The CMU machine learning protesters

ALL SIZES

http://www.flickr.com/photos/30686429@N07/3953914015/in/set-72157622330082619/

Web basics

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cs160
Fall 2009
adapted from:
http://www.stanford.edu/class/cs276/handouts/lecture13-webchar.ppt

Administrative

- CS lunch today!
- Unique hw5
  - reading
  - course feedback
- Schedule

Boolean queries

- c OR a AND f
- a AND f OR c

c b d

e d c

b d f

a f e

Outline

- Brief overview of the web
- Web Spam
- Estimating the size of the web
- Detecting duplicate pages

Brief (non-technical) history

- Early keyword-based engines
  - Altavista, Excite, Infoseek, Inktomi, ca. 1995-1997
- 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!

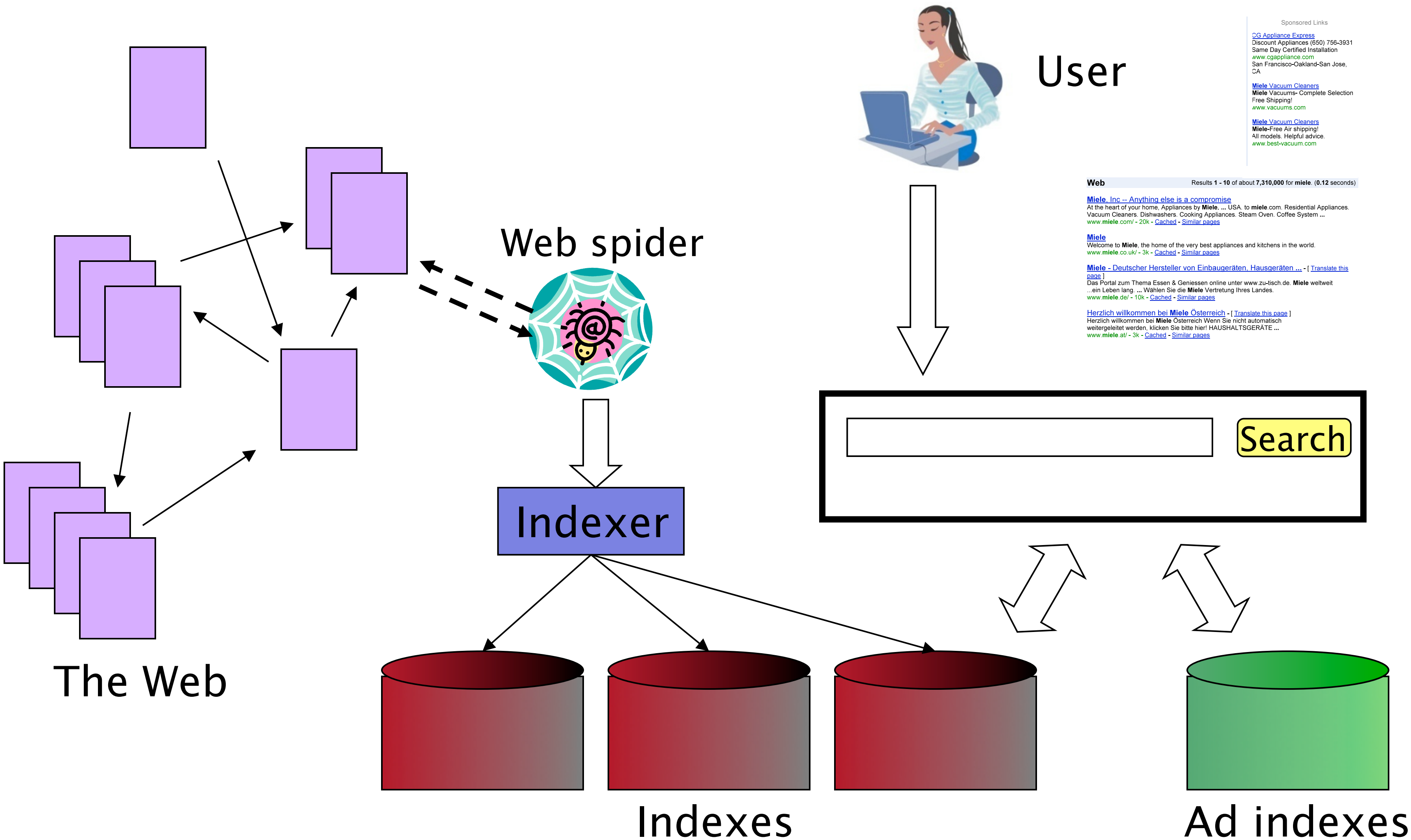
Brief (non-technical) history

- 1998+: Link-based ranking pioneered by Google
  - Blew away all early engines save Inktomi
  - 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)

Why did Google win?

- Relevance/link-based
- Simple UI
- Hardware – used commodity parts
  - inexpensive
  - easy to expand
  - fault tolerance through redundancy
- What's wrong (from the search engine's standpoint) of having a cost-per-click (CPC) model and ranking ads based only on CPC?

Web search basics



User needs/queries

- Researchers/search engines often categorize user needs/queries into different types
- For example…?

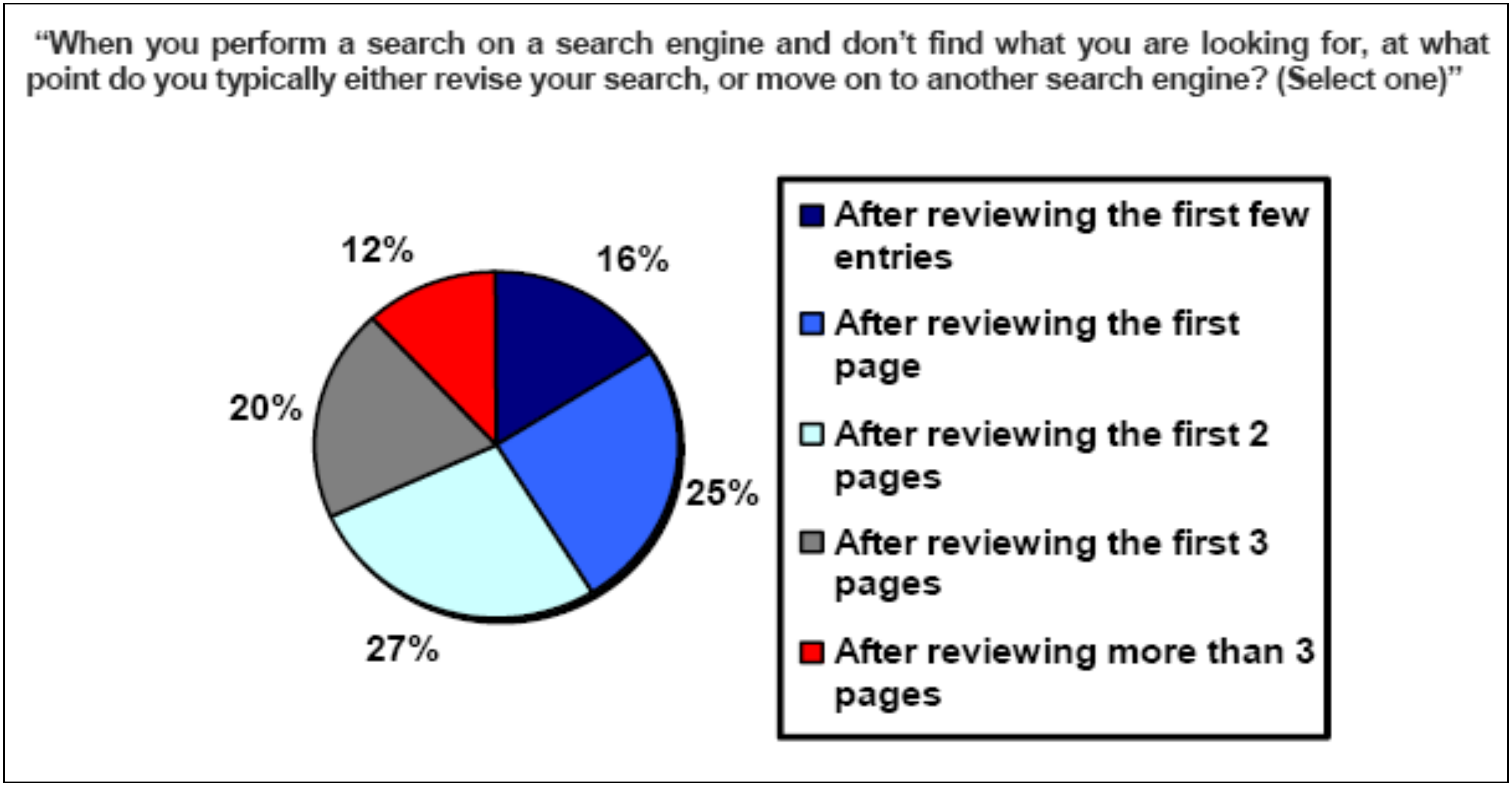
User Needs

- Need [Brod02, RL04]
  - **Informational** – want to learn about something (~40%)

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

    United Airlines
  - **Transactional** – want to do something (web-mediated) (~35%)
    - Access a service — Seattle weather
    - Downloads — Mars surface images
    - Shop — Canon S410
  - **Gray areas**
    - Find a good hub — Car rental Brasil
    - Exploratory search "see what's there"

How far do people look for results?

