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Using Cache Algorithms to Choose Shortcut Links

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Using Cache Algorithms to Choose Shortcut Links (Outline)

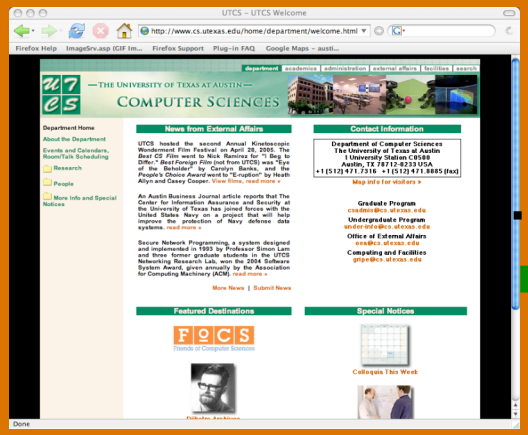
- Introduction
- A simple algorithm for choosing shortcuts
- Caching analogy
- Experimental Results
- Shortcuts on the front page
- Conclusions

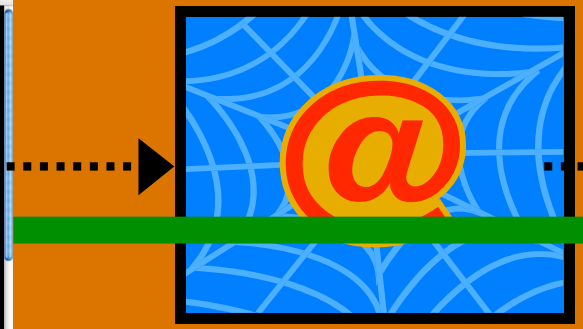
Motivation

- Visitors to websites do not always find what they need on the first page they load
- Navigational links move visitors from their current location to their desired destination
- These links are chosen manually by the author of each page
- Can we supplement these manually chosen links by adding dynamic links automatically?

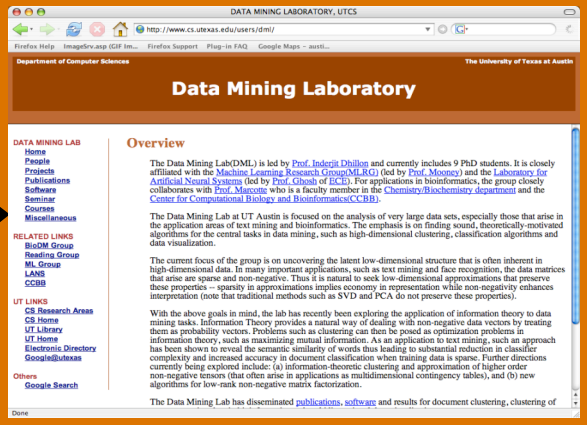
Shortcutting

Page *p*





Page *q*



- Add links based on recent access patterns

Selecting Shortcut Links

- Shortcuts on page *p* should point to pages *q* accessed *after p* within the same session
- Adding all such pages *q* is not a good solution
  - Users would be overwhelmed with thousands of links
  - Need to limit the number of shortcuts on each page
- What features characterize a good shortcut?
  - Recency
  - Frequency

A Naïve Shortcut Selection Algorithm

1. Initialize a 2-D array of counters, with one row and one column for each page.
   - A[i][j] is the number of times page *j* is accessed **after** page *i*
2. For each page *p* in each visit, find all pages *q* that occur **after** *p*. If edge *pq* is not a permanent webgraph edge, increment A[*p*][*q*]
3. For each page, add links to the *k* pages in its row with the highest counts

- This algorithm was suggested by Perkowitz in his PhD thesis
- Transformation is performed nightly and website is updated
- Uses $O(n^2)$ memory

Improving the Naïve Algorithm

- Problem: pages that are infrequently accessed may wind up with poorly-selected shortcuts, or no shortcuts
- Solution: rather than replace all shortcuts each day, replace individual shortcuts when a new shortcut is added
  - Choosing which shortcut to replace is analogous to the *cache-replacement problem*

The Cache Analogy

- Users sessions ⇔ Processes
- Web pages ⇔ Memory locations
- Shortcut destinations ⇔ Cache
- Shortcut quality ⇔ Hit ratio

A Cache-Based Shortcut Selection Algorithm

1. Initialize an array of caches of size *k*, with one cache for each page
2. For each page *p* in each visit, find all pages *q* that occur *after p*.
    1. If the edge *pq* is not a permanent webgraph edge, then register a hit for page *q* on the cache for page *p* (may involve replacement)
    2. Update the links on page *p* to reflect the new cache contents

- *Any* replacement policy will work
- Replacement policies retain pages most likely to be accessed in the future
- Uses O(*n*) memory

