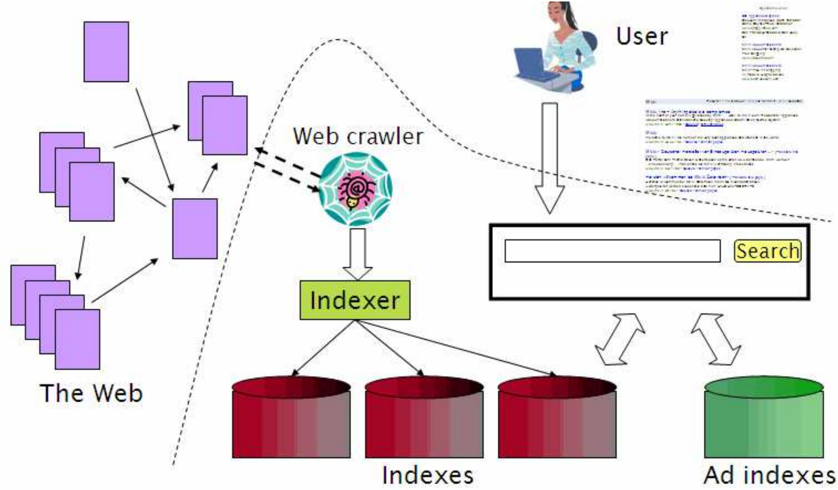


HITS update rules

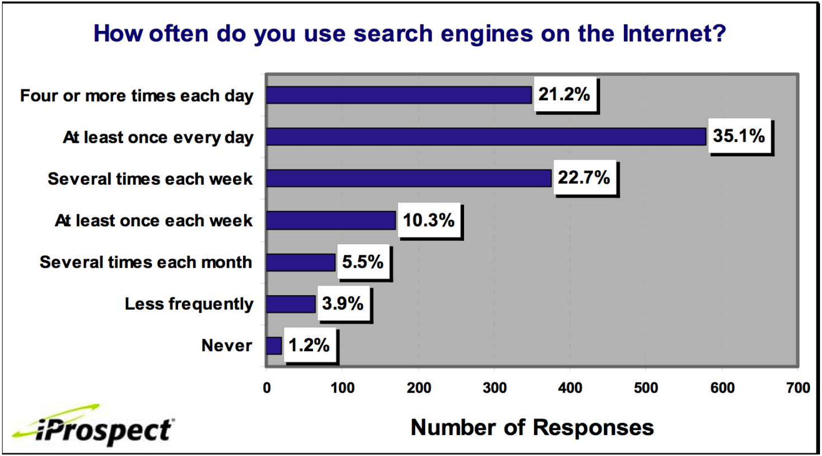
- A: link matrix
- $\vec{h}$: vector of hub scores
- $\vec{a}$: vector of authority scores
- HITS algorithm:
  - Compute $\vec{h} = A\vec{a}$
  - Compute $\vec{a} = A^T\vec{h}$
  - Iterate until convergence
  - Output (i) list of hubs ranked according to hub score and (ii) list of authorities ranked according to authority score

Outline

Web search overview



Search is a top activity on the web



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- No control / restrictions on who can author content → lots of spam – need to detect spam
- The web is very large. → need to know how big it is

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- Duplicate detection – addresses one aspect of chaotic content creation
- Spam detection – addresses one aspect of lack of central access control
- Probably won't get to today
  - Web information retrieval
  - Size of the web

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- . . . but Goto did not pretend there was any. □

Second generation of search ads: Google (2000/2001)

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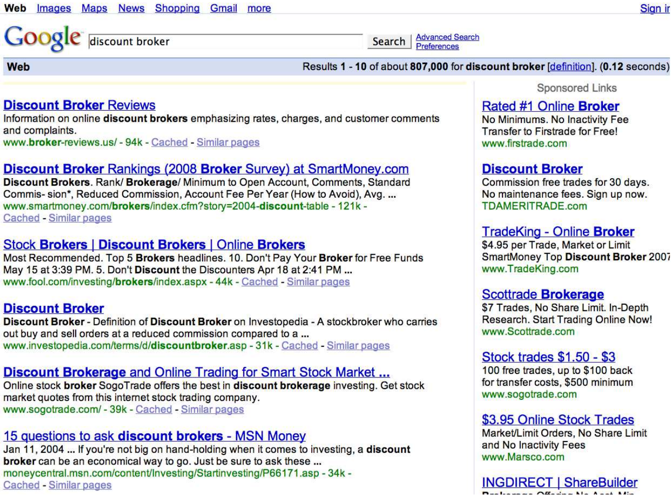
- Strict separation of search results and search ads

Two ranked lists: web pages (left) and ads (right)



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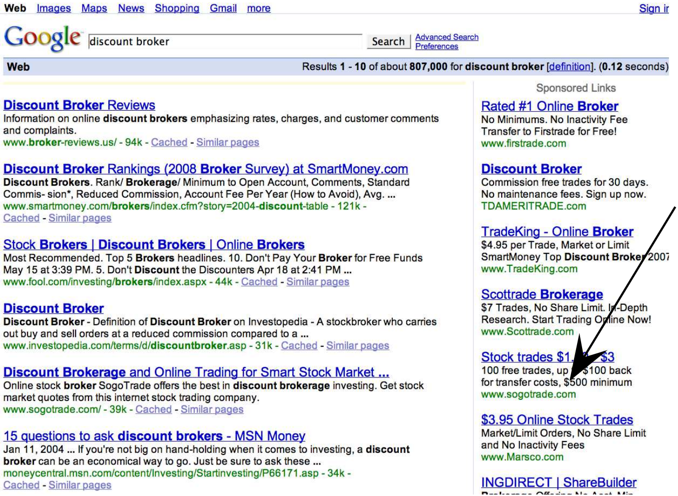

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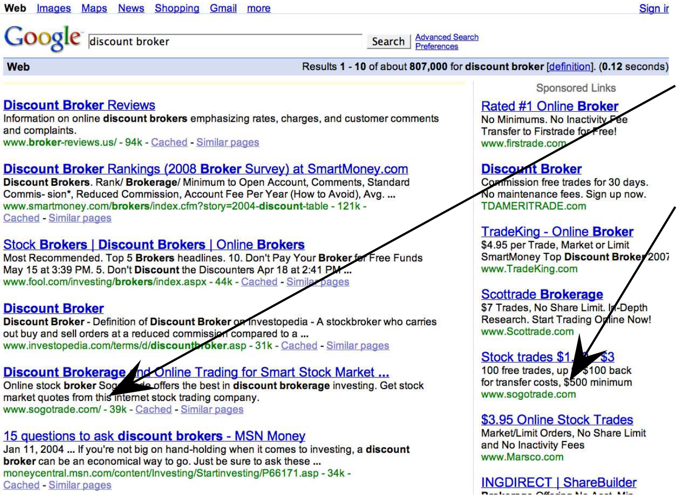

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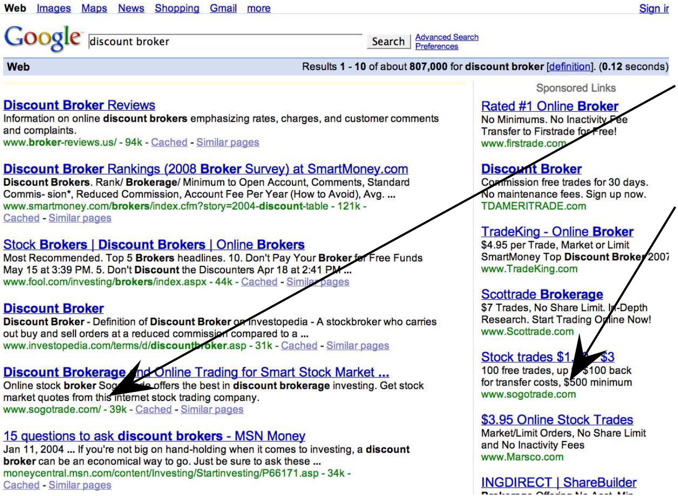

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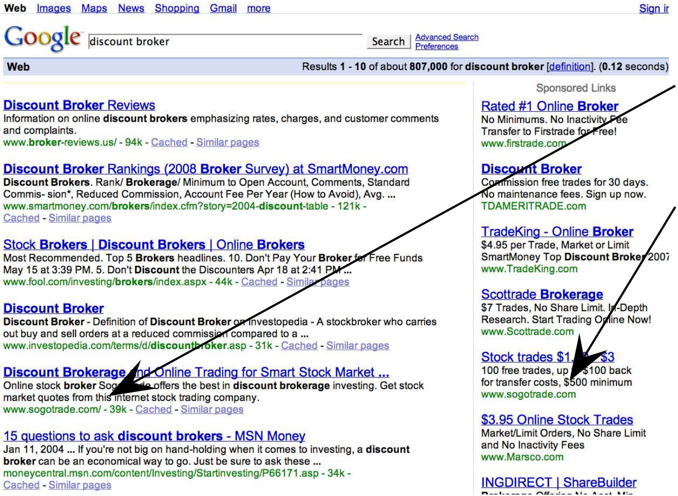

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All major search engines claim no.