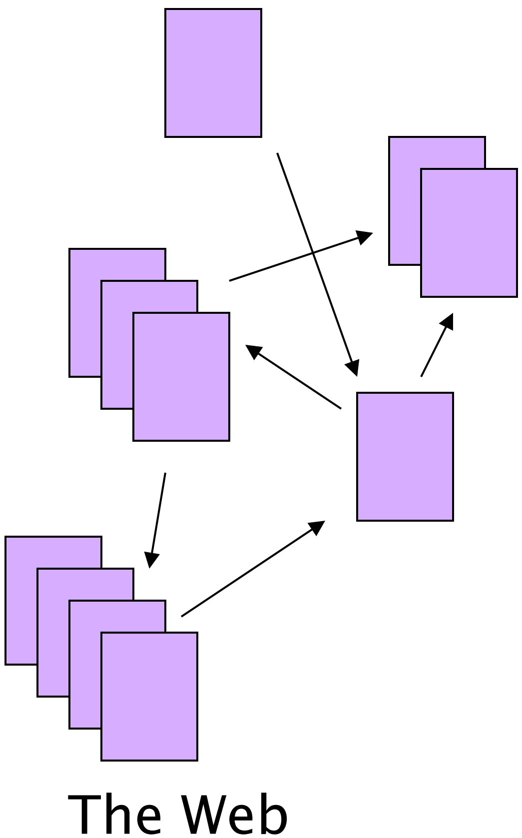


(Source: iprospect.com WhitePaper_2006_SearchEngineUserBehavior.pdf)

Users' empirical evaluation of results

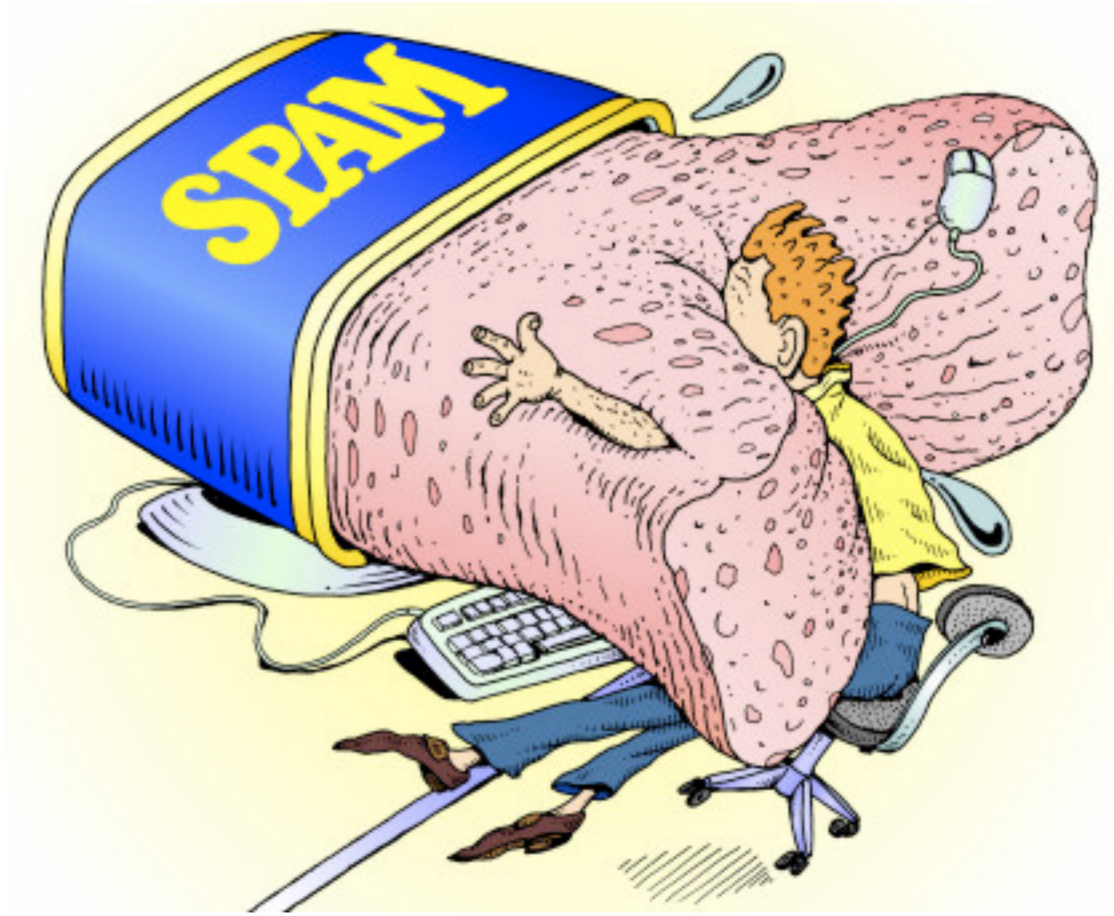
- Quality of pages varies widely
  - Relevance is not enough
  - Other desirable qualities (non IR!!)
    - Content: Trustworthy, diverse, non-duplicated, well maintained
    - Web readability: display correctly & fast
    - No annoyances: pop-ups, etc
- Precision vs. recall
  - On the web, recall seldom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

The Web document collection



- No design/co-ordination
- Content includes truth, lies, obsolete information, contradictions …
- Unstructured (text, html, …), semi-structured (XML, annotated photos), structured (Databases)…
- Financial motivation for ranked results
- Scale much larger than previous text collections … but corporate records are catching up
- Growth – slowed down from initial “volume doubling every few months” but still expanding
- Content can be *dynamically generated*

Web Spam



http://blog.lib.umn.edu/wilsper/informationcentral/spam.jpg

The trouble with sponsored search …

- It costs money. What's the alternative?
- *Search Engine Optimization:*
  - "Tuning" your web page to rank highly in the algorithmic search results for select keywords
  - Alternative to paying for placement
  - Intrinsically a marketing function
- Performed by companies, webmasters and consultants ("Search engine optimizers") for their clients
- Some perfectly legitimate, some very shady

Simplest forms

- First generation engines relied heavily on *tf/idf*
- What would you do as an SEO?
- 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

