# Web Dynamics

## Part 3 – Searching the Dynamic Web

***3.1 Crawling and recrawling policies***

*3.2 Accessing the Hidden Web*

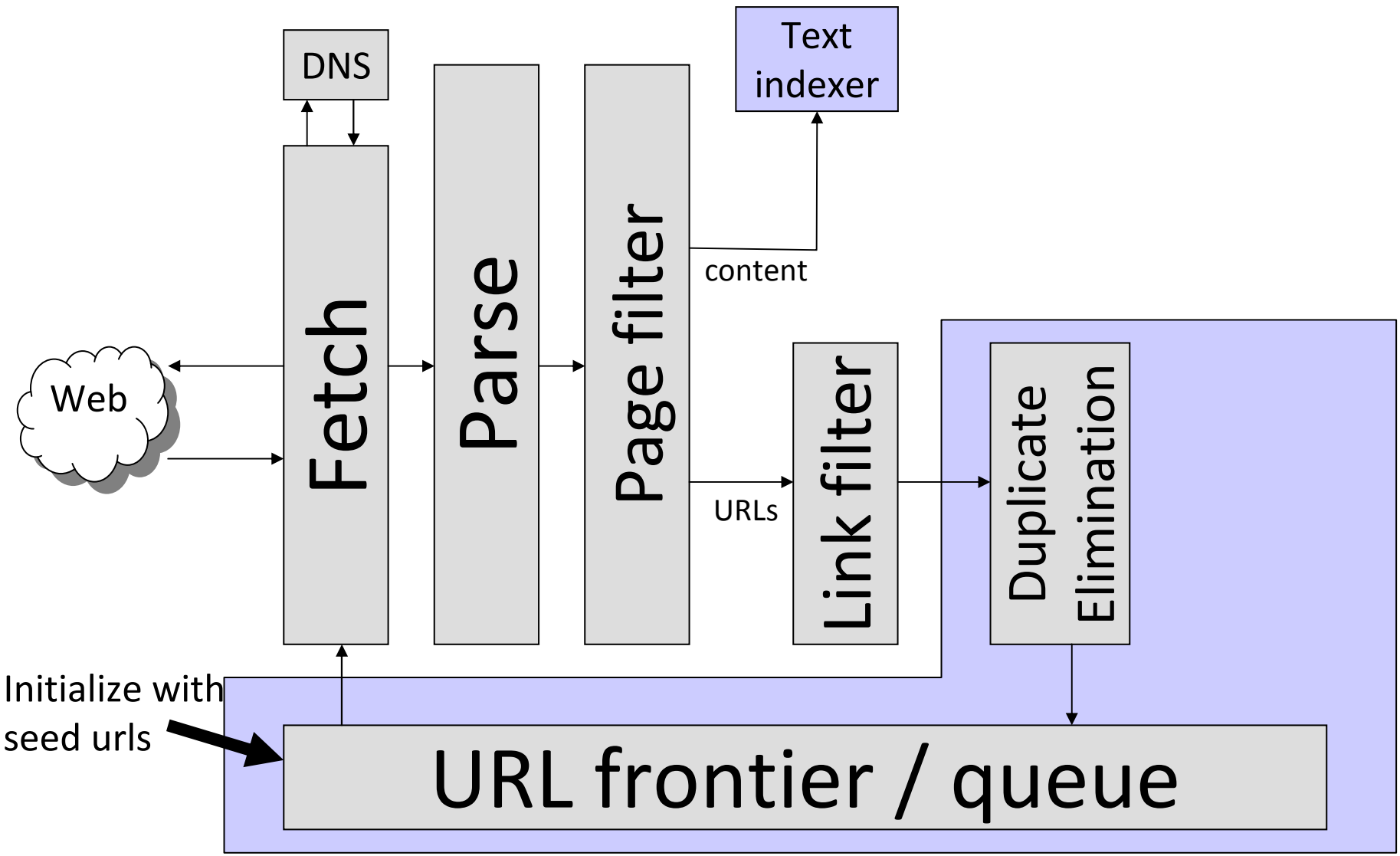
# Why crawling is difficult

- Huge size of the Web (billions of pages)
- High dynamics of the Web (page creations, updates, deletions)
- High diversity in the Web (page importance, quality, formats, conformance to standards)
- Huge amount of noise, malicious content (spam), duplicate content (Wikipedia copies)

# Requirements for a Crawler

- ***Robustness:*** resilience to (malicious or unintended) crawler traps
- ***Politeness***: respect servers' policies for accessing pages (which & how frequent)
- ***Quality***: focus on downloading "important" pages
- ***Freshness***: make sure that crawled snapshots correspond to current version of pages
- ***Scalability***: cope with growing load by adding machines & bandwidth
- ***Efficiency***: make efficient use of system resources
- ***Extensibility***: possible to add new features (data formats, protocols)

# Basic Crawler Architecture



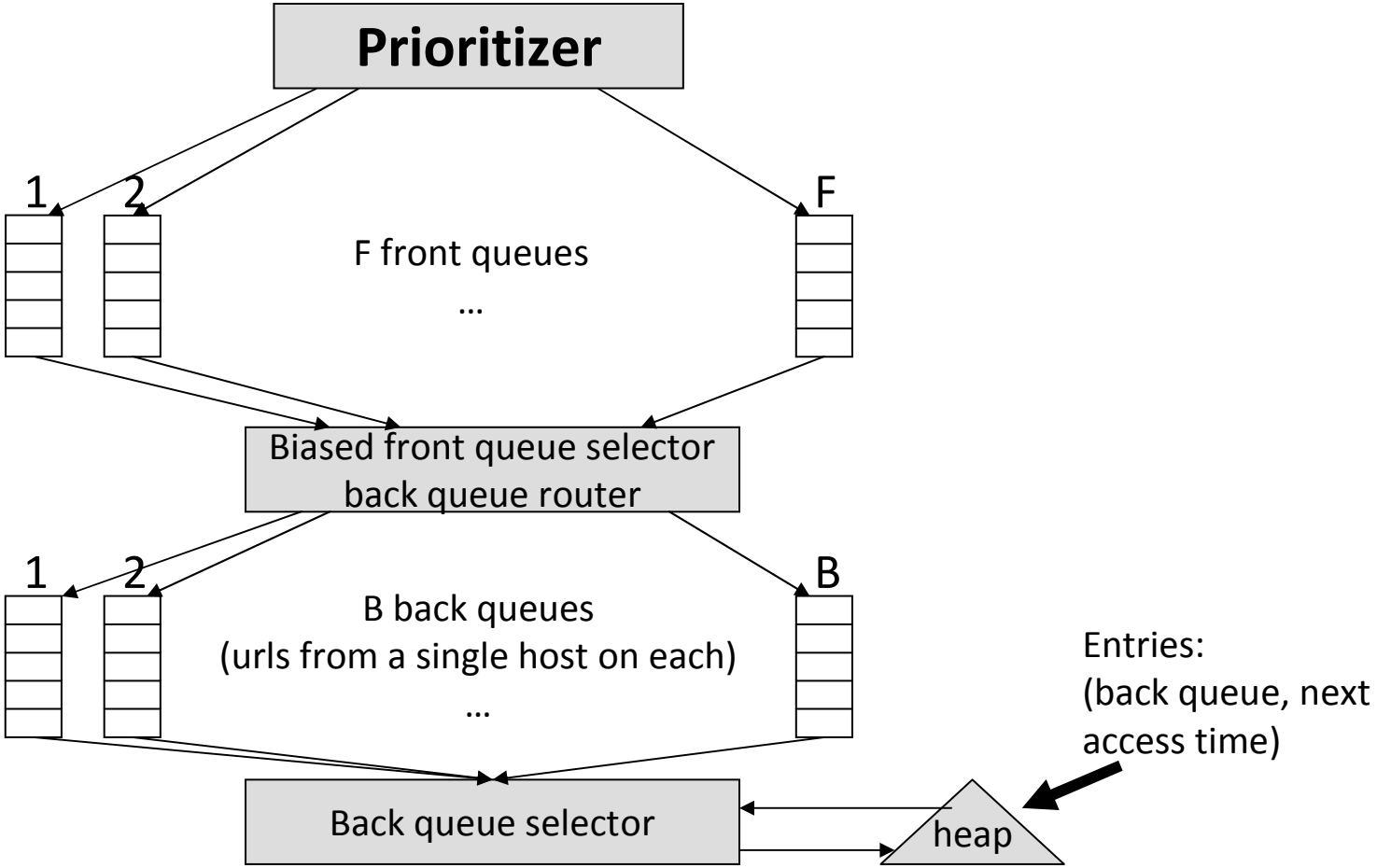
# Crawler Types

- ***Snapshot crawler***: get at most one snapshot of each page (important for archiving)
- ***Batch-mode crawler***: revisit known pages periodcally (collection is fixed)
- **Steady crawler**: continuously revisit know pages (collection is fixed)
- **Incremental crawler**: continuously revisit known pages and increase crawl quality by finding new good pages

# Queue design for snapshot crawlers

## Goals:

- Allow for different crawl priorities, but provide fairness
- Keep crawler busy while being polite



# Modeling page changes over time

**Observation:**

Page changes can be modeled by Poisson process with change rate λ:

$$f_T(t) = \begin{cases} \lambda \exp(-\lambda t) & \text{for } t > 0 \\ 0 & \text{for } t \leq 0. \end{cases}$$