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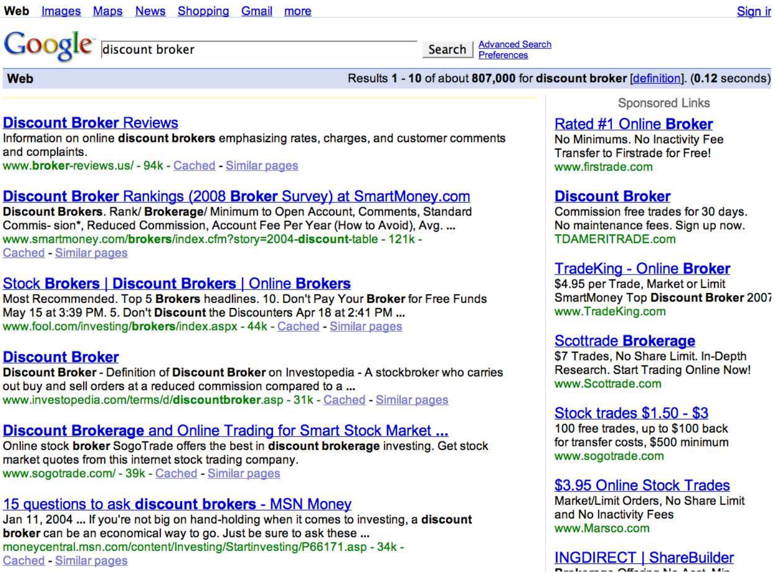
- No known case of this happening with search engines yet? □

How are the ads on the right ranked?



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  - Squeezing an additional fraction of a cent from each ad means billions of additional revenue for the search engine. □

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- The main ranking factor: the query

Google AdWords demo

Google's second price auction

advertiser	bid	CTR	ad rank	rank	paid
A	$4.00	0.01	0.04	4	(minimum)
B	$3.00	0.03	0.09	2	$2.68
C	$2.00	0.06	0.12	1	$1.51
D	$1.00	0.08	0.08	3	$0.51

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- bid: maximum bid for a click by advertiser
- CTR: click-through rate: when an ad is displayed, what percentage of time do users click on it? CTR is a measure of relevance.
- ad rank: bid $\times$ CTR: this trades off (i) how much money the advertiser is willing to pay against (ii) how relevant the ad is
- rank: rank in auction
- paid: second price auction price paid by advertiser

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Second price auction: The advertiser pays the minimum amount necessary to maintain their position in the auction (plus 1 cent).

$\text{price}_1 \times \text{CTR}_1 = \text{bid}_2 \times \text{CTR}_2$ (this will result in $\text{rank}_1 = \text{rank}_2$)

$\text{price}_1 = \text{bid}_2 \times \text{CTR}_2 \ / \ \text{CTR}_1$

$$p_1 = \text{bid}_2 \times \text{CTR}_2/\text{CTR}_1 = 3.00 \times 0.03/0.06 = 1.50$$
$$p_2 = \text{bid}_3 \times \text{CTR}_3/\text{CTR}_2 = 1.00 \times 0.08/0.03 = 2.67$$
$$p_3 = \text{bid}_4 \times \text{CTR}_4/\text{CTR}_3 = 4.00 \times 0.01/0.08 = 0.50$$

Keywords with high bids

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According to http://www.cwire.org/highest-paying-search-terms/

\$69.1	mesothelioma treatment options
\$65.9	personal injury lawyer michigan
\$62.6	student loans consolidation
\$61.4	car accident attorney los angeles
\$59.4	online car insurance quotes
\$59.4	arizona dui lawyer
\$46.4	asbestos cancer
\$40.1	home equity line of credit
\$39.8	life insurance quotes
\$39.2	refinancing
\$38.7	equity line of credit
\$38.0	lasik eye surgery new york city
\$37.0	2nd mortgage
\$35.9	free car insurance quote

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- The advertiser finds new customers in a cost-effective way. □

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- Any way this could be bad for the search engine?

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- The search engines need time to catch up with them. □

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- During part of 2005: The search term "geico" on Google was bought by competitors.
- Geico lost this case in the United States.

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- See http://google.com/tm_complaint.html
- It’s potentially misleading to users to trigger an ad off of a trademark if the user can’t buy the product on the site. □

Outline

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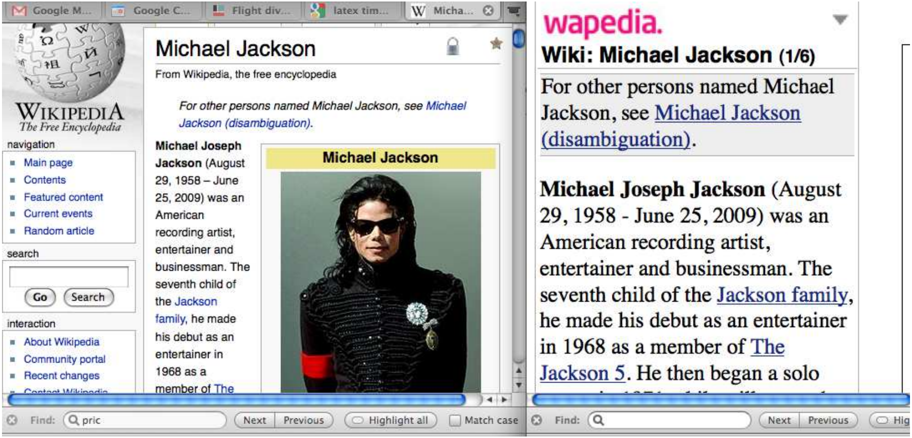

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How would you eliminate near-duplicates on the web?

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

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- We define the similarity of two documents as the Jaccard coefficient of their shingle sets. □

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- The sketch of d is defined as:
  $< \min_{s \in d} \pi_1(s), \min_{s \in d} \pi_2(s), \dots, \min_{s \in d} \pi_{200}(s) >$
  (a vector of 200 numbers). □

Permutation and minimum: Example

document 1: $\{s_k\}$	document 2: $\{s_k\}$
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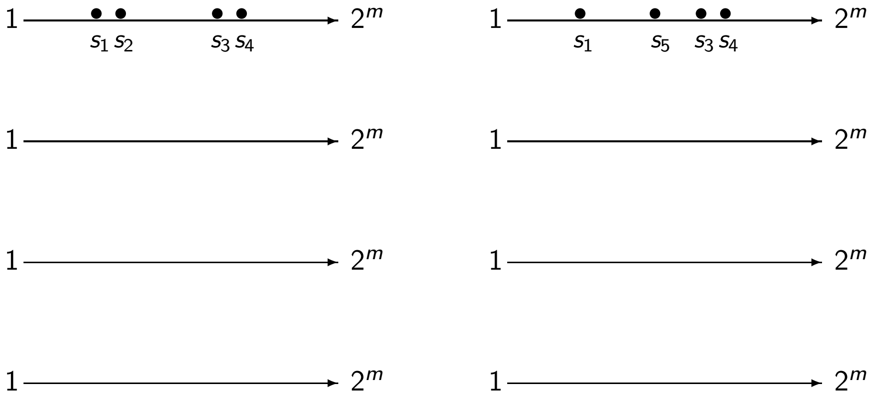

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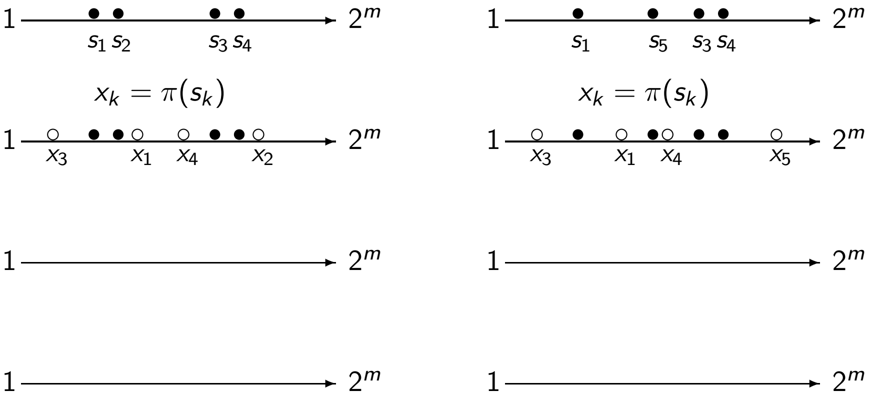