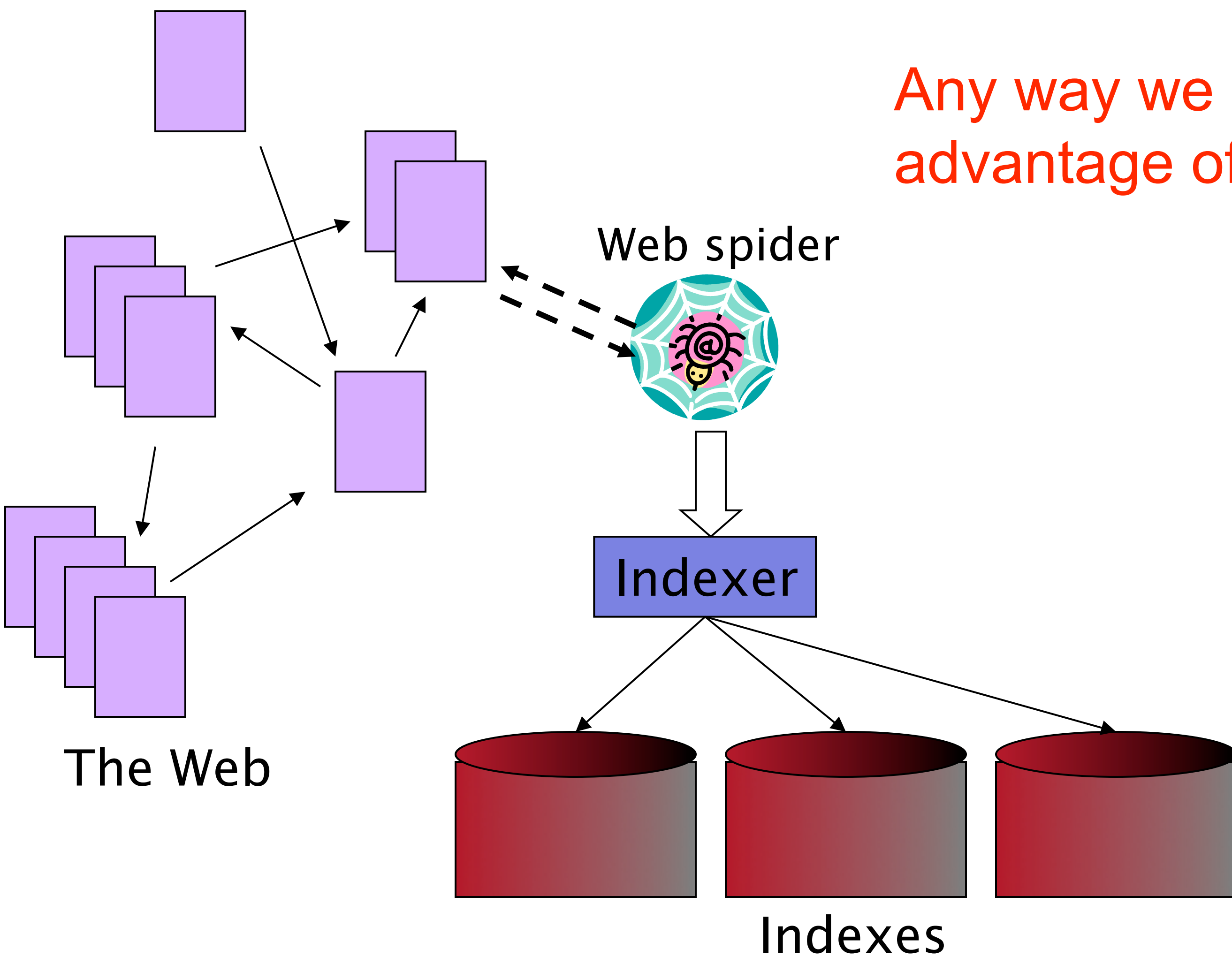
Pure word density cannot be trusted as an IR signal

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, …"

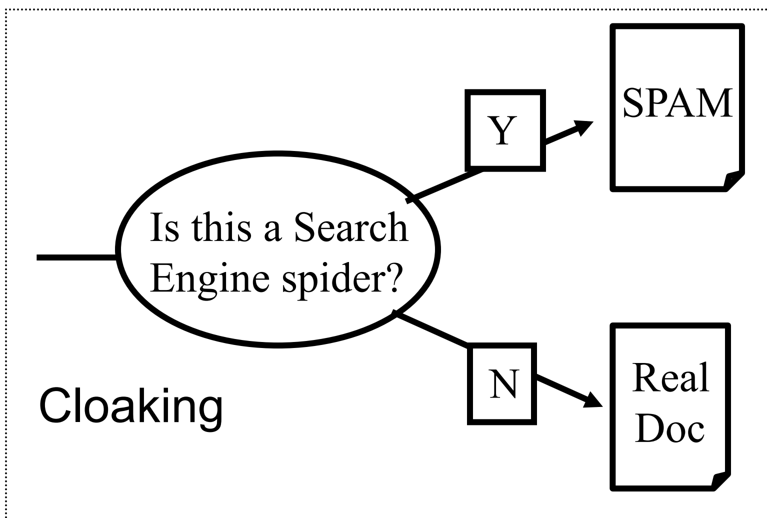
Spidering/indexing



Any way we can take advantage of this system?

Cloaking

- Serve fake content to search engine spider



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

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/

Size of the web

http://www.stormforce31.com/wximages/www.jpg

What is the size of the web?

- 7,452,502,600,001 pages (as of yesterday)
- The web is really infinite
  - Dynamic content, e.g., calendar
  - Soft 404: www.yahoo.com/<anything> is a valid page
- What about just the static web… issues?
  - Static web contains syntactic duplication, mostly due to mirroring (~30%)
  - Some servers are seldom connected
  - What do we count? A url? A frame? A section? A pdf document? An image?

Who cares about the size of the web?

- It is an interesting question, but beyond that, who cares and why?

- Media, and consequently the user
- Search engine designer (crawling, indexing)
- Researchers

What can we measure?

Besides absolute size, what else might we measure?

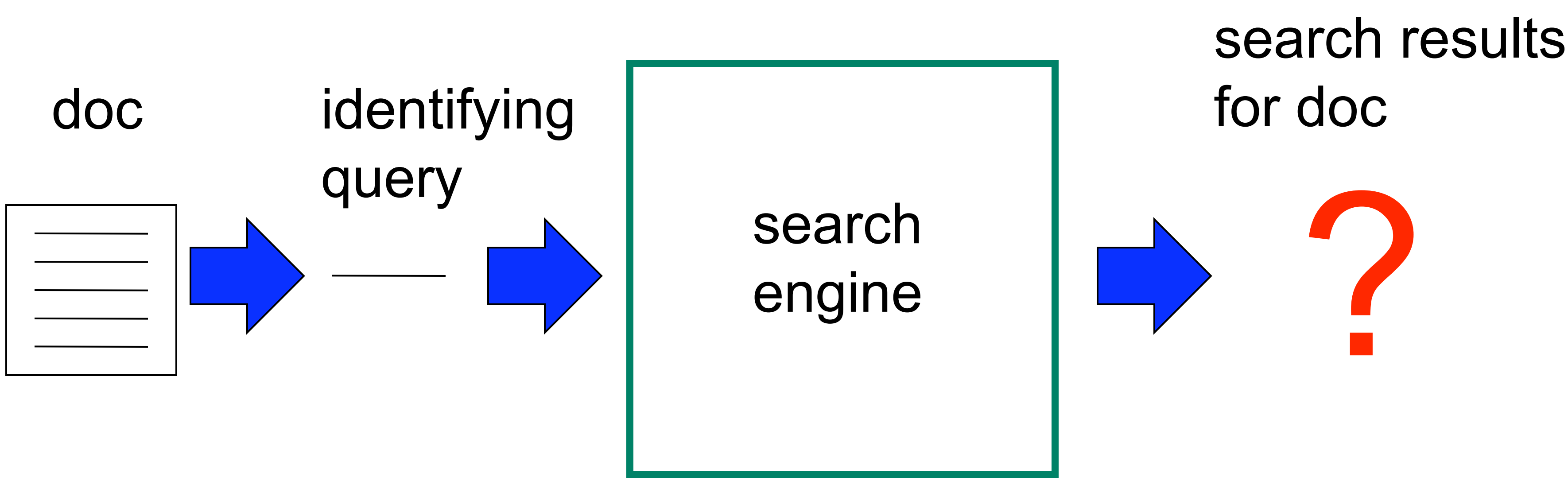
- Users interface is through the search engine
  - Proportion of the web a particular search engine indexes
  - The size of a particular search engine's index
  - Relative index sizes of two search engines

Challenges with these approaches?