Probability for at least one change until t:

$$\Pr\{T \leq t\} = \int_0^t f_T(t)\, dt = 1 - \exp(-\lambda t)$$

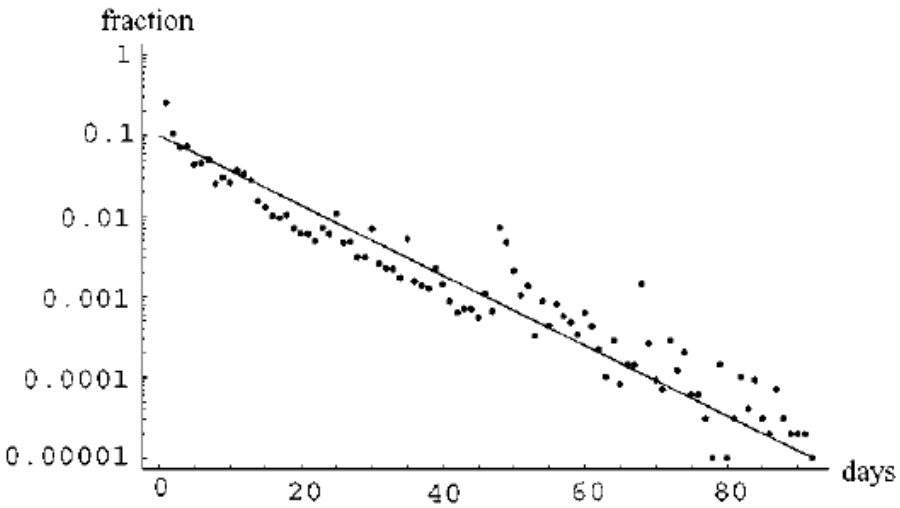
Expectation: $E[t]=1/\lambda$, variance: $var[t]=1/\lambda^2$

Note: change rates differ per page (and maybe over time)

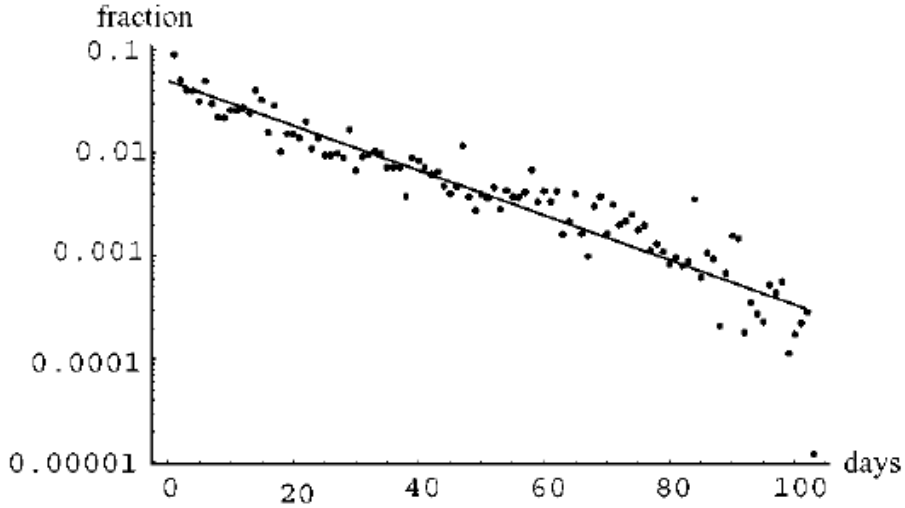
# Poisson processes on real data

Cho & Garcia-Molina, TODS 2003:

- Daily crawl of 720,000 pages from 270 sites over approx 4.5 months
- Seeds: popular pages from large Web crawl



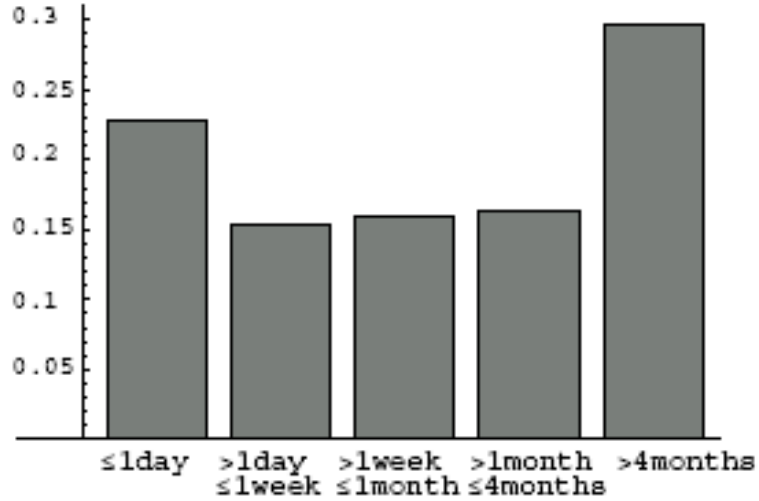

(a) For the pages that change every 10 days on average



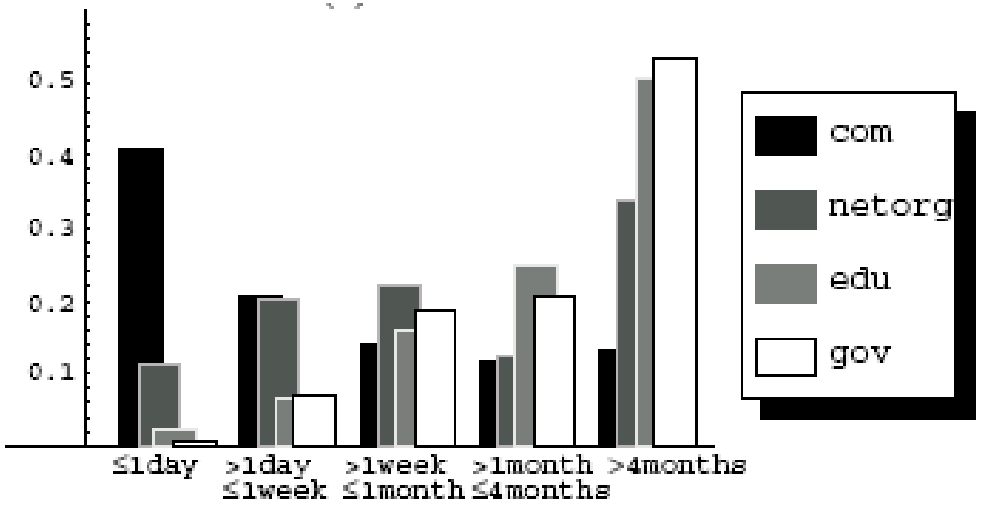

(b) For the pages that change every 20 days on average

Fig. 14. Change intervals of pages.

# Change rate distributions on the Web




(a) Over all domains




(b) For each domain

Cho & Garcia-Molina, TODS 2003

# Sampling change rates

**Goal**: determine $\lambda_i$ for fixed page *i*

Simple estimator: $n_i$ accesses with frequency $f_i$, $T_i=(n_i-1)/f_i$

For $X_i$ monitored updates in time $T_i$, estimate

$$\overline{\lambda_i} := \frac{X_i}{T_i}$$

Question: is this a good estimator?

- Is it unbiased? **No.**
- Is it consistent? **No.**

Better estimator: $n_i$ accesses with frequency $f_i$, page was **not** changed $Y_i$ times

$$\overline{\lambda_i} := -f_i \cdot \log \frac{Y_i + 0.5}{n_i + 0.5}$$

# Crawling the dynamic Web

**Challenges:**

- How do we model the „up-to-dateness“ of our index
- How frequently do we recrawl?
  - On average, update each of N pages once *within $I$ time units* (average update frequency f=1/I)
- How frequently do we schedule per-page revisits?
  - uniformly vs. depending on the change rates
- In which order do we revisit pages
  - fixed order vs. recrawl (random) vs. purely random

# Measures for recency of the index (1)

**Definition:**

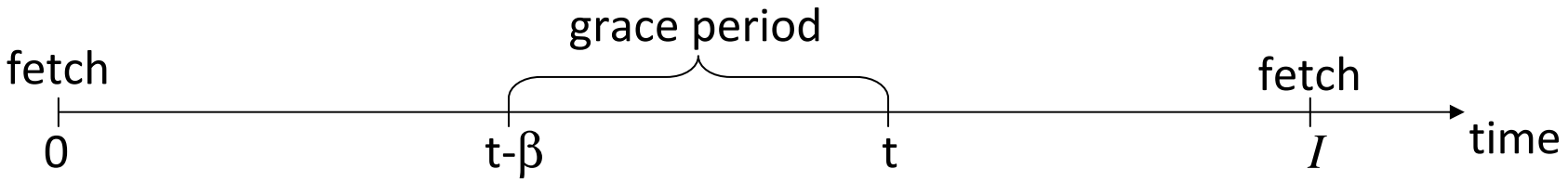
Index is **(α,β)-current at time t** when the probability that random page has been up-to-date β time units ago is at least α.

**Question to answer**:

How frequently do we need to recrawl to guarantee to be (95%,1 week)-current?

