Temporal Dynamics and Information Systems

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Information Dynamics

- Many differences between physical & digital libraries
- **Change is everywhere in digital information systems**
  - New documents (and queries) appear all the time
  - Query volume changes over time
  - Document content changes over time
  - What’s relevant to a query changes over time
    - E.g., *U.S. Open 2010* (in May vs. Sept)
    - E.g., *Hurricane Earl* (in Sept 2010 vs. before/after)
  - User interaction changes over time
    - E.g., tags, anchor text, social networks, query-click streams, etc.
- **Change is pervasive in digital information systems**
  ... yet, we’re not doing much about it!
Information Dynamics

Content Changes

User Visitation/ReVisitation

Today’s Browse and Search Experiences

But, ignores ...

iConference - Feb 9, 2011
Digital Dynamics Easy to Capture

- Easy to capture

- But ... few tools support dynamics
Overview

- Characterize change in digital content
  - Content changes over time
  - People re-visit and re-find over time

- Improve retrieval and understanding
  - Examples from our work on search and browser support ... but more general
    - Desktop: Stuff I’ve Seen; Memory Landmarks; LifeBrowser
    - News: Analysis of novelty (e.g., NewsJunkie)
    - Web: Tools for understanding change (e.g., Diff-IE)
    - Web: Retrieval models that leverage dynamics
**Stuff I’ve Seen (SIS)**

- Many silos of information

**SIS:**
- Unified access to distributed, heterogeneous content (mail, files, web, tablet notes, rss, etc.)
- Index full content + metadata
- Fast, flexible search
- Information re-use

**SIS -> Windows Desktop Search**

[Dumais et al., SIGIR 2003]
Example Desktop Searches

Looking for: recent email from Fedor that contained a link to his new demo
Initiated from: Start menu
Query: from:Fedor

Looking for: the pdf of a SIGIR paper on context and ranking (not sure it used those words) that someone (don’t remember who) sent me about a month ago
Initiated from: Outlook
Query: SIGIR

Looking for: meeting invite for the last intern handoff
Initiated from: Start menu
Query: intern handoff kind:appointment

Looking for: C# program I wrote a long time ago
Initiated from: Explorer pane
Query: QCluster*.*

Lots of metadata... especially time
Stuff I’ve Seen: Findings

- Studied using: free-form feedback, questionnaires, usage patterns from log data, in situ experiments, lab studies for richer data

- Personal stores: 5k-1500k items [SD: 100k items; 1k new items/wk]

- Information needs:
  - Desktop search != Web search
  - **People** are important - 29% queries involve names/aliases
  - **Date** is the most common sort order, even w/ “best-match” default
    - Few searches for “best” matching object
    - Many other criteria (e.g., time, people, type), depending on task
    - Need to support flexible access
  - Abstractions important - “useful” date, people, pictures
  - Age of items retrieved
    - Today (5%), Last week (21%), Last month (47%)
    - Need to support episodic access to memory
Memory Landmarks

- Importance of episodes in human memory
  - Memory organized into episodes (Tulving, 1983)
  - People-specific events as anchors (Smith et al., 1978)
  - Time of events often recalled relative to other events, historical or autobiographical (Huttenlocher & Prohaska, 1997)

- Identify and use landmarks facilitate search and information management
  - Timeline interface, augmented w/ landmarks
  - Learn Bayesian models to identify memorable events

- Extensions beyond search, e.g., Life Browser
Memory Landmarks

- General (world, calendar)
- Personal (appts, photos)

Linked to results by time

[Search Results]

[Distribution of Results Over Time]

[Ringle et al., 2003]
Memory Landmarks
Learned models of memorability

[Horvitz et al., 2004]
LifeBrowser

Images & videos
Desktop & search activity
Appts & events
Locations
Whiteboard capture

[Horvitz & Koch, 2010]

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NewsJunkie

Evolution of Context over Time

- News is a stream of information w/ evolving events
  - But, it’s hard to consume it as such
  - Personalized news using information novelty
- Identify clusters of related articles
- Characterize what a user knows about an event
- Compute the novelty of new articles, relative to this background (relevant & novel)
  - Novelty = KLDivergence (article || current_knowledge)
- Use novelty score and user preferences to guide what, when, and how to show new information

[Gabrilovich et al., WWW 2004]
NewsJunkie in Action

NewsJunkie: Pizza delivery man w/ bomb incident

Friends say Wells is innocent

Looking for two people

Copycat case in Missouri

Gun disguised as cane

Novelty Score

Article Sequence by Time
Characterizing Web Change

- Large-scale Web crawls, over time
  - Revisited pages
    - 55,000 pages crawled hourly for 18+ months
    - Unique users, visits/user, time between visits
  - Pages returned by a search engine (for ~100k queries)
    - 6 million pages crawled every two days for 6 months

[Adar et al., WSDM 2009]
Measuring Web Page Change

- **Summary metrics**
  - Number of changes
  - Amount of change
  - Time between changes

- **Change curves**
  - Fixed starting point
  - Measure similarity over different time intervals

- **Within-page changes**
Measuring Web Page Change

- **Summary metrics**
  - Number of changes
  - Amount of change
  - Time between changes

- 33% of Web pages change
- 66% of visited Web pages change
  - 63% of these change every hr.