Biggest one: search engines don't like to let people know what goes on under the hood

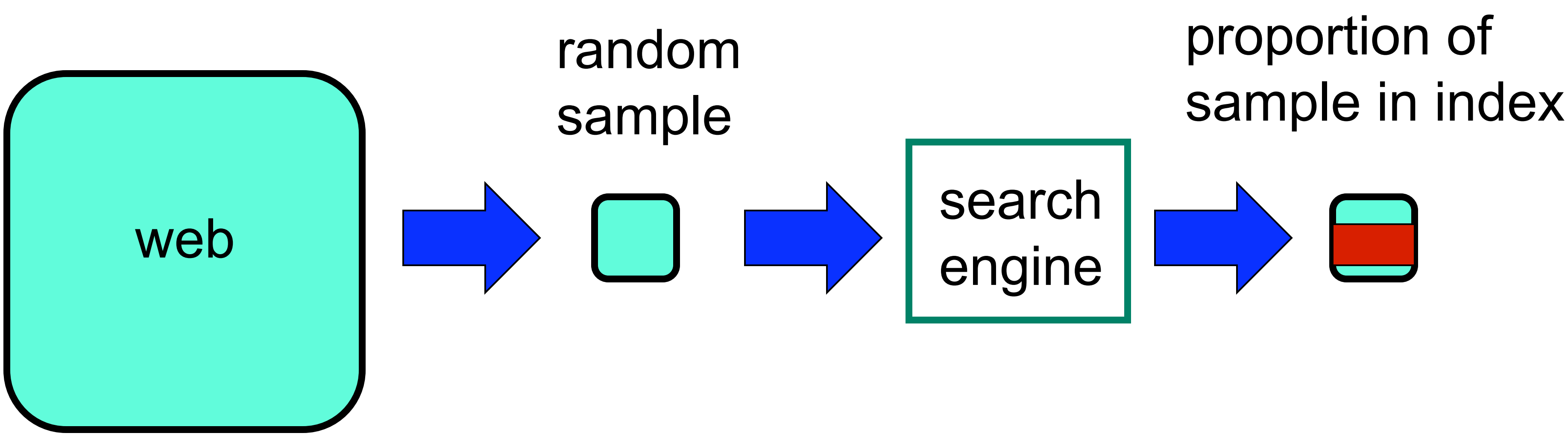
Search engines as a black box

- Although we can't ask how big a search engine's index is, we can often ask questions like "does a document exist in the index?"

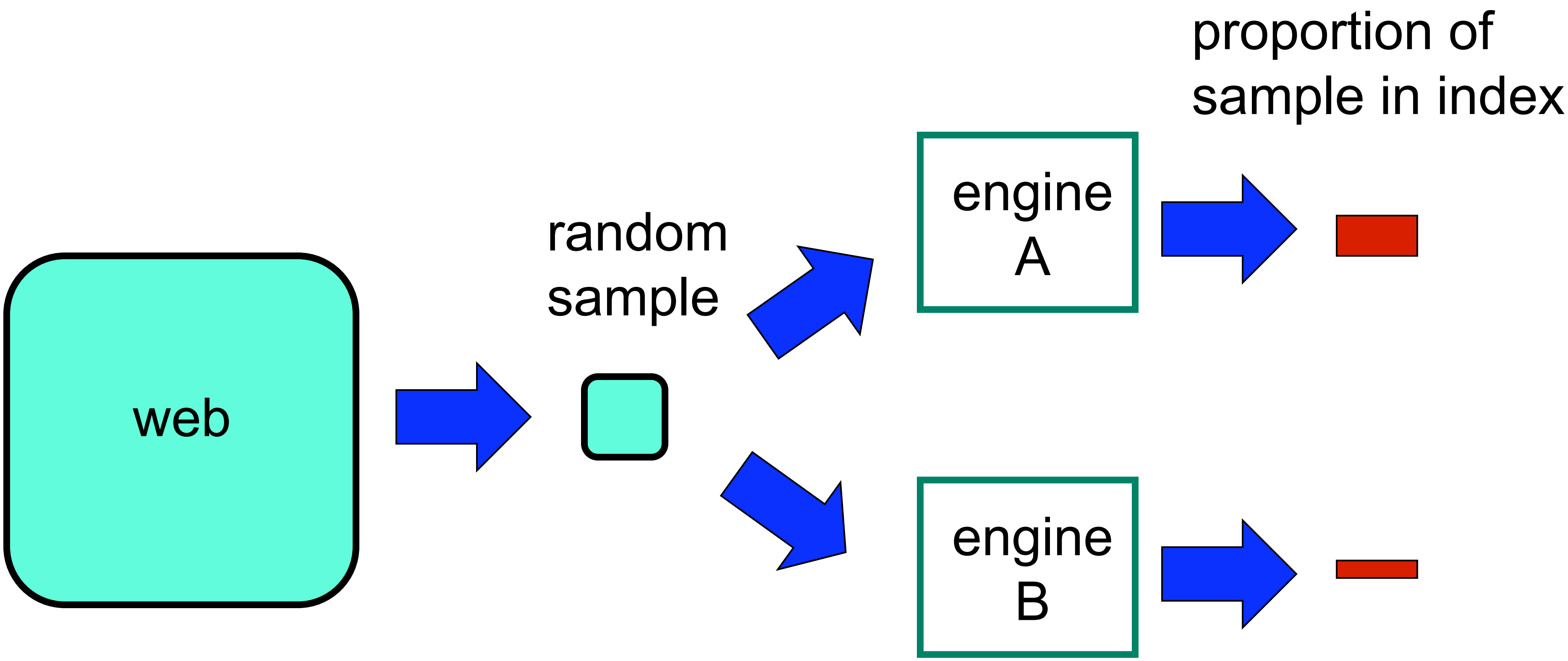


Proportion of the web indexed

- We can ask if a document is in an index
- How can we estimate the proportion indexed by a particular search engine?



Size of index A relative to index B



Sampling URLs

- Both of these questions require us to have a random set of pages (or URLs)
- Problem: Random URLs are hard to find!
- Ideas?
- Approach 1: Generate a random URL contained in a given engine
  - Suffices for the estimation of relative size
- Approach 2: Random pages/ IP addresses
  - In theory: might give us a true estimate of the size of the web (as opposed to just relative sizes of indexes)

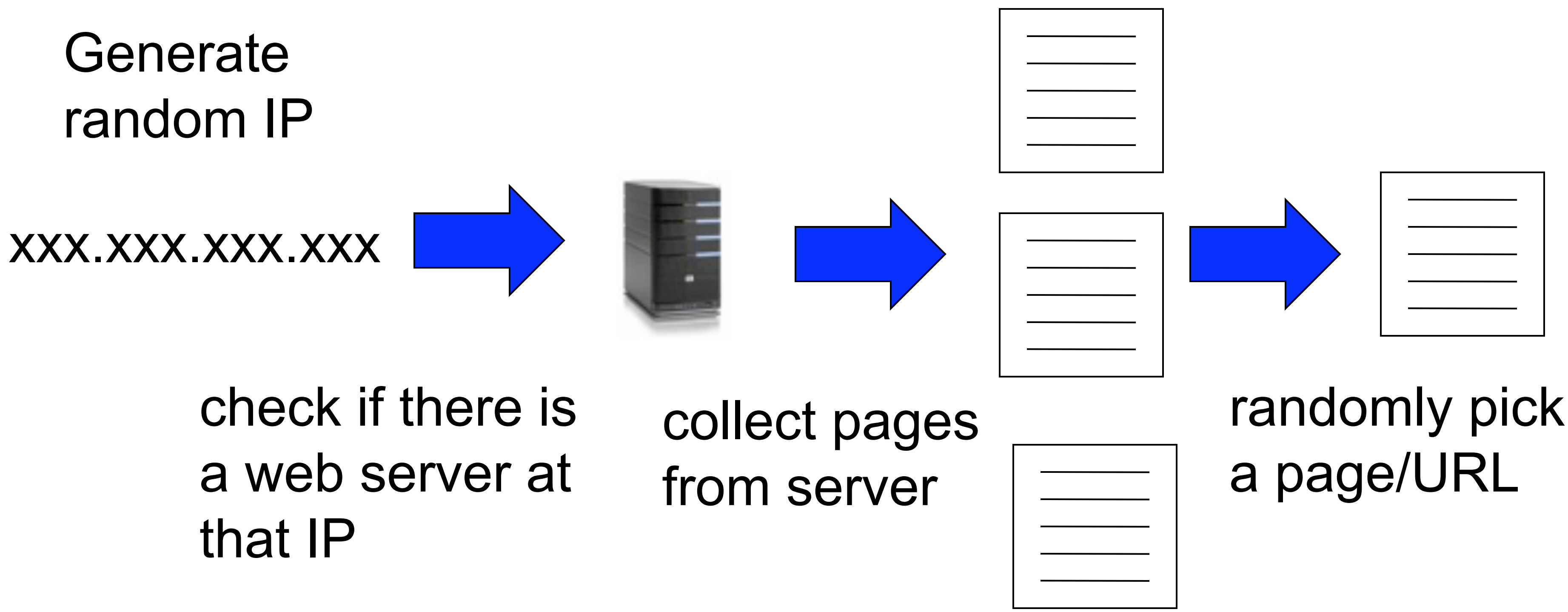
Random URLs from search engines

- Issue a random query to the search engine
  - Randomly generate a query from a lexicon and word probabilities (generally focus on less common words/queries)
  - Choose random searches extracted from a query log (e.g. all queries from Pomona College)
- From the first 100 results, pick a random page/ URL