Answer: every 18 days for 800 million page sample [Brewington and Cybenko 2000]

# Brewington&Cybenko Model




Probability that a specific document is β-current in interval [0;$I$]:

$$\underbrace{\int_0^{\beta} \frac{1}{I}\,dt}_{\text{if } t<\beta,\ \text{prob. is 1}} + \underbrace{\int_{\beta}^{I} \frac{1}{I} e^{-\lambda(t-\beta)}\,dt}_{\text{if } t>\beta,\ \text{prob. decays exponentially with delay}} = \frac{\beta}{I} + \frac{1-e^{-\lambda(I-\beta)}}{\lambda I}$$

Now average over all documents (assuming distribution w(λ) for change rates):

$$\alpha = \int_0^{\infty} w(\lambda)\left[\frac{\beta}{I} + \frac{1-e^{-\lambda(I-\beta)}}{\lambda I}\right] d\lambda$$

(see paper: 1/λ is Weibull-distributed)

# Measures for recency of the index (2)

- **Freshness F(p;t) of a page p at time t:**
  1 if p is up-to-date at time t, 0 otherwise
- **Age A(p;t) of a page p at time t:**
  time since the last update of p that is not reflected in the index
- **Freshness F(t)** of the index at time t:

$$F(t) = \frac{1}{N} \sum_{i=1}^{N} F(p_i, t)$$

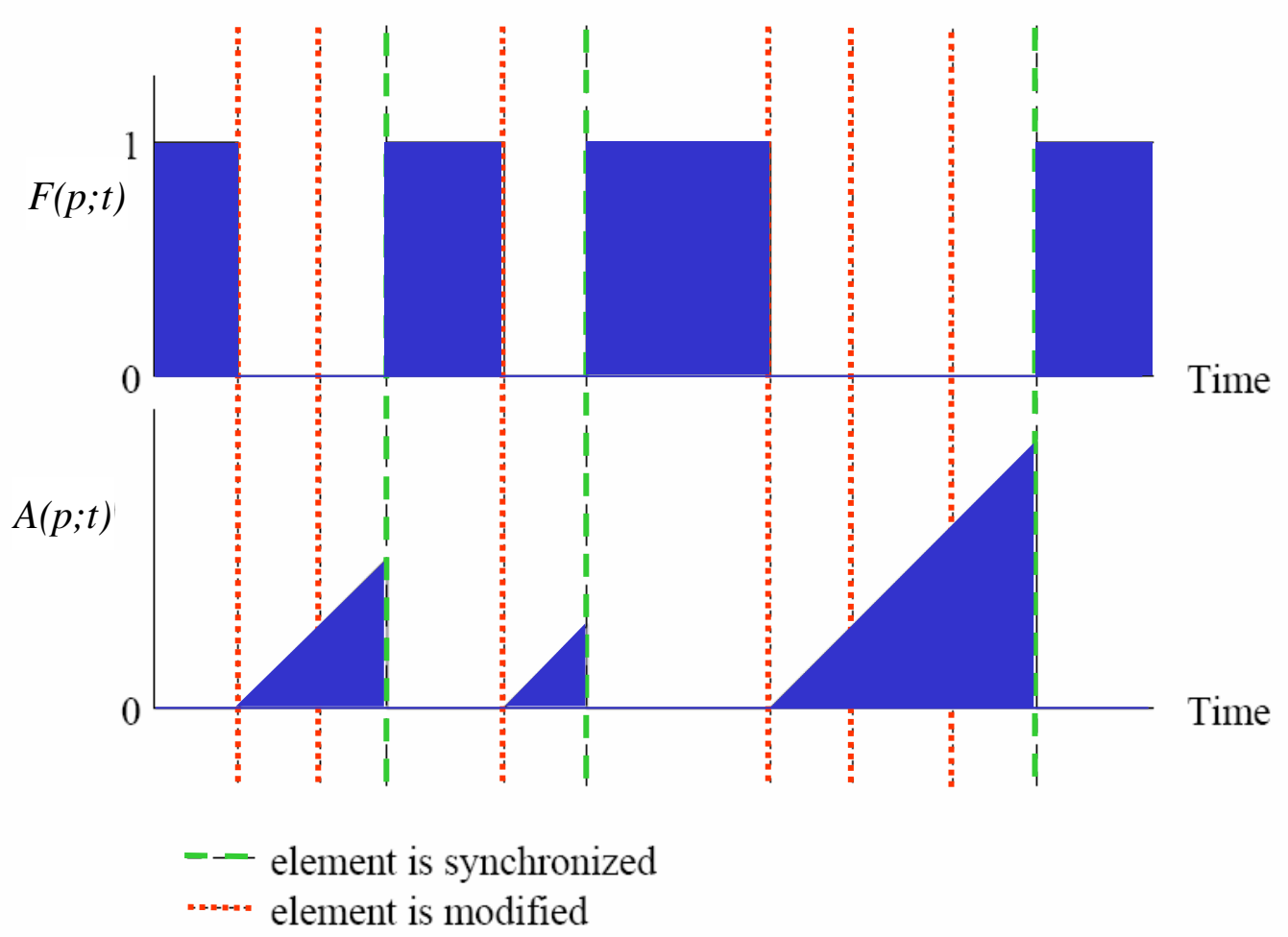
- **Average Freshness F(p)** of a page p:

$$F(p) = \lim_{t \to \infty} \frac{1}{t} \int_0^t F(p;t)dt$$

- **Average Freshness** of the index:

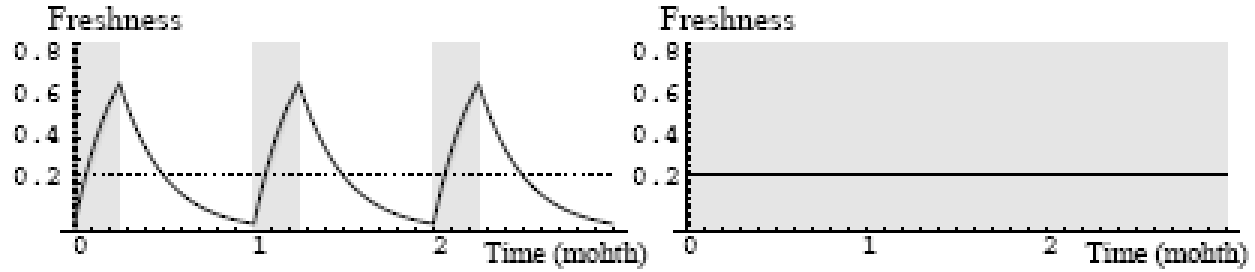
$$F = \frac{1}{N} \sum_{i=1}^{N} F(p_i)$$

# Example: freshness and age for page p




Cho & Garcia-Molina, TODS 2003

# Freshness and age for different crawlers




(a) A batch-mode crawler (b) A steady crawler

Figure 7: Freshness evolution of a batch-mode/steady crawler

grey area: time when crawler is active
solid line: F(t)
dotted line: average of F(t)

**Theorem**:
Average freshness is the same for both crawlers if load is the same

Cho & Garcia-Molina, VLDB 2000

# Expected freshness and age of a page

Assume for page p:

- p changes with rate λ
- p is synch'ed at time 0

Then

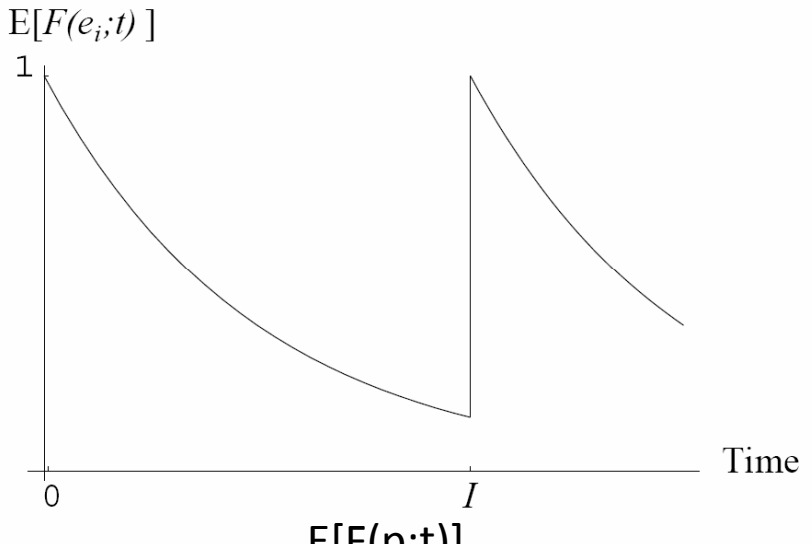
- Expected freshness of p at time t≥0:

$$E[F(p;t)] = 0 \cdot \underbrace{\left(1 - e^{-\lambda t}\right)}_{\text{P[p changed at time t]}} + 1 \cdot e^{-\lambda t} = e^{-\lambda t}$$

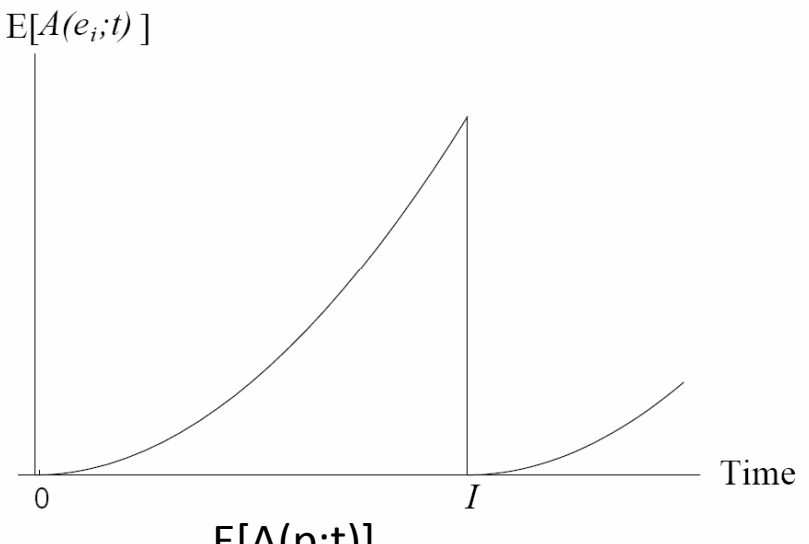
- Expected age of p at time t≥0:

$$E[A(p;t)] = \int_0^t (t-s) \underbrace{\lambda e^{-\lambda s}}_{\text{P[first change of p after time s]}} ds = t\left(1 - \frac{1 - e^{-\lambda t}}{\lambda t}\right)$$

# Expected freshness and age over time




E[F(p;t)]