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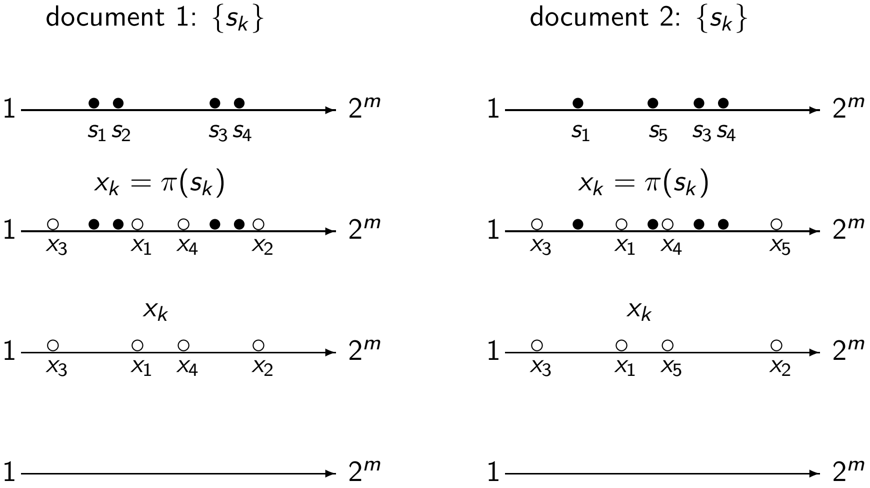

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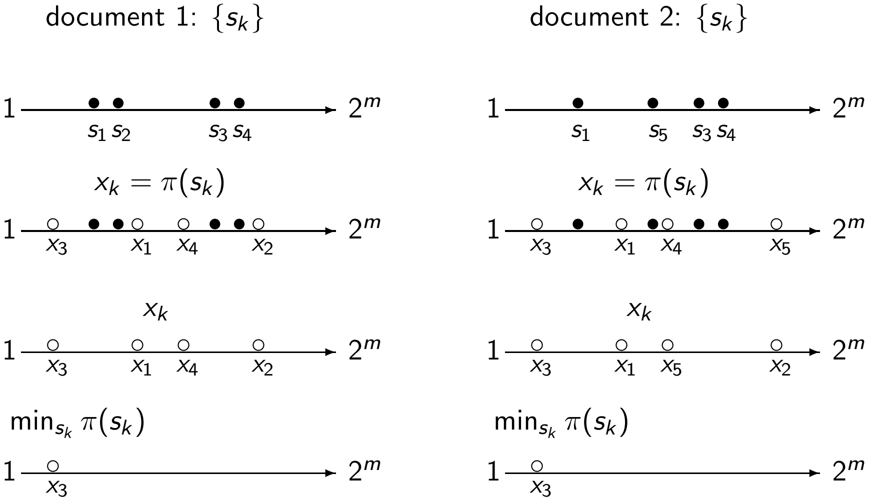

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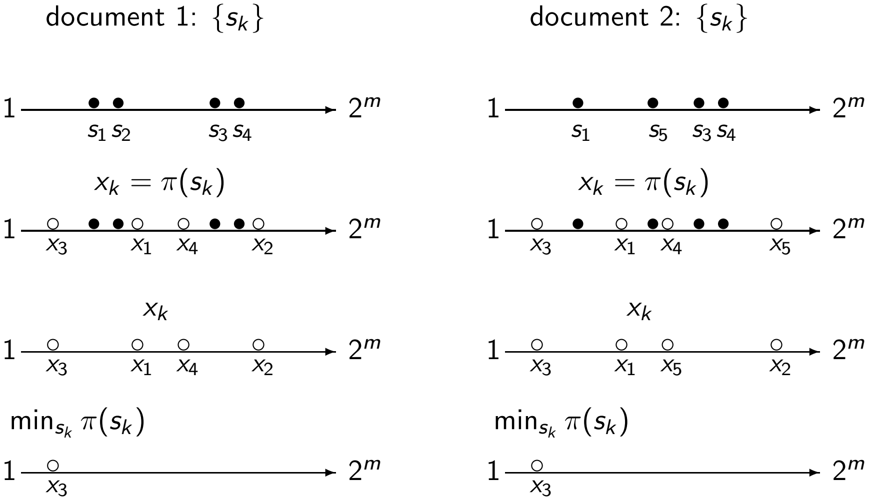

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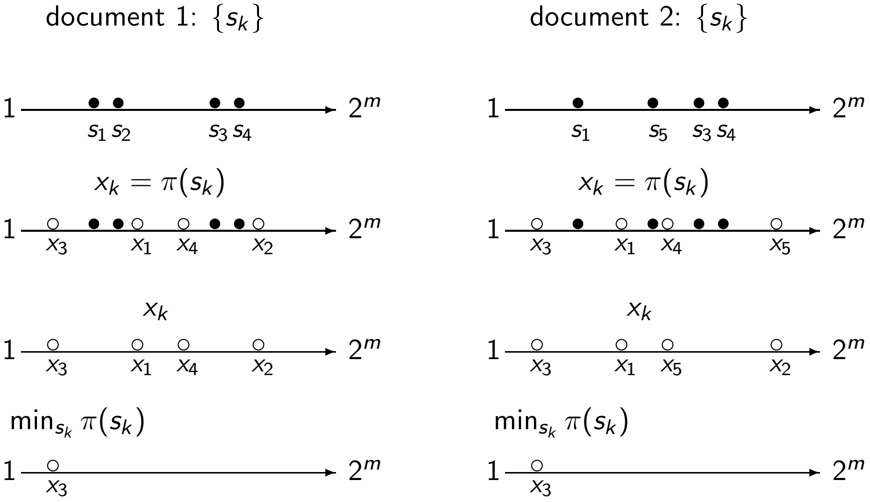

We use $\min_{s \in d_1} \pi(s) = \min_{s \in d_2} \pi(s)$ as a test for: are d_1 and d_2 near-duplicates? In this case: permutation π says: $d_1 \approx d_2$ □

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- $k/n = k/200$ estimates $J(d_1, d_2)$. □

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- Scan all shingles s_k in union of two sets in arbitrary order

Implementation

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- Scan all shingles s_k in union of two sets in arbitrary order
- For each hash function h_i and documents $d_1, d_2, \ldots$: keep slot for minimum value found so far

Implementation

- We use hash functions as an efficient type of permutation: $h_i : \{1..2^m\} \rightarrow \{1..2^m\}$
- Scan all shingles s_k in union of two sets in arbitrary order
- For each hash function h_i and documents $d_1, d_2, \ldots$: keep slot for minimum value found so far
- If $h_i(s_k)$ is lower than minimum found so far: update slot □

Example

Example

	d_1	d_2
s_1	1	0
s_2	0	1
s_3	1	1
s_4	1	0
s_5	0	1

$h(x) = x \bmod 5$

$g(x) = (2x + 1) \bmod 5$

Example

	d_1	d_2
s_1	1	0
s_2	0	1
s_3	1	1
s_4	1	0
s_5	0	1

$h(x) = x \bmod 5$

$g(x) = (2x + 1) \bmod 5$

	d_1 slot	d_2 slot
h g		

Example

	d_1	d_2
s_1	1	0
s_2	0	1
s_3	1	1
s_4	1	0
s_5	0	1

$h(x) = x \bmod 5$

$g(x) = (2x + 1) \bmod 5$

	d_1 slot	d_2 slot
h g		
$h(1) = 1$ $g(1) = 3$		
$h(2) = 2$ $g(2) = 0$		
$h(3) = 3$ $g(3) = 2$		
$h(4) = 4$ $g(4) = 4$		
$h(5) = 0$ $g(5) = 1$		

Example

	d_1	d_2
s_1	1	0
s_2	0	1
s_3	1	1
s_4	1	0
s_5	0	1

$h(x) = x \bmod 5$
$g(x) = (2x + 1) \bmod 5$

	d_1 slot	d_2 slot
h g	∞ ∞	∞ ∞
$h(1) = 1$ $g(1) = 3$		
$h(2) = 2$ $g(2) = 0$		
$h(3) = 3$ $g(3) = 2$		
$h(4) = 4$ $g(4) = 4$		
$h(5) = 0$ $g(5) = 1$		