Things to watch out for

- Biases induced by random queries
  - Query Bias: Favors content-rich pages in the language(s) of the lexicon
  - Ranking Bias: Use conjunctive queries & fetch all
  - Checking Bias: Duplicates, impoverished pages omitted
  - Malicious Bias: Sabotage by engine
  - Operational Problems: Time-outs, failures, engine inconsistencies, index modification
- Biases induced by query log
  - Samples are correlated with source of log

Random IP addresses



Random IP addresses

- [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

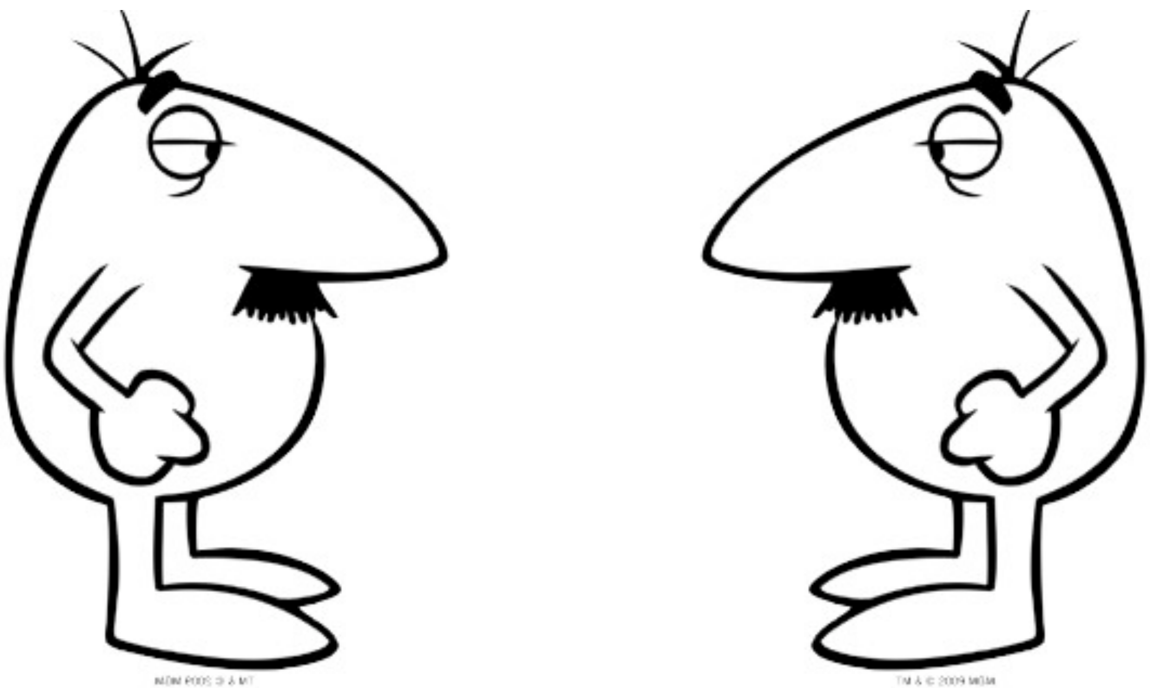
Random walks

- 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

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

Duplicate detection

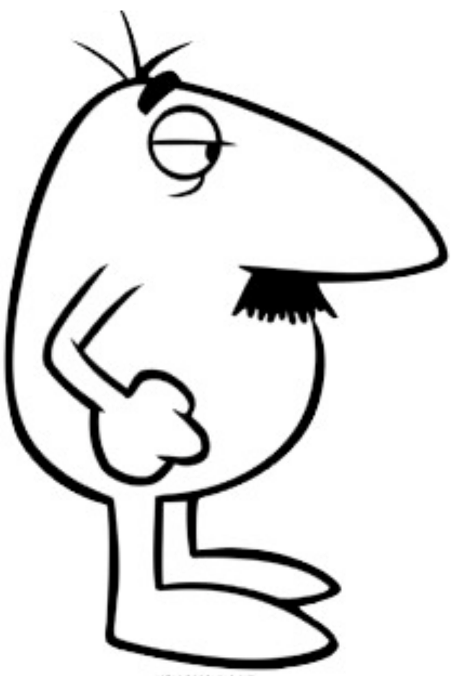


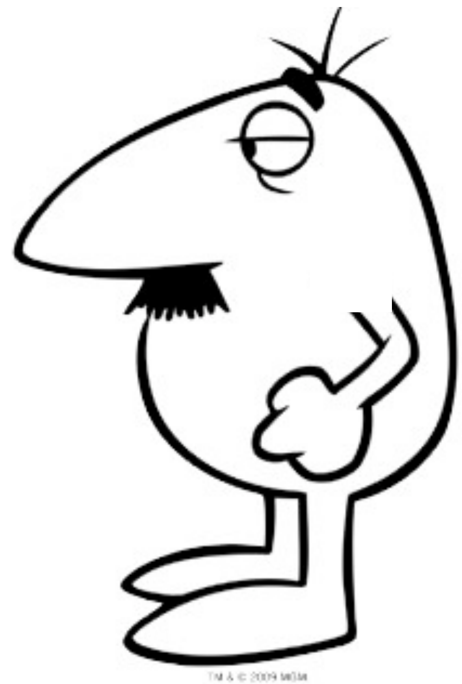
http://rlv.zcache.com/cartoon_man_with_balled_fist_postcard-p239288482636625726trdg_400.jpg

Duplicate documents

- The web is full of duplicated content
  - Redundancy/mirroring
  - Copied content
- Do we care?
- How can we detect duplicates?
- Hashing
  - Hash each document
  - Compares hashes
  - For those that are equal, check if the content is equal

Duplicate?





Near duplicate documents

- Many, many cases of near duplicates
  - E.g., last modified date the only difference between two copies of a page
- A good hashing function specifically tries not to have collisions
- Ideas?
  - Locality sensitive hashing – (http://www.mit.edu/~andoni/LSH/)
  - Similarity – main challenge is efficiency!