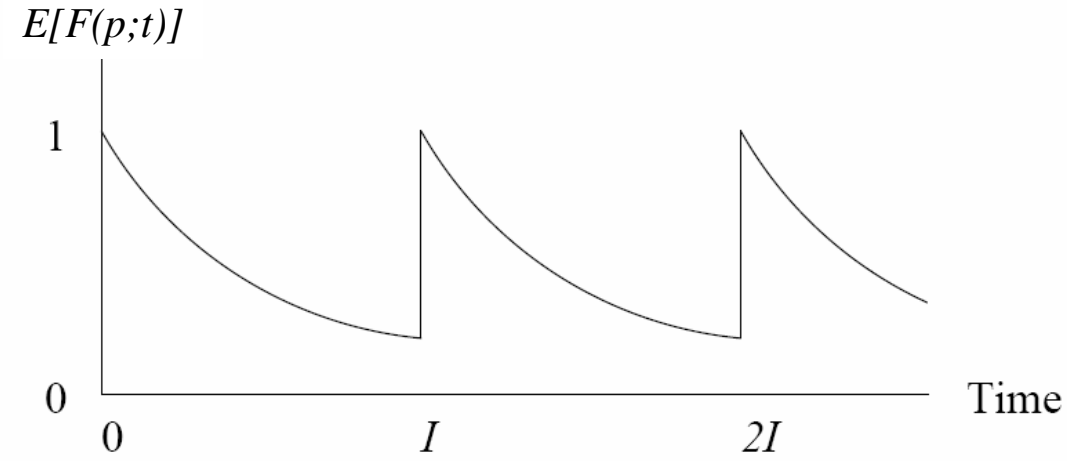

E[A(p;t)]

Cho & Garcia-Molina, TODS 2003

# Which avg. freshness can we achieve?

Assume that

- All pages change at *the same rate* λ
- All pages are sync'ed *every* $I$ time units (at rate $f=1/I$)
- Pages are always sync'ed *in a fixed order*

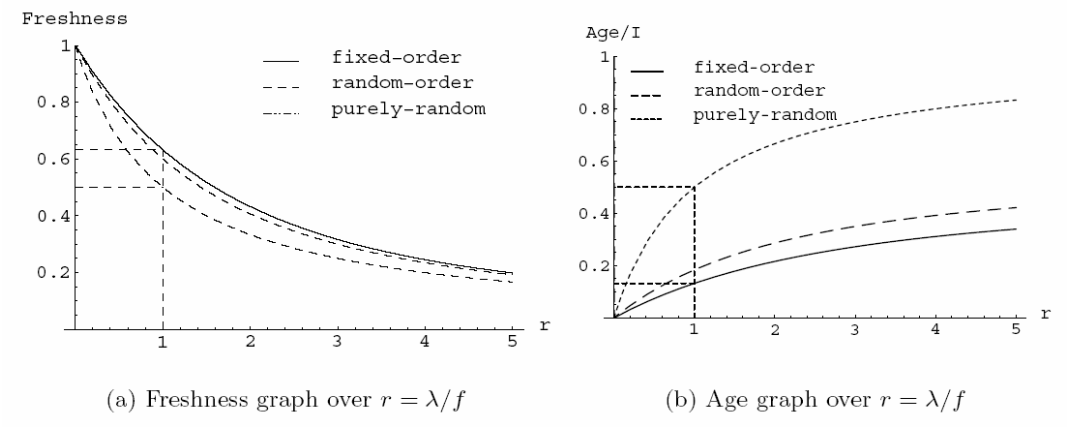



***Theorem:***

$$F(p) = \lim_{t\to\infty} \frac{1}{t}\int_0^t E[F(p;t)]dt = \frac{1}{I}\int_0^I E[F(p;t)]dt = \frac{1-e^{-\lambda I}}{\lambda I} = \frac{1-e^{-\lambda/f}}{\lambda/f} = F$$

# Are other orders better?

- **Random order**:
  update all pages once, but in random order (e.g., by recrawling)
- **Purely random order**:
  pick page to update at random




(a) Freshness graph over $r = \lambda/f$ (b) Age graph over $r = \lambda/f$

| *policy* | *Freshness* | *Age* |
|---|---|---|
| Fixed-order | $\frac{1-e^{-r}}{r}$ | $\frac{1}{f}(\frac{1}{2} - \frac{1}{r} + \frac{1-e^{-r}}{r^2})$ |
| Random-order | $\frac{1}{r}(1 - (\frac{1-e^{-r}}{r})^2)$ | $\frac{1}{f}(\frac{1}{3} + (\frac{1}{2} - \frac{1}{r})^2 - (\frac{1-e^{-r}}{r^2})^2)$ |
| Purely-random | $\frac{1}{1+r}$ | $\frac{1}{f}(\frac{r}{1+r})$ |

Cho & Garcia-Molina, TODS 2003

# Non-uniform update frequencies

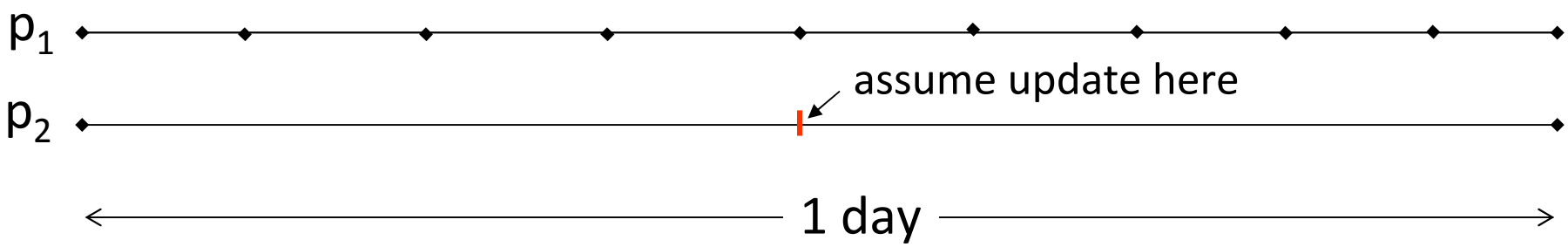
Now

- page $p_i$ changes with rate $\lambda_i$
- page $p_i$ is updated at fixed interval $I_i (= 1/f_i)$

Question: How are $f_i$ and $\lambda_i$ related?

Simple answer $f_i \propto \lambda_i$ is wrong!

# Simple example: two pages, one update




Assume

- $p_1$ changes once per interval (=9 times/day)
- $p_2$ changes once per day
- probability for change uniform in each interval

Now estimate *expected benefit of updating* $p_2$ in the middle of the day

- with prob. ½ change occurs later ⇒ benefit 0
- with prob. ½ change occurs before ⇒ benefit ½
- Expected benefit: ½ * ½ = ¼

Similar computation for $p_1$ (update in the middle of any interval):

- Expected benefit: 1/2 * 1/18 = 1/36

# Two pages, more updates

| row | $f_1 + f_2$ | $f_1$ | $f_2$ | benefit | best | |
|---|---|---|---|---|---|---|
| (a) | 1 | 1 | 0 | $\frac{1}{2} \times \frac{1}{18} = \frac{1}{36}$ | 0 | 1 |
| (b) | | 0 | 1 | $\frac{1}{2} \times \frac{1}{2} = \frac{9}{36}$ | | |
| (c) | 2 | 2 | 0 | $\frac{1}{2} \times \frac{1}{18} + \frac{1}{2} \times \frac{1}{18} = \frac{2}{36}$ | 0 | 2 |
| (d) | | 1 | 1 | $\frac{1}{2} \times \frac{1}{18} + \frac{1}{2} \times \frac{1}{2} = \frac{10}{36}$ | | |
| (e) | | 0 | 2 | $\frac{1}{3} \times \frac{2}{3} + \frac{1}{3} \times \frac{1}{3} = \frac{12}{36}$ | | |
| (f) | 5 | 3 | 2 | $\frac{3}{36} + \frac{12}{36} = \frac{30}{72}$ | 2 | 3 |
| (g) | | 2 | 3 | $\frac{2}{36} + \frac{6}{16} = \frac{31}{72}$ | | |
| (h) | 10 | 9 | 1 | $\frac{9}{36} + \frac{1}{4} = \frac{36}{72}$ | 7 | 3 |
| (i) | | 7 | 3 | $\frac{7}{36} + \frac{6}{16} = \frac{41}{72}$ | | |
| (j) | | 5 | 5 | $\frac{5}{36} + \frac{15}{36} = \frac{40}{72}$ | | |

**Rules of thumb:**

- When sync frequency (f1+f2) much smaller than change frequency (λ1+λ2), don‘t sync quickly changing pages
- Even for f1+f2≈λ1+λ2, uniform (5:5) better than proportional (9:1)

**Can we prove this?**

# Proof (1)

**Notation/Definition:**

- $F(\lambda_i, f_i)$: average freshness of $p_i$ when $p_i$ changes with rate $\lambda_i$ and is updated with rate $f_i$
- $\lambda = \frac{1}{N}\sum \lambda_i$ average change rate
- function f(x) is convex if $\frac{1}{n}\sum_{i=1}^{n} f(x_i) \geq f\left(\frac{1}{n}\sum_{i=1}^{n} x_i\right)$

$F(\lambda_i, f_i)$ is convex in $\lambda_i$ independent of the sync strategy

# Proof(2)

With *uniform* update frequency ($f_i$=f):

$$F_u = \frac{1}{N}\sum F(\lambda_i, f_i) = \frac{1}{N}\sum F(\lambda_i, f)$$

With *proportional* update frequency:

$$F_p = \frac{1}{N}\sum F(p_i) = \frac{1}{N}\sum F(\lambda, f) = F(\lambda, f)$$

here, F(pi)=F(λi,fi)=F(λ,f) because F(pi) depends only on r=λ/f

Then:

$$F_u = \frac{1}{N}\sum F(\lambda_i, f) \geq F(\frac{1}{N}\sum \lambda_i, f) = F(\lambda, f) = F_p$$