- Avg. Dice coeff. = 0.80
- Avg. time bet. change = 123 hrs.
- .edu and .gov pages change infrequently, and not by much
- popular pages change more frequently, but not by much
Measuring Web Page Change

- **Summary metrics**
  - Number of changes
  - Amount of change
  - Time between changes

- **Change curves**
  - Fixed starting point
  - Measure similarity over different time intervals

![Change curve for http://losangeles.craigslist.org/hsh/Knot point at 10 hours](image1)

![Change curve for http://allrecipes.com/Knot point at 261 hours](image2)
Measuring Within-Page Change

- DOM-level changes
- Term-level changes
  - Divergence from norm
    - cookbooks
    - salads
    - cheese
    - ingredient
    - bbq
    - …
  - “Staying power” in page
Example Term Longevity Graphs
Revisitation on the Web

- Revisitation patterns
  - Log analyses
    - Toolbar logs for *revisitation*
    - Query logs for *re-finding*
  - User survey to understand intent in revisitations

User Visitation/ReVisitation

*What was the last Web page you visited?*
*Why did you visit (re-visit) the page?*
Measuring Revisitation

- Summary metrics
  - Unique visitors
  - Visits/user
  - Time between visits

- Revisitation curves
  - Histogram of revisit intervals
  - Normalized

- 60-80% of Web pages you visit, you’ve visited before
- Many motivations for revisits
Possible Relationships Between Change and Revisitation

- Interested in change
- Monitor
- Effect change
- Transact
- Change unimportant
- Re-find old
- Change can interfere with re-finding
Revisititation and Search (ReFinding)

- Repeat query (33%)
  - Q: *iconference 2011*

- Repeat click (39%)
  - http://www.ischools.org/iConference11
  - Q: *iconference 2011; iconference*

- Big opportunity (43%)
  - 24% “navigational revisits”

<table>
<thead>
<tr>
<th></th>
<th>Repeat Click</th>
<th>New Click</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repeat Query</td>
<td>33%</td>
<td>29%</td>
</tr>
<tr>
<td>New Query</td>
<td>67%</td>
<td>10%</td>
</tr>
</tbody>
</table>

[Teevan et al., SIGIR 2007]
[Tyler et al., WSDM 2010]
Building Support for Web Dynamics

Content Changes

User Visitation/ReVisitation

Temporal IR

Diff IE
Diff-IE toolbar

Changes to page since your last visit

[Teevan et al., UIST 2009]
[Teevan et al., CHI 2010]
Interesting Features of Diff-IE

Always on

New to you

Examples of Diff-IE in Action
Expected New Content

The New York Times
Saturday, February 5, 2011

Obama Backs Suleiman-Led Transition

Elections Would be Held in September
By MARK LANDLER and HAREEM FAHMY

The Obama administration on Saturday backed attempts by Egypt's vice president, Omar Suleiman, to broker a compromise with opposition groups and prepare for elections.

WHY NOW

In Turkey's Example, Some See a Map for Egypt
By LONDON THOMAS JR.

In politics and economics, Turkey provides a powerful illustration of success in the region.

MORE FROM THE MIDDLE EAST
- Egypt's Stability Hinges on Military
- Obama Said to Fault Mideast Intelligence

BUSINESS DAY
Cheesemakers Fret Over Possible New Rules
As the government reconsiders a 60-day aging rule for raw milk cheeses, artisans fear their businesses will suffer.

WHAT'S POPULAR NOW
- The Siege of Planned Parenthood
- Obama Backs Suleiman-Led Transition

Opinion
OPINION
OPINIONATOR | FOXES
Growing a Social Business
How the rural poor can start a business without taking on debt.

WHAT'S POPULAR NOW
- Herbert: Bewitched by the Numbers
- Collins: Siege of Planned Parenthood
- Blow: Kindling of Change
- Editorial: Court Politics
- Disunion: Women and Children First
Wednesday, February 9

7:00 AM - 5:00 PM: Registration

8:45 AM - 10:30 AM: Native American Blessing / Welcoming led by Julian Arbel (Washington) followed by Keynote Address by Susan Dumais (Microsoft Research)

Location: B Level, Courtyard Ballroom

Please note that the doors will close for a short time at the commencement of our ceremony out of deference to the Native American Blessing. Stragglers will be asked to wait until the blessing has concluded before being permitted to enter.

Session Chair: Jonathan Grudin (Microsoft Research)

10:30 AM - 4:00 PM: Special Event: Microsoft Visit

This half-day visit to the Microsoft campus in Redmond will involve presentations and demos by Microsoft Research staff, as well as tours at the Microsoft Corporate headquarters. Please note that it conflicts with iConference sessions 1 through 12.

UPDATE: this tour is officially full, and space is limited to attendees who already signed up at registration.