Computing Similarity

- We could use edit distance, but way too slow
- What did we do for spelling correction?
- compare word n-gram (shingles) overlap
  - ***a rose is a rose is a rose*** →

    a_rose_is_a

    rose_is_a_rose

    is_a_rose_is

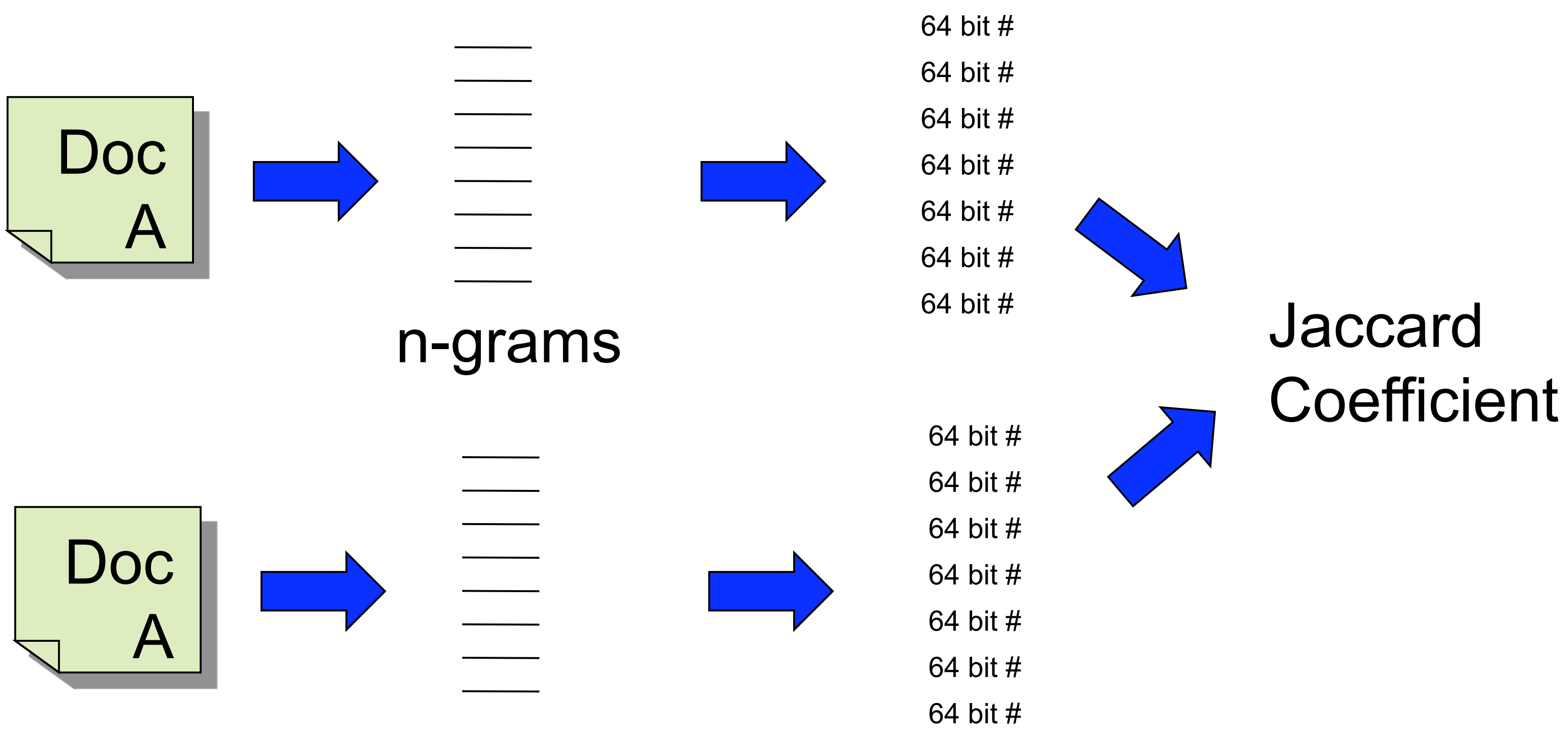
    a_rose_is_a
- Use Jaccard Coefficient to measure the similarity between documents (A and B)/(A or B)

N-gram intersection

- Computing exact set intersection of n-grams between all pairs of documents is expensive/ intractable
- How did we solve the efficiency problem for spelling correction?
  - Indexed words by character n-grams
  - AND query of the character n-grams in our query word
- Will this work for documents?
- Number of word n-grams for a document is too large!

Efficient calculation of JC

- Use a hash function that maps an n-gram to a 64 bit number



Efficient calculation of JC

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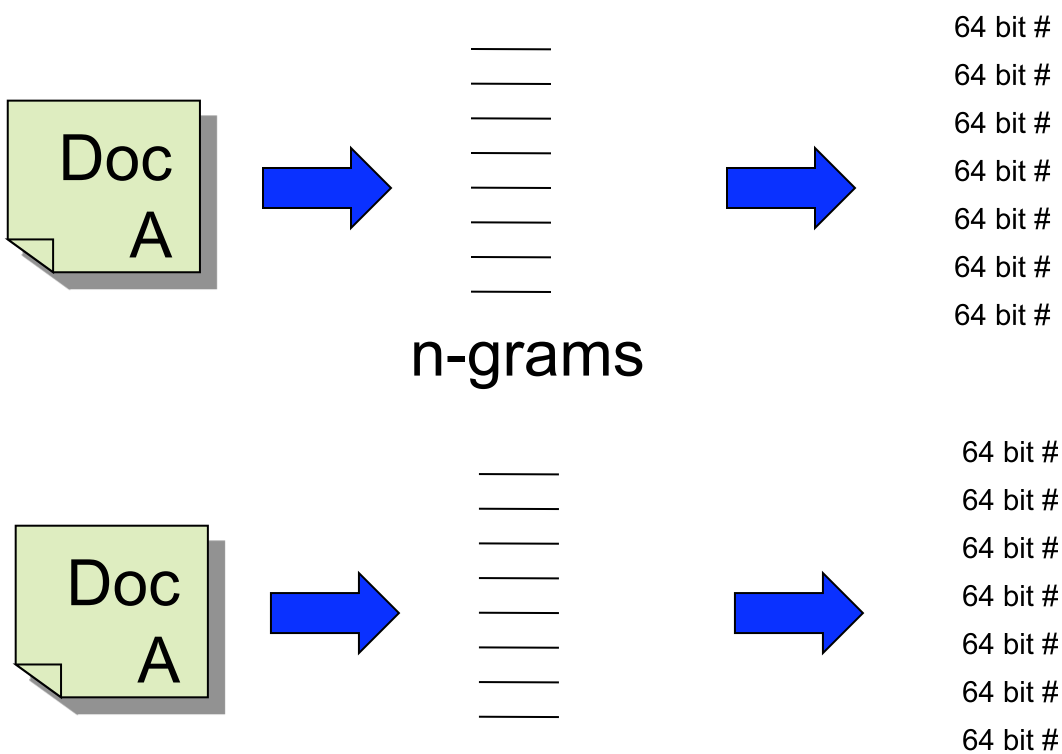
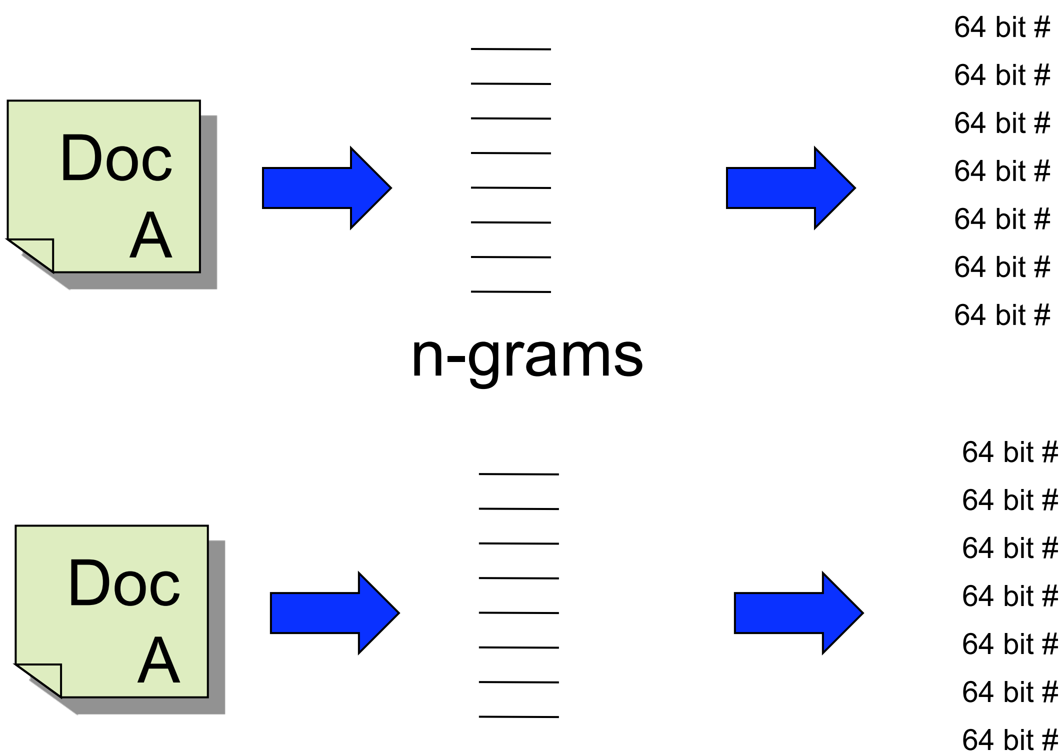


What if we just compared smallest one of each?