# Optimization Problem

Given $\lambda_i$ (i=1..N), find $f_i$ (i=1..N) that maximize

$$F = \frac{1}{N}\sum_{i=1}^{N} F(\lambda_i, f_i)$$

under the constraint that

$$\sum_{i=1}^{N} f_i = f \text{ and } f_i \geq 0 \; (i = 1..N)$$

---

Using Lagrange multipliers, this transforms to

$$\frac{\partial F(\lambda_i, f_i)}{\partial f_i} F = \mu \qquad \sum_{i=1}^{N} f_i = f$$

which can be solved numerically (for fixed order)

# Solving for the two-page example

## (λ1=9, λ2=1, f=2)

```
fsolve({diff((1-exp(-9/f1))/(9/f1),f1)=y, diff((1-exp(-1/f2))/(1/f2),f2)=y,\
f1+f2=2},{f1,f2,y},{f1=0...2,f2=0...2,y=0...100});
```

{f1 = 0.2358671910, f2 = 1.764132809, y = 0.1111111111}

## (λ1=9, λ2=1, f=10)

```
fsolve({diff((1-exp(-9/f1))/(9/f1),f1)=y, diff((1-exp(-1/f2))/(1/f2),f2)=y,\
f1+f2=10},{f1,f2,y},{f1=0...10,f2=0...10,y=0...100});
```

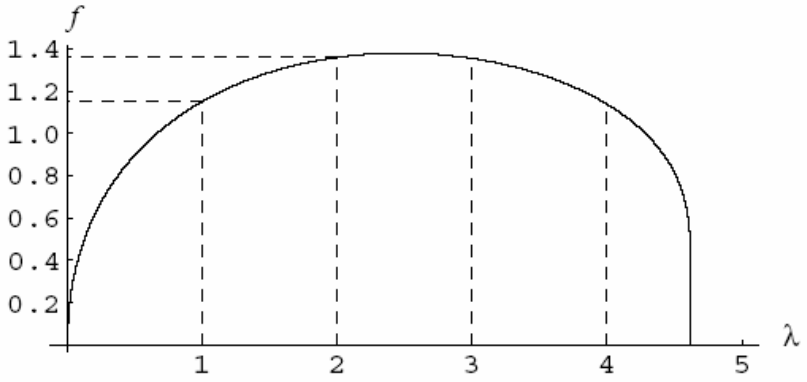
{f1 = 6.885783095, f2 = 3.114216905, y = 0.04174104014}

May require grouping of pages with similar frequency to be scalable

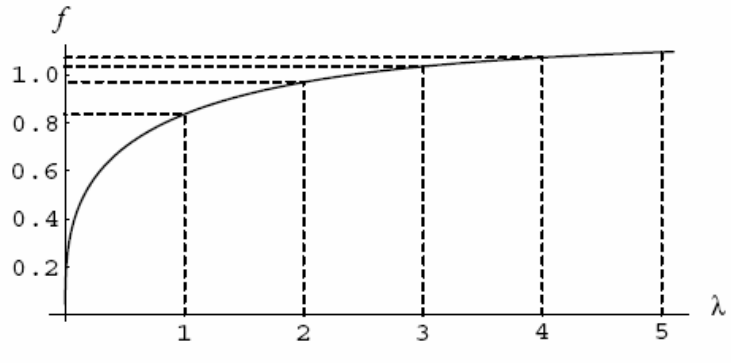
# Sync freq. as function of change freq.

| | $e_1$ | $e_2$ | $e_3$ | $e_4$ | $e_5$ |
|---|---|---|---|---|---|
| (a) change frequency | 1 | 2 | 3 | 4 | 5 |
| (b) synchronization frequency (freshness) | 1.15 | 1.36 | 1.35 | 1.14 | 0.00 |
| (c) synchronization frequency (age) | 0.84 | 0.97 | 1.03 | 1.07 | 1.09 |

Table IV. The optimal synchronization frequencies of Example 5.4




(a) synchronization frequency as a function of change frequency for freshness optimization




(b) synchronization frequency as a function of change frequency for age optimization

Fig. 11. Solution of the freshness and age optimization problem of Example 5.4

Cho & Garcia-Molina, TODS 2003

# Predicted Freshness/Age

| | overall | | com | | gov | |
|---|---|---|---|---|---|---|
| | Freshness | Age | Freshness | Age | Freshness | Age |
| Proportional | 0.12 | 400 days | 0.07 | 386 days | 0.69 | 19.3 days |
| Uniform | 0.57 | 5.6 days | 0.38 | 8.5 days | 0.82 | 2.0 days |
| Optimal | 0.62 | 4.3 days | 0.44 | 7.4 days | 0.85 | 1.3 days |

Table VII. Freshness and age prediction based on the real Web data

(assuming 1 billion pages, sync interval=1 month, reasonable distribution of change rates)

Cho & Garcia-Molina, TODS 2003

# Extension: Page Weights

**Goal:**

Provide high freshness/low age for „important“ pages (e.g., measured by click rates, pagerank, …)

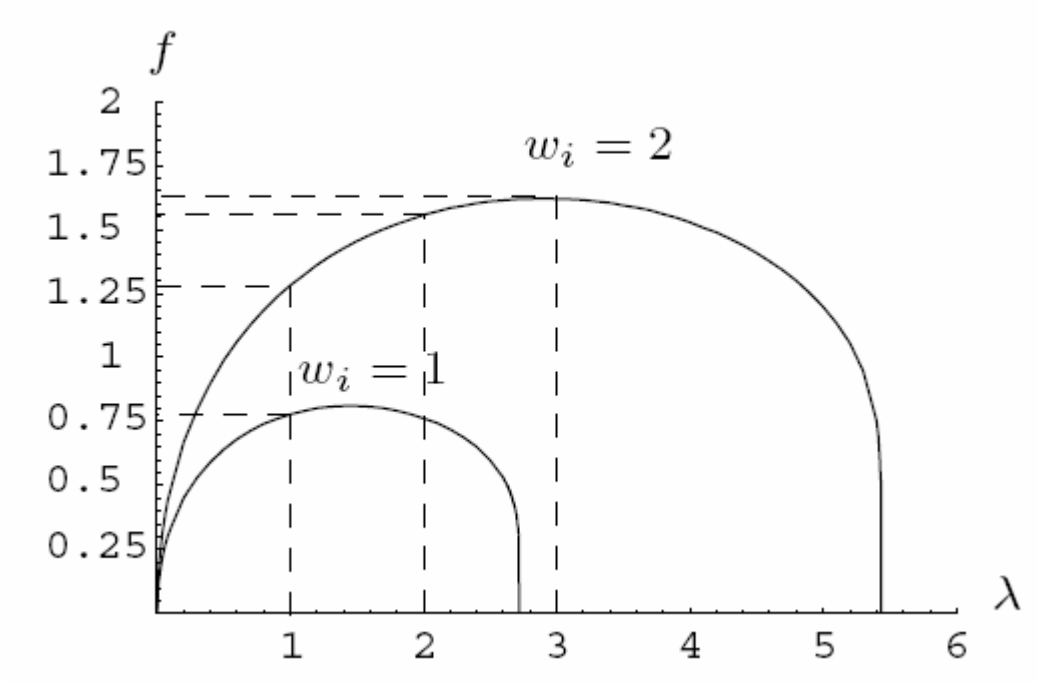
**Solution:**

Consider weighted freshness/age: $F = \frac{\sum_{i=1}^{N} w_i F(p_i)}{\sum_{i=1}^{N} w_i}$

(leads to similar opt. problem)

# Example with Page Weights

| | $e_{11}$ | $e_{12}$ | $e_{13}$ | $e_{21}$ | $e_{22}$ | $e_{23}$ |
|---|---|---|---|---|---|---|
| (a) weight ($w_i$) | 1 | | | 2 | | |
| (b) change frequency (times/day) | 1 | 2 | 3 | 1 | 2 | 3 |
| (c) synchronization frequency (freshness) | 0.78 | 0.76 | 0.00 | 1.28 | 1.56 | 1.62 |
| (d) synchronization frequency (age) | 0.76 | 0.88 | 0.94 | 0.99 | 1.17 | 1.26 |




Cho & Garcia-Molina, TODS 2003

# Crawling to Improve Result Quality

So far: every page change considered equal

$\Rightarrow$ often too conservative (advertisements, date/time, dynamic links, …)

**Goal:**

Update page only for *important* changes

**Metric 1: Result Quality**

Query results on the index should be identical to

Query results on the live Web

(see Pandey/Olston, WWW05, for details)

