Crawling for Temporal Information Retrieval

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Today: Only looking at Web IR
Web IR: First step is collecting documents from the Web
  ▶ no ‘predefined’ collection
Typically through crawlers
In this lecture: How does time affect the crawling process?
Overview

1. Introduction
2. Short Introduction to Crawling
3. Crawling & Time
4. Re-Crawling
5. Temporally Coherent Crawling
Web Crawling

- Standard method for collection of Web documents
- Using a program called (web) crawler
  - also: harvester, spider, robot
- Uses hyperlinks between documents for discovery
- Store collected documents for further processing (indexing, analysis, ...)
Web Crawling Algorithm

Basic Web Crawling Algorithm

WHILE not done
  • Get URL to fetch from queue
  • Fetch URL
  • Parse retrieved document
  • Add new URLs from document to queue
  • Store document
Additional considerations

**Politeness**
Only download one document every \( n \) seconds (typically 5-10s) to avoid overloading servers or being blocked.

**robots.txt**
Obey instructions from Web sites to crawlers.

**Parallel crawling**
Crawler typically waits for remote servers or network, run in parallel to ensure high throughput (typically 100s of parallel threads).

**Robustness**
- Against malformed input (at every layer: network, TCP/IP, HTTP, content)
- Against *spider traps* (Web sites that generate infinitely many pages)
- Against spam

**Quality**
Resulting collection should have good documents. Criteria are e.g. Relevance, Freshness, Diversity, ...
What are relevant dimensions of change?

Changing content of already crawled pages
Appearance / disappearance of pages
Appearance / disappearance of links between pages
Users of IR system change interests
Special Considerations for Time

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Content changes

- Individual pages change their content often
  - More than 40% change at least daily [CG00]
- But: No overall pattern, change occurs at different frequencies & time scales (seconds to years)

- Frequency can be modelled as a Poisson process: With
  - $X(t)$ number of occurrence of a change in $(0, t]$
  - $\lambda$ change rate
  
  $$Pr\{X(s + t) - X(t) = k\} = \frac{(\lambda t)^k}{k!}e^{-\lambda t}$$

for $k = 0, 1, ...$
Change types [OP08]

Temporal behavior of page (regions) can be classified as

- **static**  no changes
- **churn**  new content supplants old content, e.g., quote of the day
- **scroll** new content is appended to old content, e.g., blog entries
The Web changes [NCO04; Das+07]

- New pages are created at a rate of 8% per week
- During one year 80% of pages disappear
- New links are created at the rate of 25% per week
  - significantly faster than the rate of new page creation
- Links are retired at about the same pace as pages
Users change

- User interests change
- Goals of IR system maintainer change
- \( \rightarrow \) requires adaptation of crawl strategy
Re-Crawling Strategies

Crawlers need to balance different considerations:

- **Coverage** fetch new pages
- **Freshness** find updates of existing pages

**Figure:** Crawl ordering model [ON10]
Basic strategies

**Batch crawling**
- Stop and restart crawl process periodically
- Each document is only crawled one time per crawl

**Incremental crawling**
- Crawling is run continuously
- A document can be crawled multiple times during a crawl
- Crawl frequency can differ between different sites

Batch crawling is easier to implement, incremental more powerful.
Batch Crawling Strategies

- Goal is to maximize **Weighted Coverage**:

\[
WC(t) = \sum_{p \in C(t)} w(p),
\]

with

- \( t \) time since start of crawl
- \( C(t) \) pages crawled until time \( t \)
- \( w(p) \) weight of page \( p \), \( 0 \leq p \leq 1 \)

- Main strategy types (ordered by complexity):
  - Breadth-first search
  - Order by in-degree
  - Order by PageRank

**Figure**: Weighted coverage as a function of time \( t \)
Incremental Crawling Strategies

- Goal is to maximize Weighted Freshness:

\[ WF(t) = \sum_{p \in C(t)} w(p) \times f(p, t), \]

with \( f(p, t) \): freshness level of page \( p \) at time \( t \)

- Steady state average of WF:

\[
\bar{WF} = \lim_{t \to \infty} \frac{1}{t} \int_{0}^{t} WF(t) dt
\]

- Trade-off between coverage and freshness: Often treated as a business decision, needs to be tuned towards goals of specific application
Maximizing Freshness [CG03]

Model estimation: create a temporal model for each page $p$

Resource allocation: Given a maximum crawl rate $r$, decide on a revisitation frequency $r(p)$ for each page

Scheduling: Produce a crawl order that implements the targeted revisitation frequencies as close as possible
Model estimation