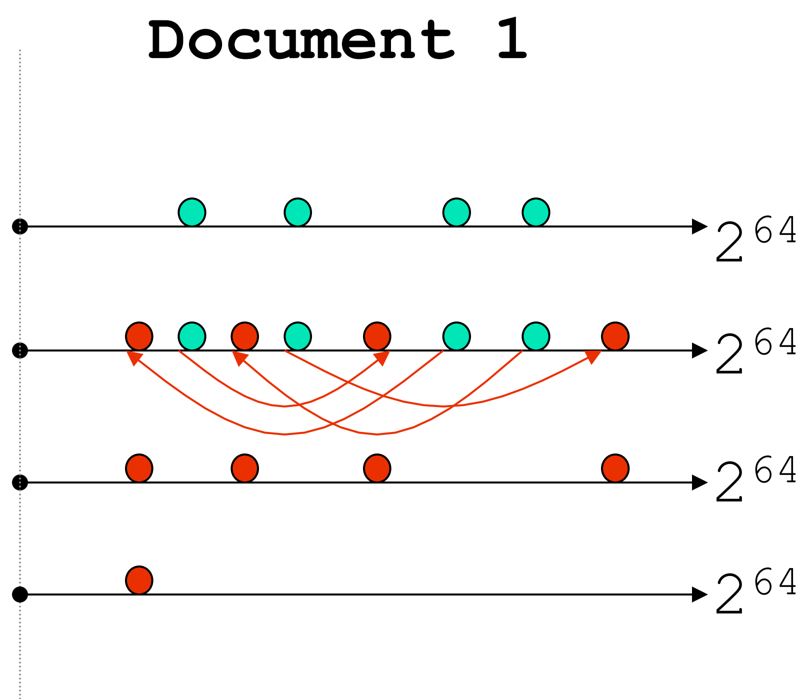
Efficient calculation of JC

- Use a hash function that maps an n-gram to a 64 bit number



- Apply a permutation to each 64 bit number
- Compare smallest values
- Repeat some number of times (say 200)