Improvement: Batched Caching

- Problem: Caching algorithms update cache on every miss
  - This is too frequent for shortcuts
- Solution: Delay updates
  - "Virtual" cache is updated normally
  - "Real" cache is copied from virtual cache periodically

Improvement: Shadow Caching

- Memory constraints are less restrictive than in a typical caching application
- Can make the virtual cache *larger* than the real cache
- When real cache is updated, populate it with the *k* "best" virtual cache items
- How do we choose the "best" items?
  - Simple: access count from prior time period
  - Better: linear combination of old score and access count from prior time period

Experiments

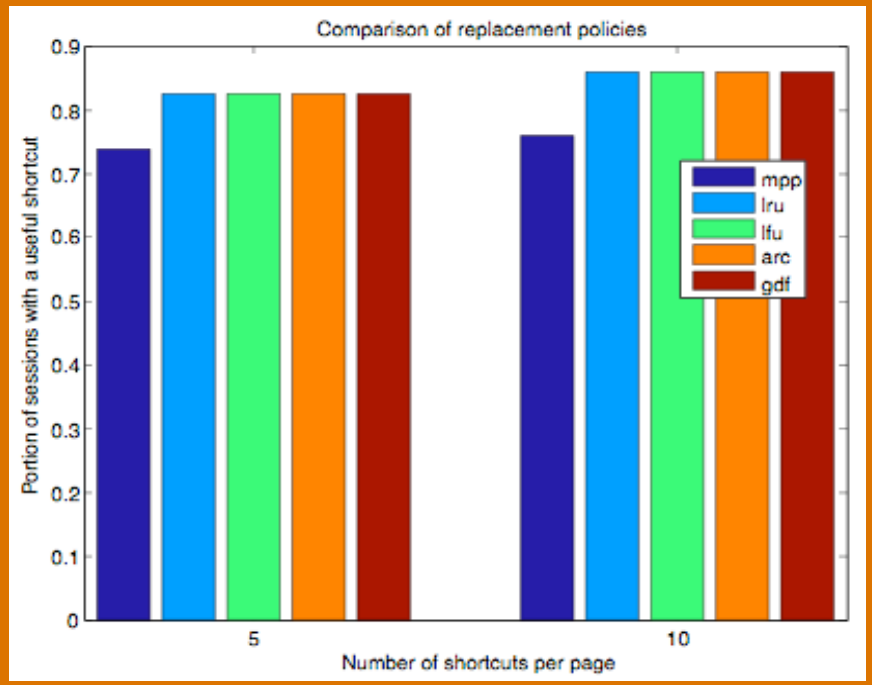
- UTCS access logs from Apr 17 - May 25
  - Robot accesses are removed
  - Long sessions with over 50 pages removed
  - Short sessions with under 3 pages removed
  - 89,000 sessions
  - 3.5 million edges in the sessions
    - Length *k* session has (*k* choose 2) edges
  - 336,000 distinct urls