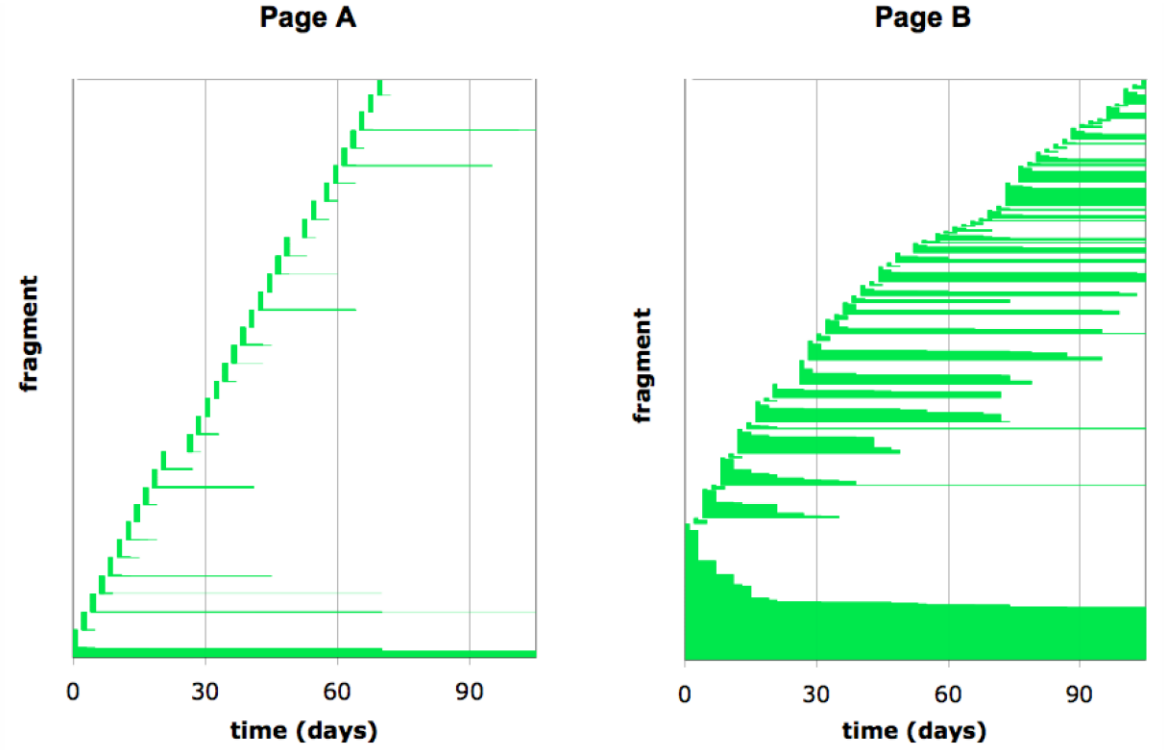
# Metric 2: Information Longevity

**Assumption:**

Content that „lasts for a while“ more important than

Content that is „transient“ (such as ads)

**Example:** lifespan of (word-level) shingles on two pages




Olston&Pandey, WWW 2008

# Quantifying Freshness / Staleness

Notation:

- S(p) = set of shingles of page p
- $p_t$ version at time t

Freshness of p at time t (relative to index time $t_p$):

$$F(p;t_p;t) = \frac{\left|S(p_{t_p}) \cap S(p_t)\right|}{\left|S(p_{t_p}) \cup S(p_t)\right|}$$ (Jaccard coefficient)

Staleness of p at time t (relative to index time $t_p$):

$$D(p;t_p;t) = 1 - \frac{\left|S(p_{t_p}) \cap S(p_t)\right|}{\left|S(p_{t_p}) \cup S(p_t)\right|}$$

# Optimizing Staleness

Assume staleness never decreases over time

$\Rightarrow$ estimate D(p;$t_p$;t) by monotone function $D_p^*(t - t_p)$

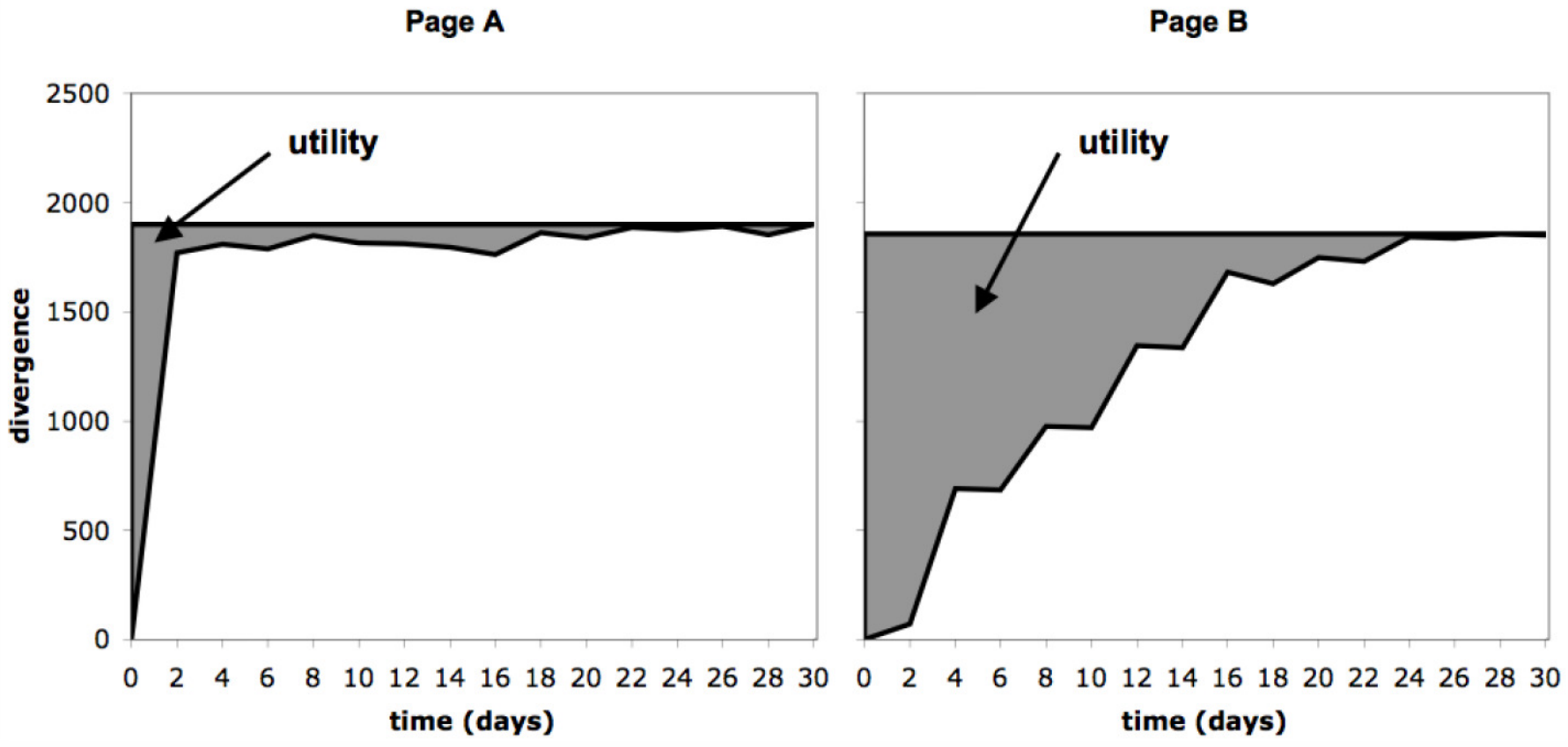
**Theorem:**

At each point in time t, refresh exactly those pages that have $U_p(t\text{-}t_p) \geq T$, where

$$U_p(t) = t \cdot D_p^*(t) - \int_0^t D_p^*(x)dx$$

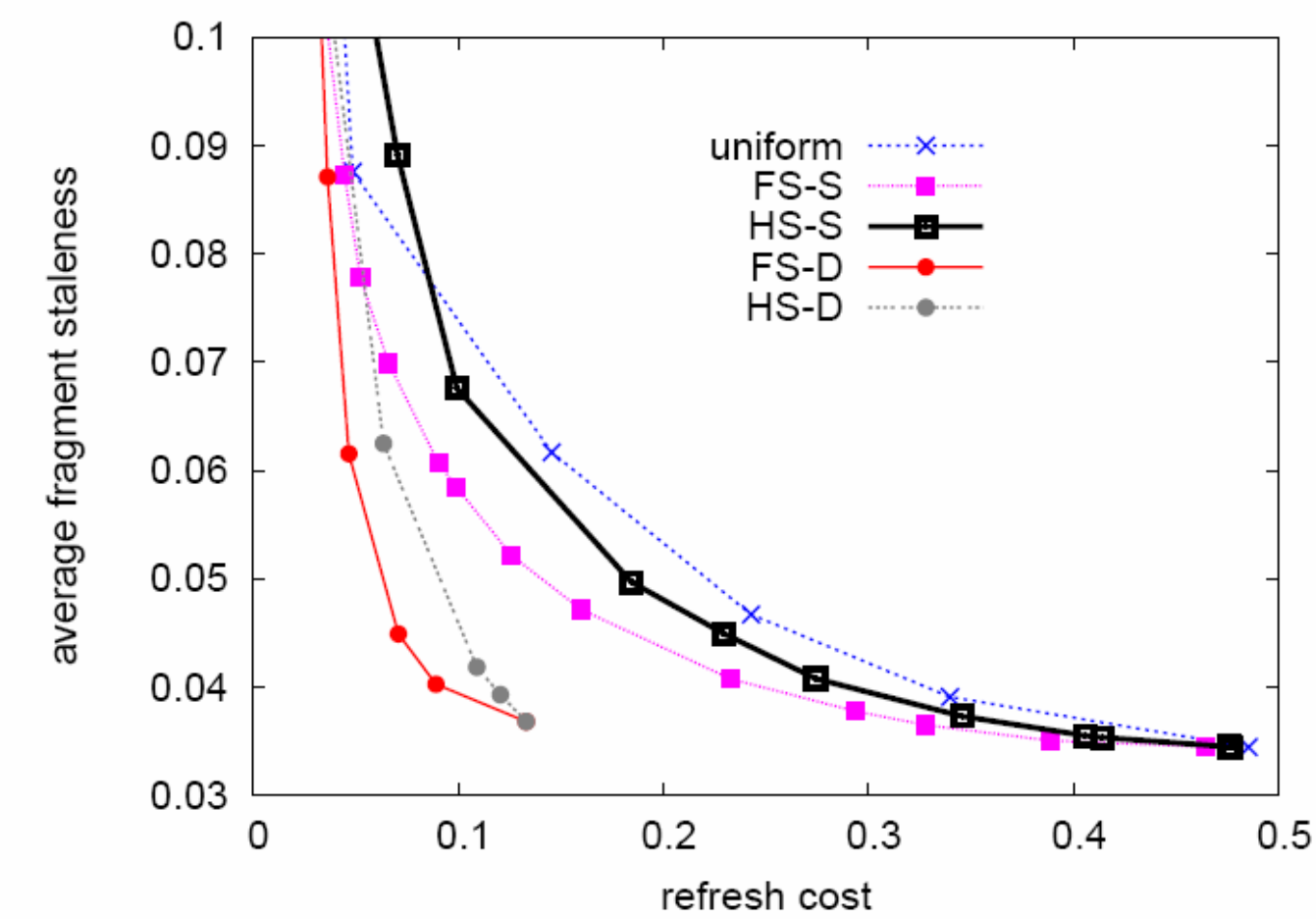
This yields optimal staleness among all schedules that do the same number of refreshes.