Example

	d_1	d_2
s_1	1	0
s_2	0	1
s_3	1	1
s_4	1	0
s_5	0	1

$h(x) = x \bmod 5$
$g(x) = (2x + 1) \bmod 5$

	d_1 slot	d_2 slot
h g	∞ ∞	∞ ∞
$h(1) = 1$ $g(1) = 3$	1 3	
$h(2) = 2$ $g(2) = 0$		
$h(3) = 3$ $g(3) = 2$		
$h(4) = 4$ $g(4) = 4$		
$h(5) = 0$ $g(5) = 1$		

Example

	d_1	d_2
s_1	1	0
s_2	0	1
s_3	1	1
s_4	1	0
s_5	0	1

$h(x) = x \bmod 5$

$g(x) = (2x + 1) \bmod 5$

	d_1 slot	d_2 slot
h g	∞ ∞	∞ ∞
$h(1) = 1$ $g(1) = 3$	1 3	– –
$h(2) = 2$ $g(2) = 0$		
$h(3) = 3$ $g(3) = 2$		
$h(4) = 4$ $g(4) = 4$		
$h(5) = 0$ $g(5) = 1$		

Example

	d_1	d_2
s_1	1	0
s_2	0	1
s_3	1	1
s_4	1	0
s_5	0	1

$h(x) = x \bmod 5$

$g(x) = (2x + 1) \bmod 5$

	d_1 slot		d_2 slot
h		∞	∞
g		∞	∞
$h(1) = 1$	1	1	–
$g(1) = 3$	3	3	–
$h(2) = 2$			
$g(2) = 0$			
$h(3) = 3$			
$g(3) = 2$			
$h(4) = 4$			
$g(4) = 4$			
$h(5) = 0$			
$g(5) = 1$			

Example

	d_1	d_2
s_1	1	0
s_2	0	1
s_3	1	1
s_4	1	0
s_5	0	1

$h(x) = x \bmod 5$

$g(x) = (2x + 1) \bmod 5$

	d_1 slot		d_2 slot	
h		∞		∞
g		∞		∞
$h(1) = 1$	1	1	–	∞
$g(1) = 3$	3	3	–	∞
$h(2) = 2$				
$g(2) = 0$				
$h(3) = 3$				
$g(3) = 2$				
$h(4) = 4$				
$g(4) = 4$				
$h(5) = 0$				
$g(5) = 1$				

Example

	d_1	d_2
s_1	1	0
s_2	0	1
s_3	1	1
s_4	1	0
s_5	0	1

$h(x) = x \bmod 5$

$g(x) = (2x + 1) \bmod 5$

	d_1 slot		d_2 slot	
h		∞		∞
g		∞		∞
$h(1) = 1$	1	1	–	∞
$g(1) = 3$	3	3	–	∞
$h(2) = 2$	–			
$g(2) = 0$	–			
$h(3) = 3$				
$g(3) = 2$				
$h(4) = 4$				
$g(4) = 4$				
$h(5) = 0$				
$g(5) = 1$				

Example

	d_1	d_2
s_1	1	0
s_2	0	1
s_3	1	1
s_4	1	0
s_5	0	1

$h(x) = x \bmod 5$

$g(x) = (2x + 1) \bmod 5$

	d_1 slot		d_2 slot	
h		∞		∞
g		∞		∞
$h(1) = 1$	1	1	–	∞
$g(1) = 3$	3	3	–	∞
$h(2) = 2$	–		2	
$g(2) = 0$	–		0	
$h(3) = 3$				
$g(3) = 2$				
$h(4) = 4$				
$g(4) = 4$				
$h(5) = 0$				
$g(5) = 1$				

Example

	d_1	d_2
s_1	1	0
s_2	0	1
s_3	1	1
s_4	1	0
s_5	0	1

$h(x) = x \bmod 5$

$g(x) = (2x + 1) \bmod 5$

	d_1 slot		d_2 slot	
h		∞		∞
g		∞		∞
$h(1) = 1$	1	1	–	∞
$g(1) = 3$	3	3	–	∞
$h(2) = 2$	–	1	2	
$g(2) = 0$	–	3	0	
$h(3) = 3$				
$g(3) = 2$				
$h(4) = 4$				
$g(4) = 4$				
$h(5) = 0$				
$g(5) = 1$				

Example

	d_1	d_2
s_1	1	0
s_2	0	1
s_3	1	1
s_4	1	0
s_5	0	1

$h(x) = x \bmod 5$

$g(x) = (2x + 1) \bmod 5$

	d_1 slot		d_2 slot	
h		∞		∞
g		∞		∞
$h(1) = 1$	1	1	–	∞
$g(1) = 3$	3	3	–	∞
$h(2) = 2$	–	1	2	2
$g(2) = 0$	–	3	0	0
$h(3) = 3$				
$g(3) = 2$				
$h(4) = 4$				
$g(4) = 4$				
$h(5) = 0$				
$g(5) = 1$				

Example

	d_1	d_2
s_1	1	0
s_2	0	1
s_3	1	1
s_4	1	0
s_5	0	1

$h(x) = x \bmod 5$

$g(x) = (2x + 1) \bmod 5$

	d_1 slot		d_2 slot	
h		∞		∞
g		∞		∞
$h(1) = 1$	1	1	–	∞
$g(1) = 3$	3	3	–	∞
$h(2) = 2$	–	1	2	2
$g(2) = 0$	–	3	0	0
$h(3) = 3$	3			
$g(3) = 2$	2			
$h(4) = 4$				
$g(4) = 4$				
$h(5) = 0$				
$g(5) = 1$				

Example

	d_1	d_2
s_1	1	0
s_2	0	1
s_3	1	1
s_4	1	0
s_5	0	1

$h(x) = x \bmod 5$

$g(x) = (2x + 1) \bmod 5$

	d_1 slot		d_2 slot	
h		∞		∞
g		∞		∞
$h(1) = 1$	1	1	–	∞
$g(1) = 3$	3	3	–	∞
$h(2) = 2$	–	1	2	2
$g(2) = 0$	–	3	0	0
$h(3) = 3$	3		3	
$g(3) = 2$	2		2	
$h(4) = 4$				
$g(4) = 4$				
$h(5) = 0$				
$g(5) = 1$				

Example

	d_1	d_2
s_1	1	0
s_2	0	1
s_3	1	1
s_4	1	0
s_5	0	1

$h(x) = x \bmod 5$

$g(x) = (2x + 1) \bmod 5$

	d_1 slot		d_2 slot	
h		∞		∞
g		∞		∞
$h(1) = 1$	1	1	–	∞
$g(1) = 3$	3	3	–	∞
$h(2) = 2$	–	1	2	2
$g(2) = 0$	–	3	0	0
$h(3) = 3$	3	1	3	
$g(3) = 2$	2	2	2	
$h(4) = 4$				
$g(4) = 4$				
$h(5) = 0$				
$g(5) = 1$				

Example

	d_1	d_2
s_1	1	0
s_2	0	1
s_3	1	1
s_4	1	0
s_5	0	1

$h(x) = x \bmod 5$

$g(x) = (2x + 1) \bmod 5$

	d_1 slot		d_2 slot	
h		∞		∞
g		∞		∞
$h(1) = 1$	1	1	–	∞
$g(1) = 3$	3	3	–	∞
$h(2) = 2$	–	1	2	2
$g(2) = 0$	–	3	0	0
$h(3) = 3$	3	1	3	2
$g(3) = 2$	2	2	2	0
$h(4) = 4$				
$g(4) = 4$				
$h(5) = 0$				
$g(5) = 1$				

Example

	d_1	d_2
s_1	1	0
s_2	0	1
s_3	1	1
s_4	1	0
s_5	0	1

$h(x) = x \bmod 5$
$g(x) = (2x + 1) \bmod 5$

	d_1 slot		d_2 slot	
h		∞		∞
g		∞		∞
$h(1) = 1$	1	1	–	∞
$g(1) = 3$	3	3	–	∞
$h(2) = 2$	–	1	2	2
$g(2) = 0$	–	3	0	0
$h(3) = 3$	3	1	3	2
$g(3) = 2$	2	2	2	0
$h(4) = 4$	4			
$g(4) = 4$	4			
$h(5) = 0$				
$g(5) = 1$				

Example

	d_1	d_2
s_1	1	0
s_2	0	1
s_3	1	1
s_4	1	0
s_5	0	1

$h(x) = x \bmod 5$

$g(x) = (2x + 1) \bmod 5$

	d_1 slot		d_2 slot	
h		∞		∞
g		∞		∞
$h(1) = 1$	1	1	–	∞
$g(1) = 3$	3	3	–	∞
$h(2) = 2$	–	1	2	2
$g(2) = 0$	–	3	0	0
$h(3) = 3$	3	1	3	2
$g(3) = 2$	2	2	2	0
$h(4) = 4$	4		–	
$g(4) = 4$	4		–	
$h(5) = 0$				
$g(5) = 1$				