- Create temporal model of temporal behavior of $p$
  - given samples of past content $p$ / pages similar to $p$
- Samples are often not be evenly-spaced
- Content can give hints about change frequency
  - HTTP headers, number of links, depth of page in site
- Similar pages have similar behavior
  - same site
  - similar content
  - similar link structure
Resource allocation

Binary Freshness model

\[ f(p, t) = \begin{cases} 
1 & \text{if old copy is equal to live copy} \\
0 & \text{otherwise} 
\end{cases} \]

- Intuitively good strategy: proportional resource allocation
  - assign revisitation frequency proportional to change frequency
- But: uniform resource allocation achieves better average binary freshness
  - assuming equal page weights
- Reason:
  - Pages with high change frequency are stale very often regardless of crawl frequency (A)
  - Pages with lower change frequency can be kept fresh more easily (B)
  - Better to keep several pages of type B fresh than wasting resources on page of type A
Continuous freshness model

\[ age(p, t) = \begin{cases} 0 & \text{if old copy is equal to live copy} \\ a & \text{otherwise} \end{cases} \]

\( a \) is the amount of time between cached and live copy

- Revisitation frequency increases with change frequency
  - \( a \) increases monotonically, crawler cannot “give up” on a page
- Instead of age, crawler can also consider content changes directly
  - distinguish between long-lived and ephemeral content
Goal: Produce a crawl ordering that implements the targeted revisitiation frequencies as close as possible
Uniform spacing of downloads of $p$ achieves best results.
Temporal Coherence in Web Archives [Den+11]

- Web archives provide historical snapshots of Web pages
- Allow navigation in old versions of page
- However: Linked pages, images, scripts are crawled at different times
  - Pages show wrong images
  - Linked pages are from different points in time
Palin's path from city hall to governor's mansion

When she played basketball in high school, Sarah Palin, the soon-to-be Republican vice presidential nominee, earned the nickname "Sarah Barracuda" for her fierce competitiveness. In the 21 months she has served as governor of Alaska, no one is suggesting she's lost her fighting edge. full story

- Palin ready to lead? [X] Analysts: Her task
- Palin to call for reform in RNC speech
- Will her gender sway women to Palin?

Republican National Convention »

- Bernstein: Democrats better take note
- Bush, McCain still an uneasy alliance
- Interactive: How conventions work
- McCain arrives in Minnesota for convention [X]
- Key players: Timna, The Forum In Depth

LIVE: Watch coverage of the RNC & Tropical Storm Hanna

 CNN TV »
Web Archive user accesses documents through *time-travel queries* for timepoints $T_1$ and $T_2$.

Archive is incomplete, usually retrieves documents that are temporally closest to queried time.

- *observation interval* is the time interval where a given page is returned for a query.

Retrieved pages differ from actual Web pages at that time.
Measuring Temporal Coherence

Blur

- The **blur of a Web page** $p_i$ captured at $t_i$ is the expected number of changes between $t_i$ and query time $t$, averaged over observation interval $[0, \Delta n]$:

$$B(p_i, t_i, n, \Delta) = \frac{1}{n\Delta} \int_0^n \lambda_i \cdot |t - t_i| dt = \frac{\lambda_i \omega(t_i, n, \Delta)}{n\Delta}$$

where

$$\omega(t_i, n, \Delta) = t_i^2 - t_i n\Delta + \frac{(n\Delta)^2}{2}$$

is the **download schedule penalty**.

- The **blur of an Archive** is the sum of the blur values of individual pages

$\omega(t_i, n, \Delta)$ can be interpreted as the penalty of downloading page $p_i$ at time $t_i$. 
Optimal crawl strategy

- Based on formalization of blur we can infer best crawl strategy
  - Depends on change frequency
  - Pages with highest frequency are scheduled in the middle of the crawl
  - “organ pipe” arrangement
  - Proof in paper

- Optimal strategy for known change frequencies
- Extension towards online algorithm possible
Conclusion

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**Project**

- **Re-crawling strategies based on content**
  - Different page types have different temporal behaviors
    - Home page vs blog archive vs. news feed
  - Categorize a given page into such a category
  - Task: Implementation and evaluation on provided test set
References I


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<tr>
<th>Reference Code</th>
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<tbody>
<tr>
<td>[OP08]</td>
<td>Christopher Olston and Sandeep Pandey</td>
<td>“Recrawl Scheduling Based on Information Longevity”</td>
<td>WWW ’08</td>
<td>2008</td>
<td>10.1145/1367497.1367557</td>
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