# Intuition for Utility Function




Olston&Pandey, WWW 2008

# Experiment: Staleness




HS: freshness-based („holistic“)
FS: staleness-based („fragment“)

-S: estimation of D* over all snapshots
-D: estimation of D* for each snapshot

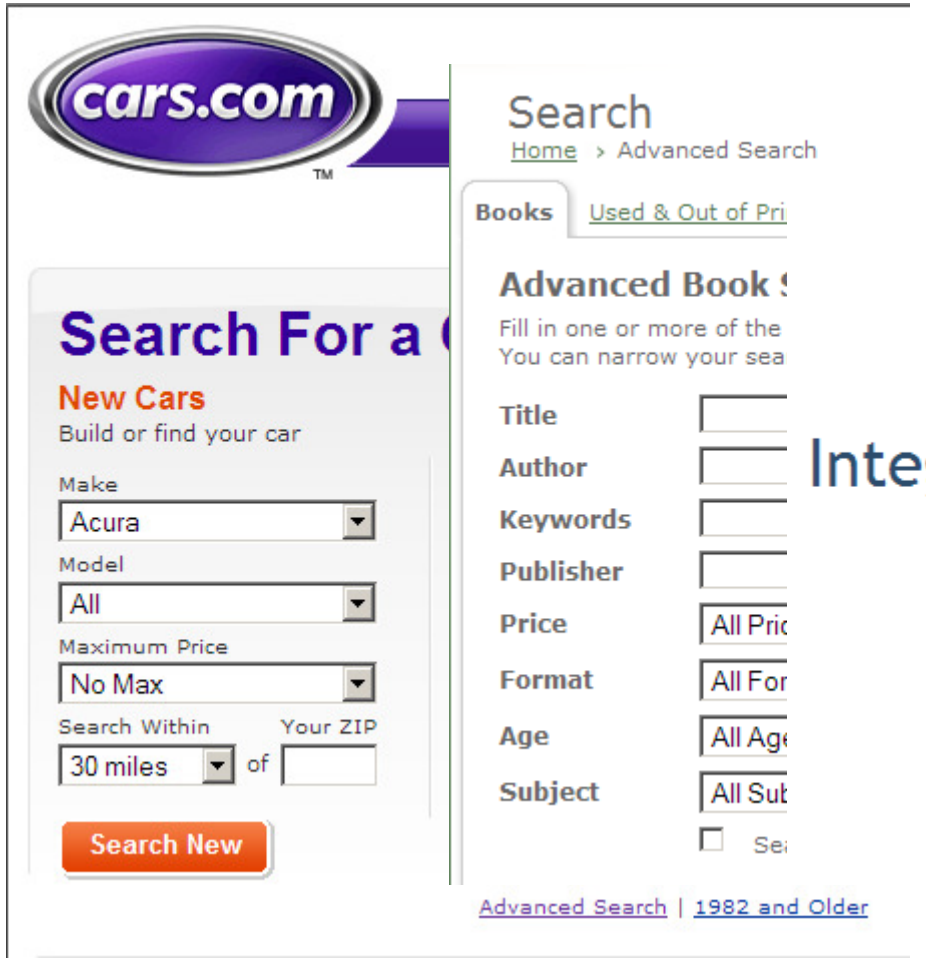
# Web Dynamics

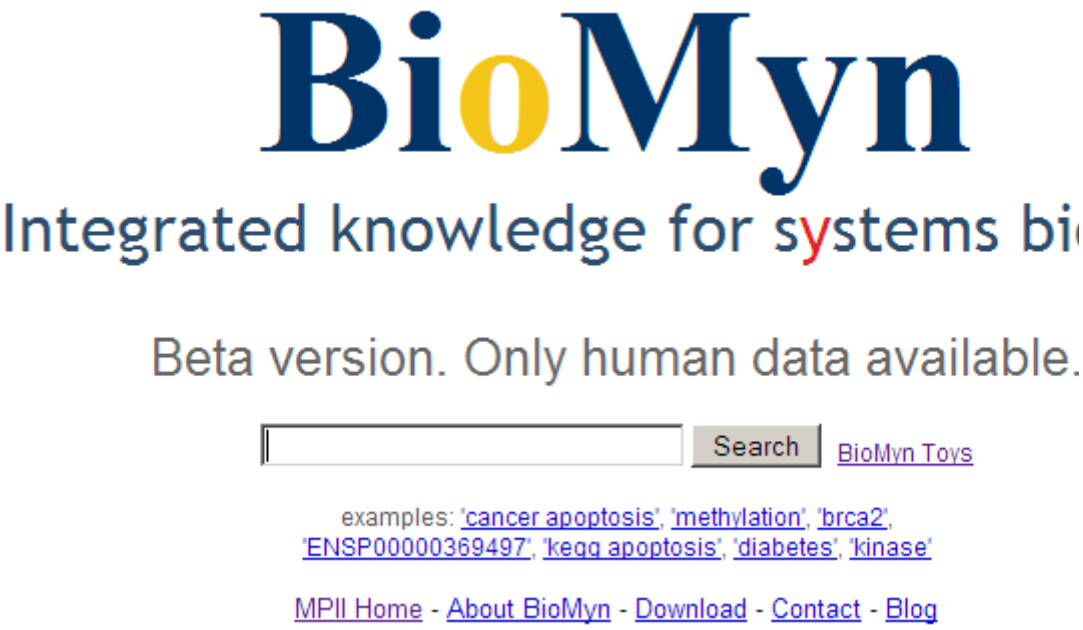
## Part 3 – Searching the Dynamic Web

*3.1 Crawling and recrawling policies*

***3.2 Accessing the Hidden Web***

# Introducing the Hidden/Deeb/Invisible Web




Data only accessible through Web forms

estimate: ~100 petabytes from approx. 100 million sources, compared to ~200 terabytes for the „surface Web“)

# Diversity of „Hidden Web“-Sources

„Hidden Web“-sources differ in

- amount of provided data
- quality/authority of provided data
- freshness of provided data
- covered application domain(s)
- richness of interface (text box, selection,…)

How can such dynamic sources be included in a search engine‘s index?

# Approach 1: Meta Search Engines

Automated domain selection

query: honda civic

Structured query interface: make=Honda, model=Civic, …

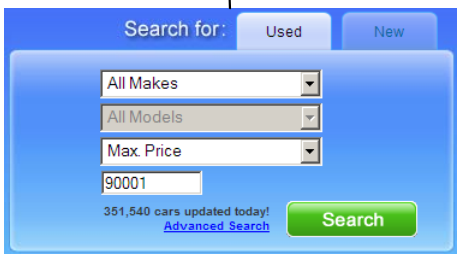
Keyword query interface+mapper: honda, civic, …

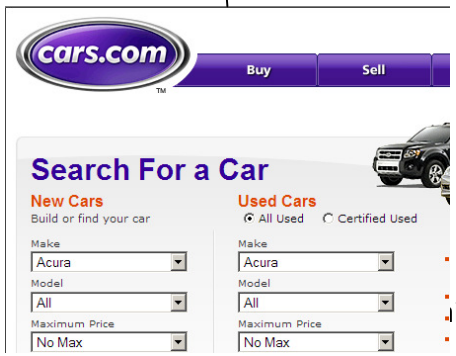
Integrated Schema + Mappers (make, model, version, price, …)

Local schema: (make, model, price)

Local schema: (make, model, price, miles)

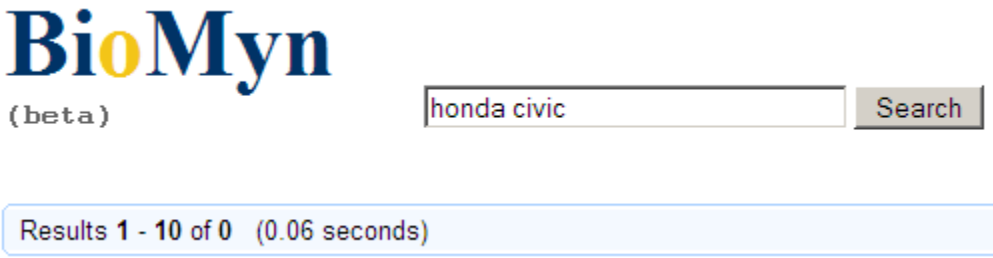
Local schema: (marke, modell, version, endpreis, …)




# Pros and Cons

Good: Information always up-to-date




**But:**

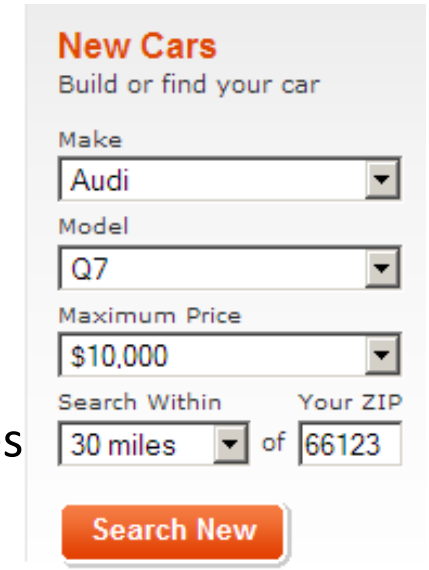
- Includes major manual work (mapper definition), does not scale well
- Requires complex domain detection („java“, „jaguar“)
- Cannot easily cope with interface changes
- Automated processes are error-prone

# Approach 2: Surfacing

- Generate „reasonable“ inputs for each form
- Index result pages (identified by their url) like static Web pages
- Follow outgoing links

**http://www.autoscout24.de/List.aspx?vis=1&make=9&model=18683&...**

# Selecting a few good inputs is important




11 values

~ 2000 combinations

100 values

~ 100,000 values

$\Rightarrow$ 220 billion combinations possible!