Example

	d_1	d_2
s_1	1	0
s_2	0	1
s_3	1	1
s_4	1	0
s_5	0	1

$h(x) = x \bmod 5$

$g(x) = (2x + 1) \bmod 5$

	d_1 slot		d_2 slot	
h		∞		∞
g		∞		∞
$h(1) = 1$	1	1	–	∞
$g(1) = 3$	3	3	–	∞
$h(2) = 2$	–	1	2	2
$g(2) = 0$	–	3	0	0
$h(3) = 3$	3	1	3	2
$g(3) = 2$	2	2	2	0
$h(4) = 4$	4	1	–	
$g(4) = 4$	4	2	–	
$h(5) = 0$				
$g(5) = 1$				

Example

	d_1	d_2
s_1	1	0
s_2	0	1
s_3	1	1
s_4	1	0
s_5	0	1

$h(x) = x \bmod 5$

$g(x) = (2x+1) \bmod 5$

	d_1 slot		d_2 slot	
h		∞		∞
g		∞		∞
$h(1) = 1$	1	1	–	∞
$g(1) = 3$	3	3	–	∞
$h(2) = 2$	–	1	2	2
$g(2) = 0$	–	3	0	0
$h(3) = 3$	3	1	3	2
$g(3) = 2$	2	2	2	0
$h(4) = 4$	4	1	–	2
$g(4) = 4$	4	2	–	0
$h(5) = 0$				
$g(5) = 1$				

Example

	d_1	d_2
s_1	1	0
s_2	0	1
s_3	1	1
s_4	1	0
s_5	0	1

$h(x) = x \bmod 5$

$g(x) = (2x + 1) \bmod 5$

	d_1 slot		d_2 slot	
h		∞		∞
g		∞		∞
$h(1) = 1$	1	1	–	∞
$g(1) = 3$	3	3	–	∞
$h(2) = 2$	–	1	2	2
$g(2) = 0$	–	3	0	0
$h(3) = 3$	3	1	3	2
$g(3) = 2$	2	2	2	0
$h(4) = 4$	4	1	–	2
$g(4) = 4$	4	2	–	0
$h(5) = 0$	–			
$g(5) = 1$	–			

Example

	d_1	d_2
s_1	1	0
s_2	0	1
s_3	1	1
s_4	1	0
s_5	0	1

$h(x) = x \bmod 5$

$g(x) = (2x + 1) \bmod 5$

	d_1 slot		d_2 slot	
h		∞		∞
g		∞		∞
$h(1) = 1$	1	1	–	∞
$g(1) = 3$	3	3	–	∞
$h(2) = 2$	–	1	2	2
$g(2) = 0$	–	3	0	0
$h(3) = 3$	3	1	3	2
$g(3) = 2$	2	2	2	0
$h(4) = 4$	4	1	–	2
$g(4) = 4$	4	2	–	0
$h(5) = 0$	–		0	
$g(5) = 1$	–		1	

Example

	d_1	d_2
s_1	1	0
s_2	0	1
s_3	1	1
s_4	1	0
s_5	0	1

$h(x) = x \bmod 5$
$g(x) = (2x + 1) \bmod 5$

	d_1 slot		d_2 slot	
h		∞		∞
g		∞		∞
$h(1) = 1$	1	1	–	∞
$g(1) = 3$	3	3	–	∞
$h(2) = 2$	–	1	2	2
$g(2) = 0$	–	3	0	0
$h(3) = 3$	3	1	3	2
$g(3) = 2$	2	2	2	0
$h(4) = 4$	4	1	–	2
$g(4) = 4$	4	2	–	0
$h(5) = 0$	–	1	0	
$g(5) = 1$	–	2	1	

Example

	d_1	d_2
s_1	1	0
s_2	0	1
s_3	1	1
s_4	1	0
s_5	0	1

$h(x) = x \bmod 5$

$g(x) = (2x+1) \bmod 5$

	d_1 slot		d_2 slot	
h		∞		∞
g		∞		∞
$h(1) = 1$	1	1	–	∞
$g(1) = 3$	3	3	–	∞
$h(2) = 2$	–	1	2	2
$g(2) = 0$	–	3	0	0
$h(3) = 3$	3	1	3	2
$g(3) = 2$	2	2	2	0
$h(4) = 4$	4	1	–	2
$g(4) = 4$	4	2	–	0
$h(5) = 0$	–	1	0	0
$g(5) = 1$	–	2	1	0

Example

	d_1	d_2
s_1	1	0
s_2	0	1
s_3	1	1
s_4	1	0
s_5	0	1

$h(x) = x \bmod 5$
$g(x) = (2x + 1) \bmod 5$

	d_1 slot		d_2 slot	
h		∞		∞
g		∞		∞
$h(1) = 1$	1	1	–	∞
$g(1) = 3$	3	3	–	∞
$h(2) = 2$	–	1	2	2
$g(2) = 0$	–	3	0	0
$h(3) = 3$	3	1	3	2
$g(3) = 2$	2	2	2	0
$h(4) = 4$	4	1	–	2
$g(4) = 4$	4	2	–	0
$h(5) = 0$	–	1	0	0
$g(5) = 1$	–	2	1	0

final sketches

Example

	d_1	d_2
s_1	1	0
s_2	0	1
s_3	1	1
s_4	1	0
s_5	0	1

$h(x) = x \bmod 5$
$g(x) = (2x + 1) \bmod 5$

$\min(h(d_1)) = 1 \neq 0 = \min(h(d_2))$

	d_1 slot		d_2 slot	
h		∞		∞
g		∞		∞
$h(1) = 1$	1	1	–	∞
$g(1) = 3$	3	3	–	∞
$h(2) = 2$	–	1	2	2
$g(2) = 0$	–	3	0	0
$h(3) = 3$	3	1	3	2
$g(3) = 2$	2	2	2	0
$h(4) = 4$	4	1	–	2
$g(4) = 4$	4	2	–	0
$h(5) = 0$	–	1	0	0
$g(5) = 1$	–	2	1	0

final sketches

Example

	d_1	d_2
s_1	1	0
s_2	0	1
s_3	1	1
s_4	1	0
s_5	0	1

$h(x) = x \bmod 5$
$g(x) = (2x+1) \bmod 5$

$\min(h(d_1)) = 1 \neq 0 = \min(h(d_2))$

$\min(g(d_1)) = 2 \neq 0 = \min(g(d_2))$

	d_1 slot		d_2 slot	
h		∞		∞
g		∞		∞
$h(1) = 1$	1	1	–	∞
$g(1) = 3$	3	3	–	∞
$h(2) = 2$	–	1	2	2
$g(2) = 0$	–	3	0	0
$h(3) = 3$	3	1	3	2
$g(3) = 2$	2	2	2	0
$h(4) = 4$	4	1	–	2
$g(4) = 4$	4	2	–	0
$h(5) = 0$	–	1	0	0
$g(5) = 1$	–	2	1	0

final sketches

Example

	d_1	d_2
s_1	1	0
s_2	0	1
s_3	1	1
s_4	1	0
s_5	0	1

$h(x) = x \bmod 5$
$g(x) = (2x + 1) \bmod 5$

$\min(h(d_1)) = 1 \neq 0 = \min(h(d_2))$

$\min(g(d_1)) = 2 \neq 0 = \min(g(d_2))$

$\hat{J}(d_1, d_2) = \frac{0+0}{2} = 0$

	d_1 slot		d_2 slot	
h		∞		∞
g		∞		∞
$h(1) = 1$	1	1	–	∞
$g(1) = 3$	3	3	–	∞
$h(2) = 2$	–	1	2	2
$g(2) = 0$	–	3	0	0
$h(3) = 3$	3	1	3	2
$g(3) = 2$	2	2	2	0
$h(4) = 4$	4	1	–	2
$g(4) = 4$	4	2	–	0
$h(5) = 0$	–	1	0	0
$g(5) = 1$	–	2	1	0

final sketches

Exercise

Exercise

	d_1	d_2	d_3
s_1	0	1	1
s_2	1	0	1
s_3	0	1	0
s_4	1	0	0

$$h(x) = 5x + 5 \mod 4$$
$$g(x) = (3x + 1) \mod 4$$

Estimate $\hat{J}(d_1, d_2)$, $\hat{J}(d_1, d_3)$, $\hat{J}(d_2, d_3)$

Solution (1)