Efficient JC

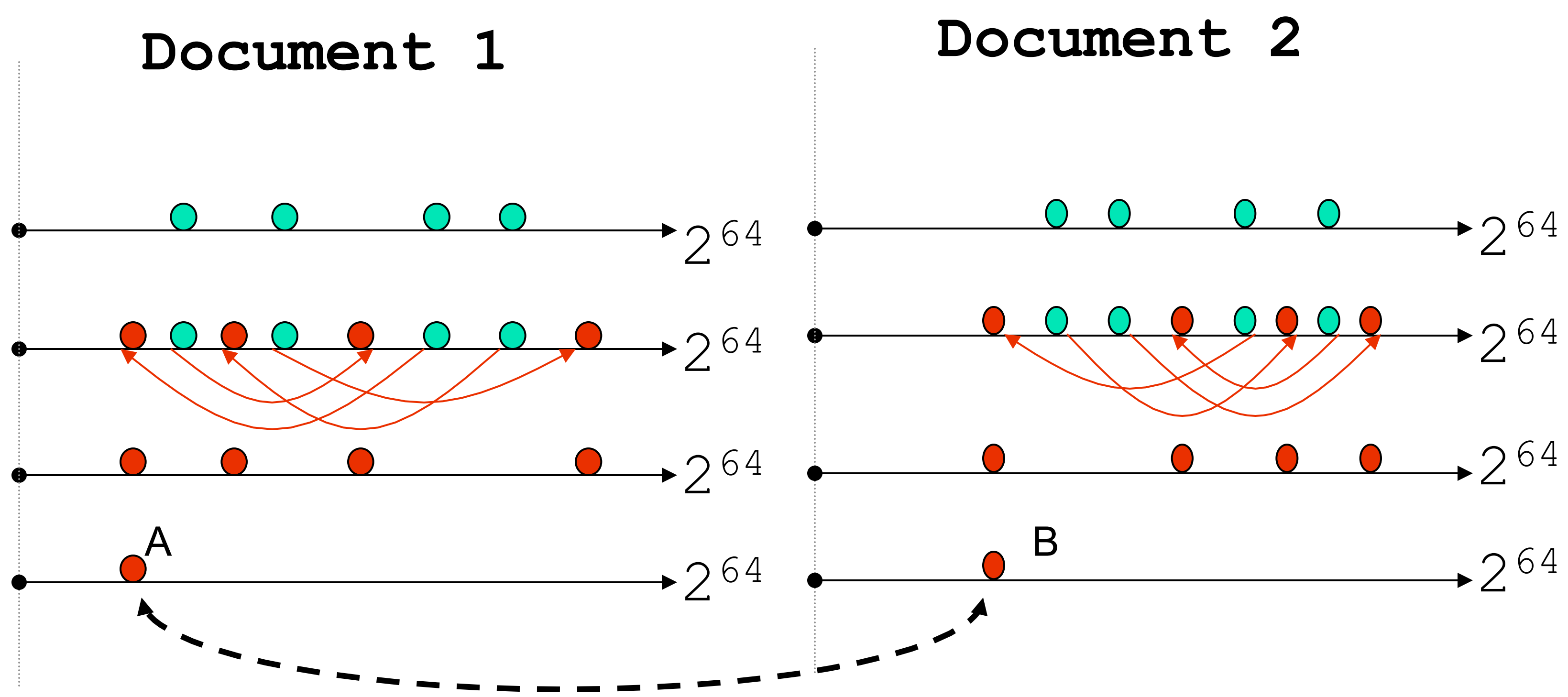


Start with 64-bit *n-grams*

Permute on the number line with π_i

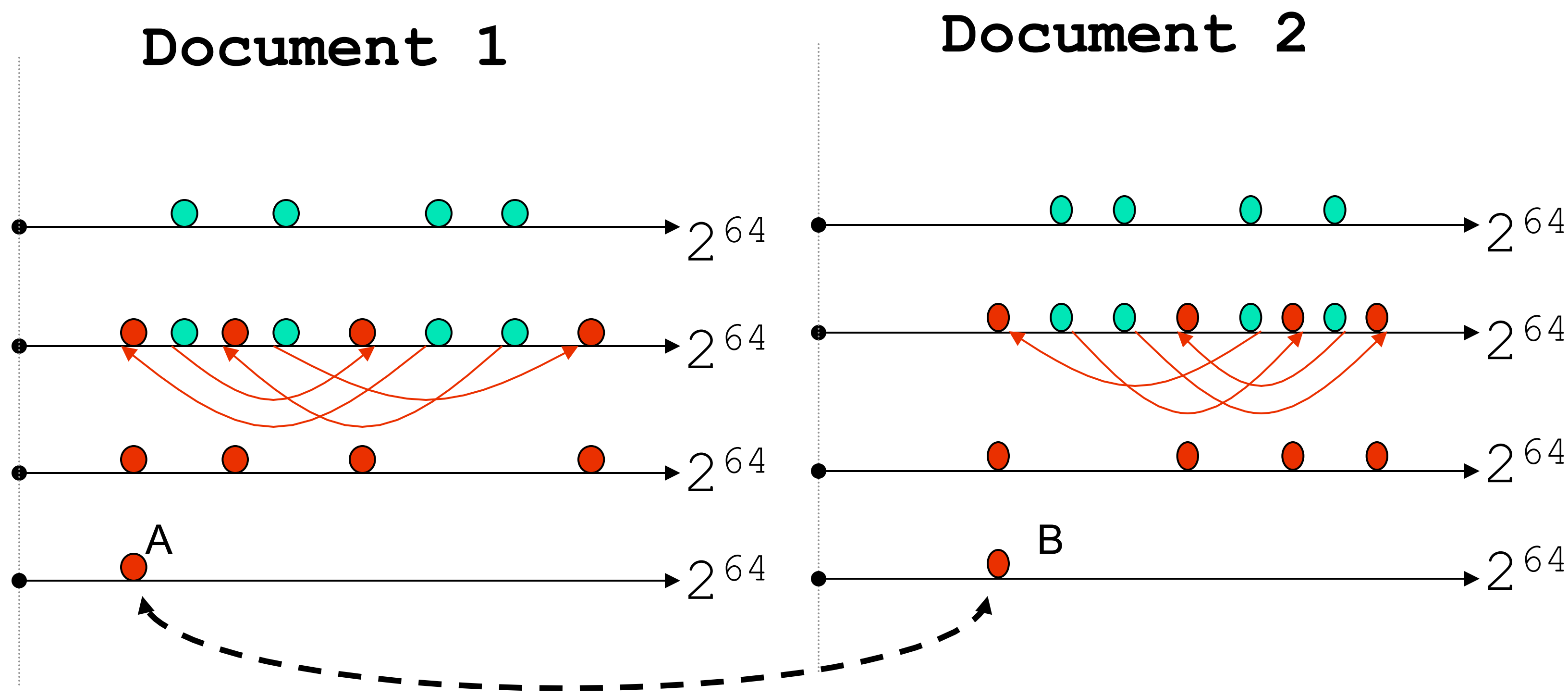
Pick the min value

Test if Doc1 = Doc2



Are these equal?

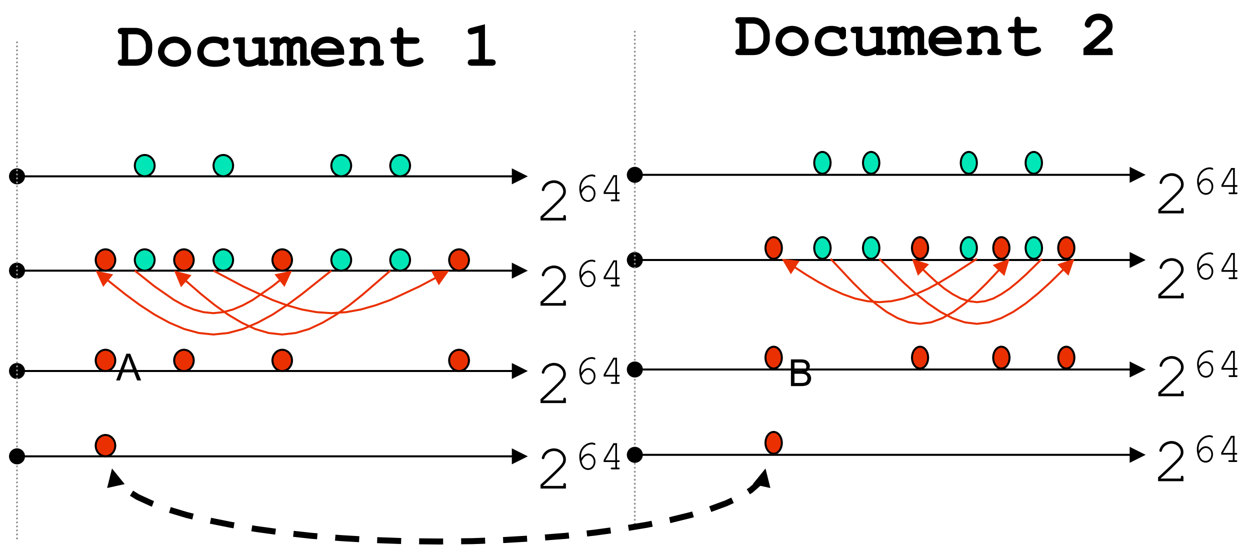
Test if Doc1 = Doc2



The minimum values after the permutations will be equal with probability =

`Size_of_intersection / Size_of_union`

Claim…



- Repeat this, say 200 times, with different permutations
- Measure the number of times they're equal
- This is a reasonable estimate for the JC

All signature pairs

- Now we have an extremely efficient method for *estimating* a Jaccard coefficient for a single pair of documents.
- But we still have to estimate N^2 coefficients where N is the number of web pages.
  - Still slow
- Need to reduce the set of options
  - locality sensitive hashing (LSH)
  - sorting (Henzinger 2006)

Cool search engines

- What do you think will be the most important feature(s) in next-generation search algorithms?
- Is it better to have a broad, general search engine or one that is tailored to your needs?
- What new markets can be explored using a search engine?
- Some of these search engines are niche-specific sites and others are search aggregators. Is web search diverging in the direction of many topic-specific sites or converging to one large find-everything site? Is one of these better? What should we be aiming for?
- What are the benefits of live updating searches (Collecta) vs. previously indexed content (Google)?
- How do you think Collecta is able to find results so quickly?
- The article mentions “inserting a human element into search.” What exactly does this mean? How can a web search include human power? Is that useful?

Set Similarity of sets C_i , C_j

$$\text{Jaccard}(C_i, C_j) = \frac{|C_i \cap C_j|}{|C_i \cup C_j|}$$

- View sets as columns of a matrix A; one row for each element in the universe. a_{ij} = 1 indicates presence of item i in set j
- Example

C_1	C_2
0	1
1	0
1	1
0	0
1	1
0	1

Jaccard(C_1,C_2) = 2/5 = 0.4

Key Observation

- For columns C_i, C_j, four types of rows

	C_i	C_j
A	1	1
B	1	0
C	0	1
D	0	0

- Overload notation: A = # of rows of type A
- **Claim**

$$\text{Jaccard}(C_i, C_j) = \frac{A}{A + B + C}$$

"Min" Hashing

- Randomly permute rows
- Hash $h(C_i)$ = index of first row with 1 in column C_i
- Surprising Property

$$P\left[h(C_i) = h(C_j)\right] = \text{Jaccard}\left(C_i, C_j\right)$$

- Why?
  - Both are A/(A+B+C)
  - Look down columns C_i, C_j until first non-Type-D row
  - $h(C_i) = h(C_j)$ ←→ type A row

Min-Hash sketches

- Pick *P* random row permutations
- MinHash sketch

  $Sketch_D$ = list of *P* indexes of first rows with 1 in column C

- Similarity of signatures
  - Let $sim[sketch(C_i),sketch(C_j)]$ = fraction of permutations where MinHash values agree
  - Observe $E[sim(sig(C_i),sig(C_j))] = Jaccard(C_i,C_j)$

Example

	C_1	C_2	C_3
R_1	1	0	1
R_2	0	1	1
R_3	1	0	0
R_4	1	0	1
R_5	0	1	0

Signatures

	S_1	S_2	S_3
Perm 1 = (12345)	1	2	1
Perm 2 = (54321)	4	5	4
Perm 3 = (34512)	3	5	4

Similarities

	1-2	1-3	2-3
Col-Col	0.00	0.50	0.25
Sig-Sig	0.00	0.67	0.00

Implementation Trick

- Permuting universe even once is prohibitive
- **Row Hashing**
  - Pick P hash functions $h_k: \{1,\ldots,n\} \rightarrow \{1,\ldots,O(n)\}$
  - Ordering under h_k gives random permutation of rows
- **One-pass Implementation**
  - For each C_i and h_k, keep "slot" for min-hash value
  - Initialize all slot(C_i,h_k) to infinity
  - Scan rows in arbitrary order looking for 1's
    - Suppose row R_j has 1 in column C_i
    - For each h_k,
      - if $h_k(j) <$ slot(C_i,h_k), then slot(C_i,h_k) $\leftarrow h_k(j)$

Example

	C_1	C_2
R_1	1	0
R_2	0	1
R_3	1	1
R_4	1	0
R_5	0	1

$h(x) = x \bmod 5$

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

	C_1 slots	C_2 slots
$h(1) = 1$	1	
$g(1) = 3$	3	
$h(2) = 2$	1	
$g(2) = 0$	3	
$h(3) = 3$	1	
$g(3) = 2$	2	
$h(4) = 4$	1	
$g(4) = 4$	2	
$h(5) = 0$	1	
$g(5) = 1$	2	

Comparing Signatures

- Signature Matrix S
  - Rows = Hash Functions
  - Columns = Columns
  - Entries = Signatures
- Can compute – Pair-wise similarity of any pair of signature columns