(but only 650,000 cars in the database)

(remember from part 1: the Web is infinite!)

# Finding „good“ inputs: templates

**Simplifying model:**

selects, text fields

Web form with inputs **X1…Xn** provides access to database D

**Problem:**

Find ***query templates*** $T \subseteq \{X1 \ldots Xn\}$ and input value sets Vi for each input $Xi \in T$ such that instantiating T by submitting input value combinations to the form (leaving $Xk \notin T$ blank)

1. yields good coverage of D ⟸ difficult to measure
2. is efficient, i.e., does not return too many duplicates

⇑

How can we measure this?

# Template Informativeness

Fix ***signature function S(p)*** for Web pages (e.g., word-level shingles)

**Approach:**

Measure ***informativeness*** of results for template T with input set G(T) (all possible inputs) as

$$I(T) = \frac{\left|\{S(p) \mid p \text{ generated by } T \text{ with input } g \in G(T)\}\right|}{\left|G(T)\right|}$$

**Definition:**

Template T ***informative*** iff $I(T) \geq \tau$

In practice: Ignore T where |G(T)|>10,000; consider only a sample of G(T) (up to 200 inputs per template)

# Finding Informative Templates: ISIT

```
informative:=∅; // inform. templates
candidates:={{Xi}};
while (candidates!=∅)
  for each X∈candidates:
    if (X not informative) remove X;
  informative∪=candidates;
  c:=∅; // set of cands for next step
  for each X∈candidates, I input:
     c∪=(X∪I);
  candidates=c;
```

# Informative Templates: Experiments

ISIT efficiency: 500,000 (randomly chosen) HTML forms

Table 1: Distribution of HTML Forms by the number of inputs.

| Num. Inputs | Num. Forms | Num. Inputs | Num. Forms |
|---|---|---|---|
| 1 | 429271 | 6 | 1684 |
| 2 | 43776 | 7 | 1071 |
| 3 | 12987 | 8 | 418 |
| 4 | 7378 | 9 | 185 |
| 5 | 3101 | 10 | 129 |

| Num. Inputs | Max Templates [dimension $\leq 3$] | Average Templates Tested | Average Templates Informative | Average URLs Analyzed |
|---|---|---|---|---|
| 1 | 1 [1] | 1 | 1 | 23 |
| 2 | 3 [3] | 2.82 | 1.76 | 136 |
| 3 | 7 [7] | 5.38 | 3.04 | 446 |
| 4 | 15 [14] | 8.80 | 3.75 | 891 |
| 5 | 31 [25] | 12.66 | 5.93 | 1323 |
| 6 | 63 [41] | 17.43 | 7.17 | 1925 |
| 7 | 127 [63] | 24.81 | 10.62 | 3256 |
| 8 | 255 [92] | 29.46 | 13.45 | 3919 |
| 9 | 511 [129] | 35.98 | 15.80 | 4239 |
| 10 | 1023 [175] | 41.46 | 17.71 | 5083 |

ISIT effectiveness: 12 selected forms

| No. | URL with HTML form | Cartesian product | URLs Generated | Estimated Database | Records Retrieved |
|---|---|---|---|---|---|
| 1 | http://www2.imm.dtu.dk/pubdb/public/index_public.php | 53550 | 1349 | 4518 | 4518 |
| 2 | http://dermatology.jwatch.org/cgi/archive | 32400 | 179 | 3122 | 1740 |
| 3 | http://www.kies.com.au/listings.php | 129654 | 81 | 62 | 61 |
| 4 | http://aarpmagazine.org/food/recipeguide | 150822 | 365 | 314 | 273 |
| 5 | http://www.shadetrees.org/search.php | 313170 | 181 | 1699 | 1756 |
| 6 | http://www.dasregistry.org/listServices.jsp | 2 million | 627 | 295 | 267 |
| 7 | http://www.nch.org.uk/ourservices/index.php?i=402 | 2.5 million | 34 | 27 | 27 |
| 8 | http://www.lodgerealestate.co.nz/?nav=rentsearch | 4.7 million | 26 | 87 | 74 |
| 9 | http://www.pipa.gov.ps/search_db.asp | 68 million | 1274 | 409 | 409 |
| 10 | http://www.biztransact.com/ | 257 million | 13,209 | 100,000+ | 10,937 |
| 11 | http://projects.bebif.be/enbi/albertinerift/common/search | 948 billion | 2406 | 2287 | 1257 |
| 12 | http://oraweb.aucc.ca/showcupid.html | 3.2 trillion | 34 | 27 | 27 |

Madhavan et al., VLDB 2008

# Handling Text Inputs

Problem: No (small) set of input values available

Solution: Iterative sampling

1. Pick ***most important terms*** from the page with the text input (using tf*idf), check informativeness
2. To create next set of input values, pick most important terms ***from all pages generated*** so far (excluding those appearing on all pages)
3. Stop when set is stable

# Experimental Results: Text Inputs

Table 5: Examples of HTML forms with text boxes comparing the the actual size of the database (number of records) against the number of URLs generated and the number of records retrieved: (first) on the first results page when using only the text box, (select) on the first page using only select menus, and (first++) on the first page and the pages that have links from it when using only the text box,

| No. | Form URL | Estimated Database | Keywords Selected | Results Per Page | Records Retrieved | | |
|---|---|---|---|---|---|---|---|
| | | | | | first | select | first++ |
| 1 | http://kbase.gofrugaltech.com/ | 382 | 169 | 20 | 348 | n.a. | 381 |
| 2 | http://nsidc.org/data/index.html | 506 | 355 | 20 | 475 | 102 | 478 |
| 3 | http://www.hhmi.org/news/search.html | 1700 | 500 | 25 | 1485 | 320 | 1585 |
| 4 | http://ww.azom.com/ | 4700 | 500 | 10 | 2136 | n.a. | 3124 |
| 5 | https://secure.financeweek.co.uk/cgi-bin/iadmin.cgi?page=68 | 5000 | 500 | 50 | 4118 | 1316 | 4118 |
| 6 | http://www.angis.org.au/Databases/BIRX/ | 18200 | 500 | 100 | 5315 | n.a. | n.a. |
| 7 | http://english.ibd.com.cn/databank.asp | 21200 | 500 | 10 | 2661 | 306 | 4697 |
| 8 | http://federalgovernmentjobs.us/ | 60300 | 500 | 10 | 3096 | n.a. | 12127 |
| 9 | http://praca.gratka.pl/ | 15800 | 500 | 20 | 4012 | 290 | 11043 |
| 10 | http://www.rhdsc.gc.ca/fr/ministeriel/recherche/index.shtml | 21800 | 500 | 200 | 13324 | 724 | 19332 |

Madhavan et al., VLDB 2008

# Current challenges for Crawling/Indexing

- ***Non-HTML content*** (Flash, SilverLight)
  $\Rightarrow$ single big „object“, encapsulates content and outgoing links
- ***Dynamic pages*** where program in the browser loads content directly from the server (AJAX)
  $\Rightarrow$ only 1 URL for application, inaccessible for standard crawlers (no Javascript!)
- ***Highly dynamic data*** (social networks, Twitter)
- ***Non-textual data*** (images, videos, …)

# References

**Main references:**


- P. Baldi, P. Frasconi, P. Smyth: **Modeling the Internet and the Web**, chapter 6
- G. Pant et al.: **Crawling the Web**, Web Dynamics book, 153—178, 2004
- J. Bar-Ilan: **Search engine ability to cope with the changing Web**, Web Dynamics book, 195—218, 2004
- J. Cho, H. Garcia-Molina: **Effective page refresh policies for Web crawlers,** ACM Trans. Database Syst. 28(4), 390-426, 2003


**Additional references:**


- C.D. Manning et al.: **Introduction to Information Retrieval**, Chapter 20, Cambridge University Press, 2008
- J. Cho, H. Garcia-Molina: **Estimating frequency of change**, ACM Transactions on Internet Technology 3(3), 256—290, 2003
- I. Hellsten et al.: **Multiple presents: how search engines rewrite the past**, New Media & Society 8(6), 901—924, 2006
- D. Lewandowski: **A three-year study on the freshness of web search engine databases**, Information Science 34(6), 917—831, 2008
- R. Baeza-Yates et al.: **Crawling a country: better strategies than breadth-first for Web page ordering**, WWW Conference, 2005
- R. Baeza-Yates et al.: **Web structure, dynamics and page quality**, SPIRE conference, 2002
- J. Cho, H. Garcia-Molina: **Parallel crawlers**, WWW Conference, 2002
- B.E. Brewington, G.Cybenko: **How dynamic is the Web?** Computer Networks 33(1-6), 257-276, 2000
- S. Pandey, C. Olston: **User-Centric Web Crawling, WWW Conference**, 2005.
- C. Olston, S. Pandey: **Recrawl Scheduling Based on Information Longevity**, WWW Conference, 2008
- J. Madhavan et al.: **Google's Deep-Web Crawl**, VLDB Conference, 2008
- P.G. Ipeirotis et al.: **To Search or To Crawl? Towards a Query Optimizer for Text-Centric Crawls**, SIGMOD Conference, 2006.