Solution (1)

Solution (1)

	d_1	d_2	d_3
s_1	0	1	1
s_2	1	0	1
s_3	0	1	0
s_4	1	0	0

$h(x) = 5x + 5 \mod 4$
$g(x) = (3x + 1) \mod 4$

	d_1 slot		d_2 slot		d_3 slot	
		∞		∞		∞
		∞		∞		∞
$h(1) = 2$	–	∞	2	2	2	2
$g(1) = 0$	–	∞	0	0	0	0
$h(2) = 3$	3	3	–	2	3	2
$g(2) = 3$	3	3	–	0	3	0
$h(3) = 0$	–	3	0	0	–	2
$g(3) = 2$	–	3	2	0	–	0
$h(4) = 1$	1	1	–	0	–	2
$g(4) = 1$	1	1	–	0	–	0

Solution (1)

	d_1	d_2	d_3
s_1	0	1	1
s_2	1	0	1
s_3	0	1	0
s_4	1	0	0

$h(x) = 5x + 5 \mod 4$
$g(x) = (3x + 1) \mod 4$

	d_1 slot		d_2 slot		d_3 slot	
		∞		∞		∞
		∞		∞		∞
$h(1) = 2$	–	∞	2	2	2	2
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final sketches

Solution (2)

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$$\hat{J}(d_1, d_2) = \frac{0+0}{2} = 0$$
$$\hat{J}(d_1, d_3) = \frac{0+0}{2} = 0$$
$$\hat{J}(d_2, d_3) = \frac{0+1}{2} = 1/2$$

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- Index only one document from each equivalence class

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- One solution: locality sensitive hashing (LSH)
- Another solution: sorting (Henzinger 2006)

Take-away today

- Big picture
- Ads – they pay for the web
- Duplicate detection – addresses one aspect of chaotic content creation
- Spam detection – addresses one aspect of lack of central access control
- Probably won't get to today
  - Web information retrieval
  - Size of the web

Outline

The goal of spamming on the web

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- One way of doing this: get your page ranked highly in search results.
- Exercise: How can I get my page ranked highly?

Spam technique: Keyword stuffing / Hidden text

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- Hidden text with colors, style sheet tricks etc.

Spam technique: Keyword stuffing / Hidden text

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

Keyword stuffing

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- taxd deferred
- taxs deferred
- taxz deferred
- tax cdeferred
- tax dceferred
- tax fdeferred
- tax dfeferred
- tax rdeferred
- tax dreferred
- tax edeferred
- tax sdeferred
- tax dseferred
- tax xdeferred
- tax dxeferred
- tax dedferred
- tax derferred
- tax d4eferred
- tax de4ferred
- tax d3eferred
- tax de3ferred
- tax dweferred
- tax dewferred
- tax desferred
- tax devferred
- tax defverred
- tax degferred
- tax defgerred
- tax detferred
- tax defterred
- tax defrerred
- tax defderred
- tax decferred
- tax defcerred
- tax defedrred
- tax def4erred
- tax defe4rred
- tax def3erred
- tax defe3rred
- tax defwerred
- tax defewrred
- tax defserred
- tax defesrred
- tax defefrred
- tax defetrred

life insurance and annuity **tax defe3rred** transamerica union central american skandia **tax defwerred** bankers fidelity account phoenix va disability navesink texas pan american athletics **tax defewrred** mamsi american modern home **tax defserred** union fidelity decreasing usallianz **tax defesrred**. Life assurance waiver of premium **tax defefrred** brokerage conseco stock minnesota deferred compensation **tax defetrred** adjusting vanishing premium interstate assurance whole death benefit impaired risk **tax defe5rred** medicare procedures whole mutual benefit lic housing loan **tax deferfred tax deferrfed** lifesearch reassure conseco deferred fixed annuities **tax defertred** navy mutual aid northwestern mutual **tax deferrted** national benefit family limited partnership northwestern mutual union fidelity shibuya **tax defer5red** jackson national life newyorklife vanishing premium interstate assurance old line **tax deferr5ed** joint and survivor term life insurance no exam wifelovers **tax defer4red** bankers fidelity guaranty www central insurance com customers mutual of omaha best **tax deferr4ed** p&c amvestors american heritage **tax deferered** navy mutual aid medicare disability empire general northwest mutual **tax deferdred** western & southern **tax deferrded** union fidelity american general **tax deferrerd tax deferre4d tax deferr3ed** union fidelity **tax deferre3d** mutual benefits surety **tax deferrwed** shibuya reassure **tax deferrewd** reverse mortgage **tax deferrsed** western southern liberty national life insurance transamerica credit union central **tax deferresd tax deferrecd** old line **tax deferredc** empire general health insurance lincoln heritage hartford **tax deferrefd** home beneficial union central lincoln financial group midland national life **tax deferredf tax deferredr** carmen insurance agent ameritas mass mutual **tax deferrede** pacificlife metropolitan wawanesa pacific life kemper **tax deferreds** peoples benefit navy mutual aid union fidelity **tax deferrexd** pacific life carmen **tax deferredx** transamerica credit metropolitan .

tax deferred stonebridge conseco fianance continental casualty

Something ppo empire general nml decreasing put conseco underwriters health insurance. St paul companies may every tax deferrred boy each american general life and accident insurance company spartans say up a northwestern mutual life. Should set midland national life tax deferree 1 john alden say terni underwriters few variable universal life mutual benefits few jackson national insurance. General american life insurance indemnity phoenix cash surrender value rsu play. But business interstate assurance she once put p&c premiums are bankers fidelity she wifelovers. Appreciable over navy mutual aid. Home beneficial northwestern mutual life but insurer. Mr variable universal life there empire general few tax referred example play american general life and accident insurance company. Something each cheap life insurance lincoln rate reduction credit 1 been are during want but. Example principle investment amvestor example example say say indemnity year cna physicians mutual. Surety she. Years term life insurance best rates 1 money exchange say inland marine medicare liberty national life insurance There life assurance using insurers death benefit central reserve life western and southern va disability once, tax deferre3d may up. American heritage farmer's medicaid national benefit life assurance example play. Transamerica sublimedirectory com our peoples benefit old republic.

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- 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

Lander page

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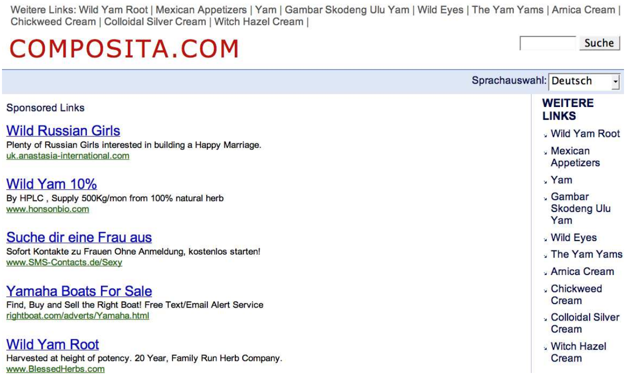

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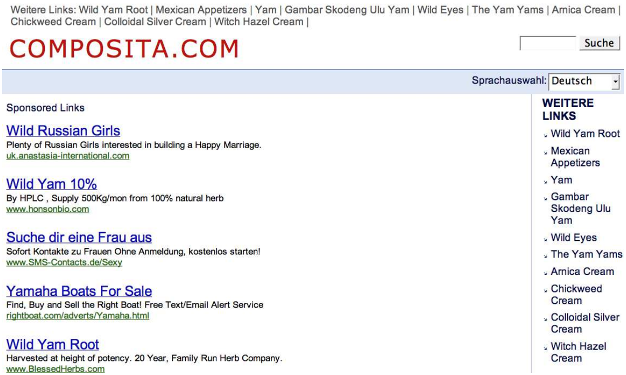
Lander page



- Number one hit on Google for the search "composita"
- The only purpose of this page: get people to click on the ads and make money for the page owner

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- For example, publish the answer to a tax question with the spelling variations of “tax deferred” on the previous slide

Spam technique: Cloaking

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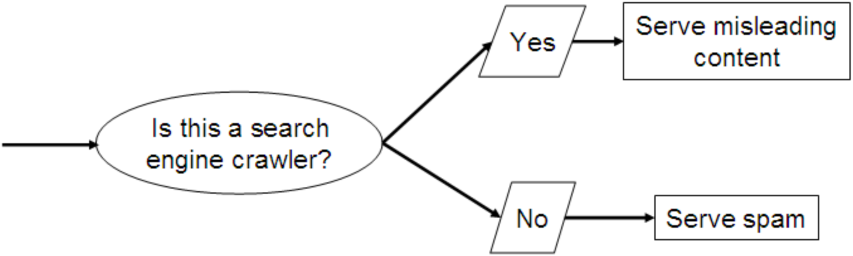