Replacement Policies Tested

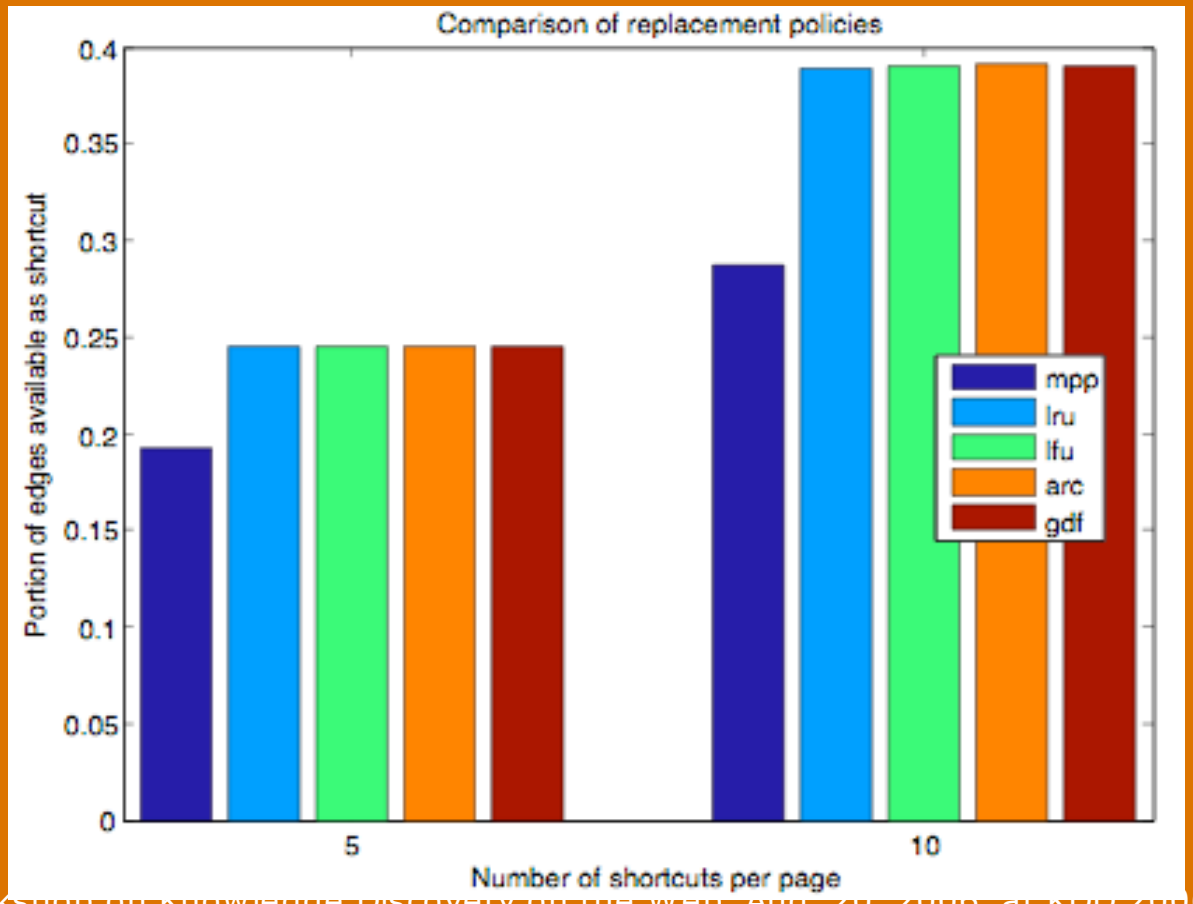
- LRU – Least Recently Used
- LFU – Least Frequently Used
- ARC – Adaptive Replacement Cache
  - Maintains two caches to balance between frequently used and recently used pages
- GDF – Greedy Dual Frequency
  - Like LFU, but with some recency information
- MPP – Most Popular Policy
  - This is the naïve popularity algorithm

Results: Most sessions benefit from shortcuts

- Caching selection outperforms naïve popularity selection



Results: Many edges traversed are available as shortcuts

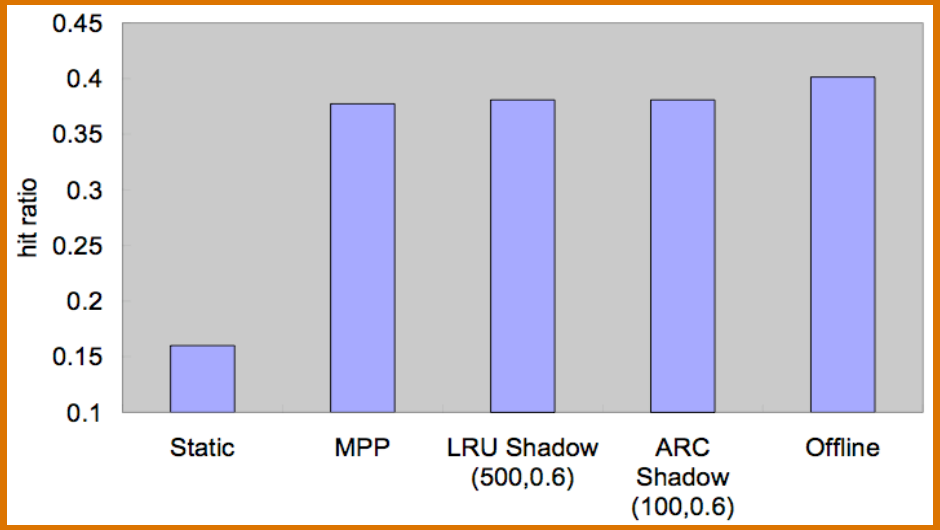


Shortcuts on the Front Page

- The front page serves as a portal
  - Users who load the front page may be interested in *any* content on the site
- Ignore sessions, build shortcuts from **all** pages that are accessed
- Rate success by portion of pages accessed that were shortcut linked on front page

Example of Front Page Shortcuts

Front Page Results



- "Static" refers to the original UTCS front page content
- Naïve mpp performs well, since the top pages receive many hits during each time period
  - Still requires $O(n^2)$ memory
- "Offline" chooses the best possible shortcuts with knowledge of the future

Conclusions

- Shortcutting is a simple, effective way of helping site visitors find the information they need
- Adding only a few links provides connections to almost every page a visitor would want to visit
- Our algorithms are memory efficient and outperform the basic popularity algorithm

Future Work

- How quickly can users get to their intended destination?
  - This assumes that there is a single intended destination, and that we can identify it
- How often are shortcut links actually used?
  - Deployment, and user study

Questions?