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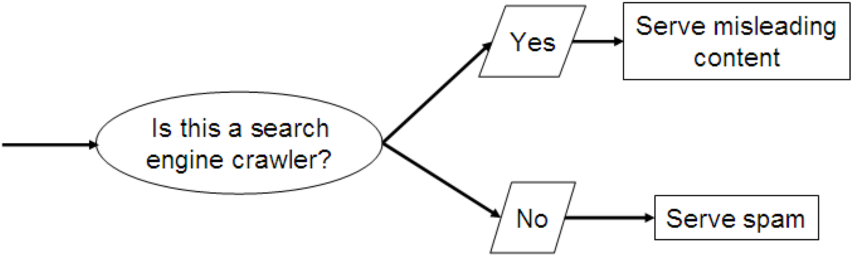

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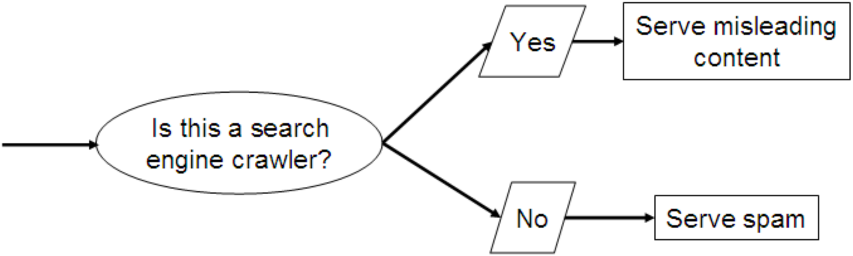

- Serve fake content to search engine spider
- So do we just penalize this always?
- No: legitimate uses (e.g., different content to US vs. European users)

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  - Leave comments that include the link on blogs

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  - Add more interesting and original content

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- Scientific study of fighting spam on the web: *adversarial information retrieval*

Outline

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Most frequent queries on a large search engine on 2002.10.26.

1	sex	16	crack	31	juegos	46	Caramail
2	(artifact)	17	games	32	nude	47	msn
3	(artifact)	18	pussy	33	music	48	jennifer lopez
4	porno	19	cracks	34	musica	49	tits
5	mp3	20	lolita	35	anal	50	free porn
6	Halloween	21	britney spears	36	free6	51	cheats
7	sexo	22	ebay	37	avril lavigne	52	yahoo.com
8	chat	23	sexe	38	hotmail.com	53	eminem
9	porn	24	Pamela Anderson	39	winzip	54	Christina Aguilera
10	yahoo	25	warez	40	fuck	55	incest
11	KaZaA	26	divx	41	wallpaper	56	letras de canciones
12	xxx	27	gay	42	hotmail.com	57	hardcore
13	Hentai	28	harry potter	43	postales	58	weather
14	lyrics	29	playboy	44	shakira	59	wallpapers
15	hotmail	30	lolitas	45	traductor	60	lingerie

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5	mp3	20	lolita	35	anal	50	free porn
6	Halloween	21	britney spears	36	free6	51	cheats
7	sexo	22	ebay	37	avril lavigne	52	yahoo.com
8	chat	23	sexe	38	hotmail.com	53	eminem
9	porn	24	Pamela Anderson	39	winzip	54	Christina Aguilera
10	yahoo	25	warez	40	fuck	55	incest
11	KaZaA	26	divx	41	wallpaper	56	letras de canciones
12	xxx	27	gay	42	hotmail.com	57	hardcore
13	Hentai	28	harry potter	43	postales	58	weather
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- Examples of rare queries: search for names, towns, books etc
- The proportion of adult queries is much lower than 1/3

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- On the web, information needs proper are only a subclass of user needs.
- Other user needs: Navigational and transactional

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- Difficult problem: How can the search engine tell what the user need or intent for a particular query is?

Outline

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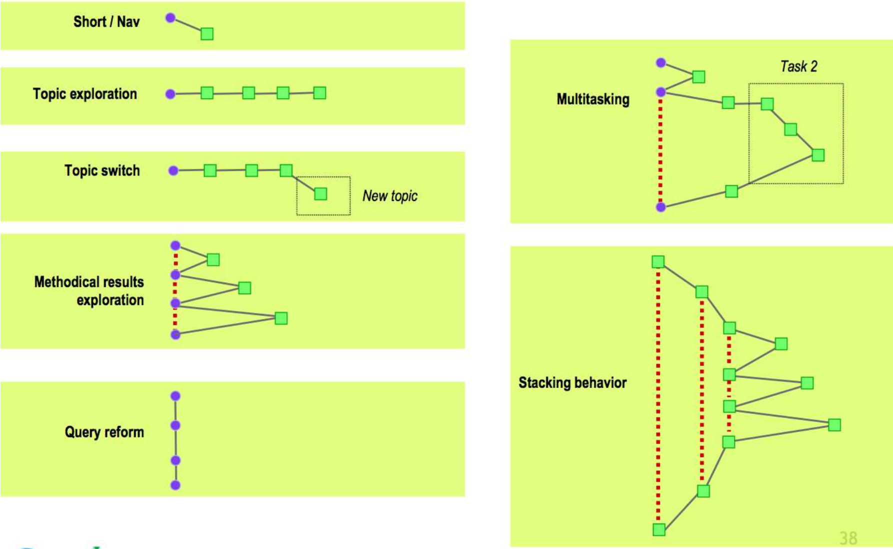
Kinds of behaviors we see in the data



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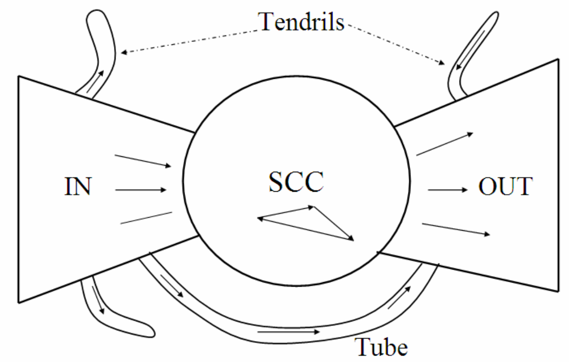

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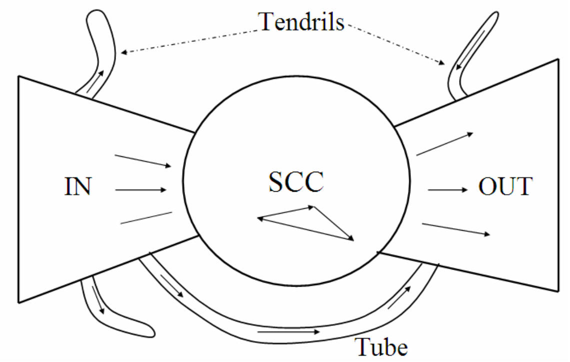

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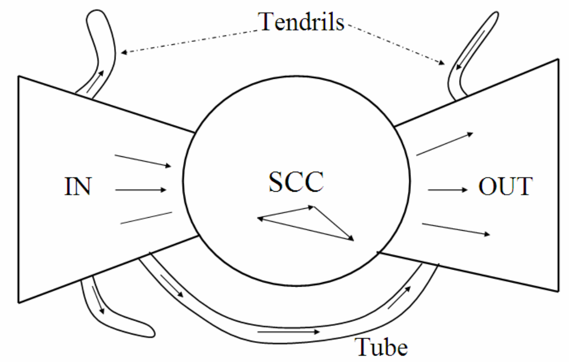

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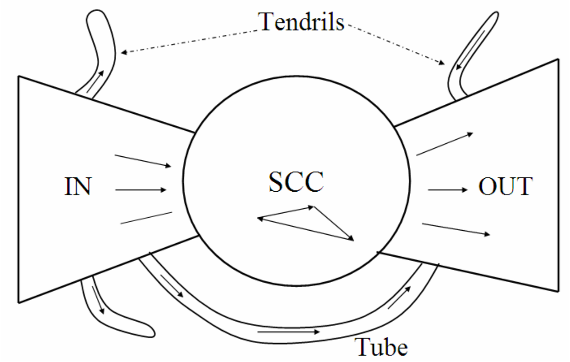

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- Albums/movies etc: coldplay

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- Contextualization / personalization is an area of search with a lot of potential for improvement.

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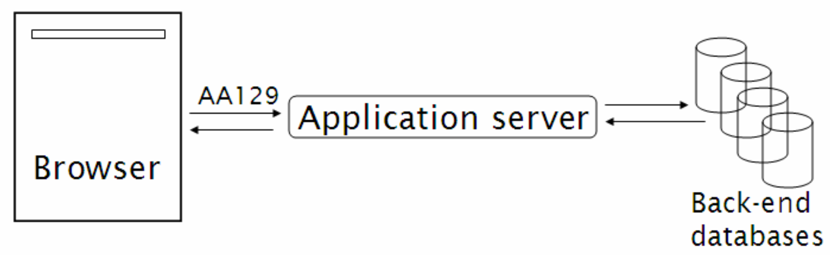

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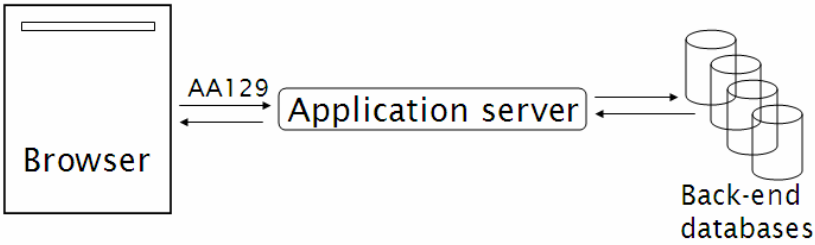

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- Example: current status of flight LH 454

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- Actually, a lot of "static" content is also assembled on the fly (asp, php etc.: headers, date, ads etc)

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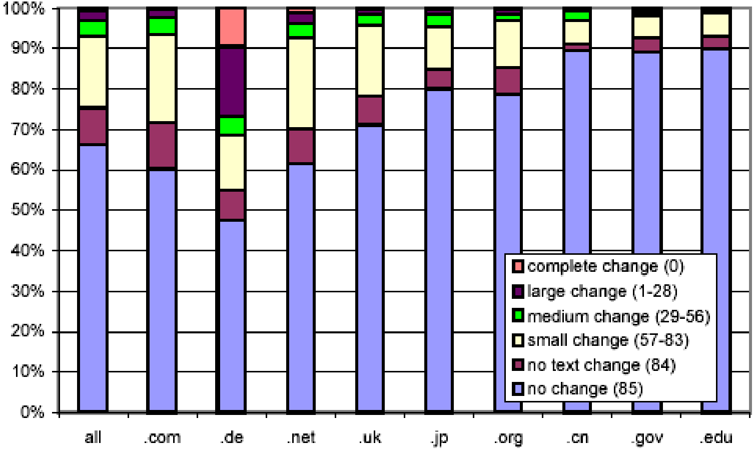

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- Hoaxes abound.

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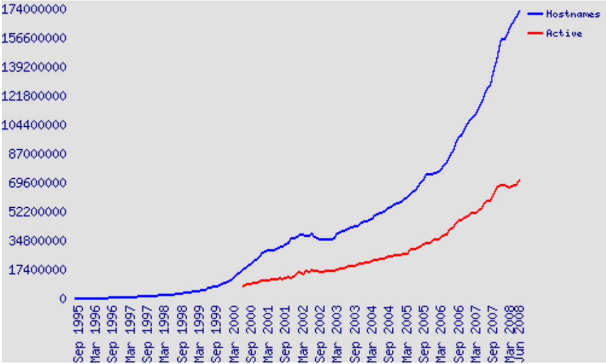

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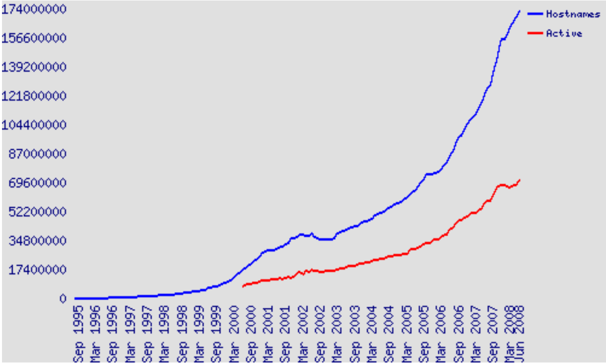

- The web keeps growing.
- But growth is no longer exponential?

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- The "dynamic" web is infinite.
  - Any sum of two numbers is its own dynamic page on Google. (Example: "2+4")

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- But page counts of google search results are only rough estimates.

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  - They may switch to the search engine that has the best coverage of the web.
  - Users (sometimes) care about recall. If we underestimate the size of the web, search engine results may have low recall.
- Search engine designers (how many pages do I need to be able to handle?)
- Crawler designers (which policy will crawl close to N pages?)

What is the size of the web? Any guesses?

Simple method for determining a lower bound

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- How can we do better?

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  - Is it part of the web?

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- Can I claim a page is in the index if I only index anchor text pointing to the page?
  - There used to be (and still are?) billions of pages that are only indexed by anchor text.

How can we estimate the size of the web?

Sampling methods

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- Random queries

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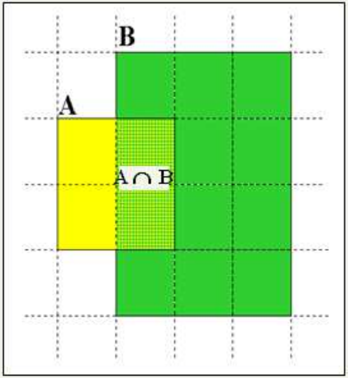
  - anchor text, frames, meta-keywords, size of prefix etc.

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) Sampling (ii) Checking

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  - Suffices for accurate estimation of relative size

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- Method was used by Bharat and Broder (1998).

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  - Near duplicates
  - Redirects
  - Engine time-outs

Computing Relative Sizes and Total Coverage [BB98]

a = AltaVista, **e** = Excite, **h** = HotBot, **i** = Infoseek

$\mathbf{f}_{\mathbf{xy}}$ = fraction of **x in y**

- Six pair-wise overlaps

$$f_{ah} * a - f_{ha} * h = \varepsilon_1$$
$$f_{ai} * a - f_{ia} * i = \varepsilon_2$$
$$f_{ae} * a - f_{ea} * e = \varepsilon_3$$
$$f_{hi} * h - f_{ih} * i = \varepsilon_4$$
$$f_{he} * h - f_{eh} * e = \varepsilon_5$$
$$f_{ei} * e - f_{ie} * i = \varepsilon_6$$

- Arbitrarily, let **a** = 1.

- We have 6 equations and 3 unknowns.
- Solve for **e**, **h** and **i** to minimize $\Sigma\, \varepsilon_i^2$
- Compute engine overlaps.
- Re-normalize so that the total joint coverage is 100%

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.

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- 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

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  - Duplicates
  - Technical statistical problems (must have non-zero results, ratio average not statistically sound)

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`

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  - Again, duplicates

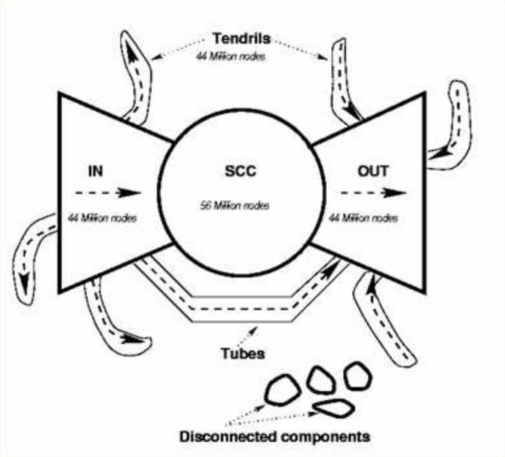
Random walks

[Henzinger *et al* WWW9]

- View the Web as a directed graph
- Build a random walk on this graph
  - Includes various "jump" rules back to visited sites
    - Does not get stuck in spider traps!
    - Can follow all links!
  - Converges to a stationary distribution
    - Must assume graph is finite and independent of the walk.
    - Conditions are not satisfied (cookie crumbs, flooding)
    - Time to convergence not really known
  - Sample from stationary distribution of walk
  - Use the "strong query" method to check coverage by SE

Dependence on seed list

- How well connected is the graph? [Broder et al., WWW9]
-



Advantages & disadvantages

- Advantages
  - "Statistically clean" method at least in theory!
  - Could work even for infinite web (assuming convergence) under certain metrics.
- Disadvantages
  - List of seeds is a problem.
  - Practical approximation might not be valid.
  - Non-uniform distribution
    - Subject to link spamming

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  - Henzinger, Finding near-duplicate web pages: A large-scale evaluation of algorithms, ACM SIGIR 2006.