11:00 AM - 12:30 PM:

Session 1: Alternative Event
Understand Page Dynamics
Studying Diff-IE

- **Feedback buttons**
- **Survey**
  - Prior to installation
  - After a month of use
- **Logging**
  - URLs visited
  - Amount of change when revisited
- **Experience interview**
People Revisit More

- Perception of revisitation remains constant
  - How often do you revisit?
  - How often are revisits to view new content?

- Actual revisitation increases
  - Last week: 45.0% of visits are revisits
  - First week: 39.4% of visits are revisits

- Why are people revisiting more with DIFF-IE?
Revisited Pages Change More

- Perception of change increases
  - What proportion of pages change regularly?
  - How often do you notice unexpected change?

- Amount of change seen increases
  - Last week: 32.4% revisits changed, by 9.5%
  - First week: 21.5% revisits changed, by 6.2%

- Diff-IE is driving visits to changed pages
  - It supports people in understanding change
Other Examples of Dynamics and User Experience

- **Content changes**
  - Diff-IE (Teevan et al., 2008)
  - Zoetrope (Adar et al., 2008)
  - Diffamation (Chevalier et al., 2010)
  - Temporal summaries and snippets...

- **Interaction changes**
  - Explicit annotations, ratings, wikis, etc.
  - Implicit interest via interaction patterns
    - Edit wear and read wear (Hill et al., 1992)
Leveraging Dynamics for Retrieval

Content Changes

User Visitation/ReVisitation

Temporal IR
Temporal Retrieval Models

- Current retrieval algorithms look only at a single snapshot of a page
- But, Web pages change over time
- Can we leverage this to improved retrieval?
  - Pages have different rates of change
    - Different priors (using change vs. link structure)
  - Terms have different longevity (staying power)
    - Some are always on the page; some transient
  - Language modeling approach to ranking

\[
P(D \mid Q) = P(D) P(Q \mid D)
\]

Change prior Term longevity

[Elisas et al., WSDM 2010]
Relevance and Page Change

- Page change is related to relevance judgments
  - Human relevance judgments
    - 5 point scale - Perfect/Excellent/Good/Fair/Bad
  - Rate of Change -- 60% Perfect pages; 30% Bad pages

- Use change rate as a document prior (vs. priors based on link structure like Page Rank)
  - Shingle prints to measure change

\[ P(D | Q) = P(D) \cdot P(Q | D) \]
Relevance and Term Change

- Terms patterns vary over time
- Represent a document as a mixture of terms with different “staying power”
  - Long, Medium, Short

\[ P(Q|D) = \lambda_L P(Q|D_L) + \lambda_M P(Q|D_M) + \lambda_S P(Q|D_S) \]

\[ P(D|Q) = P(D) \cdot P(Q|D) \]

Term longevity
Evaluation: Queries & Documents

- 18K Queries, 2.5M Judged Documents
  - 5-level relevance judgment (Perfect ... Bad)
- 2.5M Documents crawled weekly for 10 wks

- Navigational queries
  - 2k queries identified with a “Perfect” judgment
  - Assume these relevance judgments are consistent over time
Experimental Results

![Graph showing experimental results]

- Baseline Static Model
- Dynamic Model
- Dynamic Model + Change Prior
- Change Prior

% Gain/Loss in nDCG vs nDCG cutoff
Temporal Retrieval, Ongoing Work

- Initial evaluation
  - Focused on navigational queries
  - Assumed their relevance is “static” over time

- But, there are many other cases ...
  - E.g., *US Open 2010* (in June vs. Sept)
  - E.g., *World Cup Results* (in 2010 vs. 2006)

- Ongoing evaluation
  - Collecting explicit relevance judgments, query frequency, interaction data and page content over time
  - Developing temporal IR models, temporal snippets

[Kulkarni et al., WSDM 2011]
Relevance over Time

- **Query:** *march madness*  [Mar 15 - Apr 4, 2010]
Other Examples of Dynamics and Information Systems

- **Query dynamics**
  - Kulkarni et al. (2011); Jones & Diaz (2004); Diaz (2009); Kotov et al. (2010)

- **Document dynamics, for crawling and indexing**
  - Adar et al. (2009); Cho & Garcia-Molina (2000); Fetterly et al. (2003)

- **Temporal retrieval models**
  - Elsas & Dumais (2010); Liu & Croft (2004); Efron (2010); Aji et al. (2010)

- **Extraction of temporal entities within documents**

- **Protocol extension for retrieving versions over time**
  - E.g., Memento (Van de Sompel et al., 2010)
Summary

Web content changes: page-level, term-level

Relating revisitation and change allows us to
- Identify pages for which change is important
- Identify interesting components within a page

People revisit and re-find Web content

Temporal IR: Leverages change for improved IR

Diff-IE: Supports (and influences) interaction and understanding
Challenges and Opportunities

- Temporal dynamics are pervasive in information systems
- Influence many aspect of information systems
  - Systems: protocols, crawling, indexing, caching
  - Document representations: meta-data generation, information extraction, sufficient statistics at page and term-level
  - Retrieval models: term weights, document priors, etc.
  - User experience and evaluation
- Better supporting temporal dynamics of information
  - Requires digital preservation and temporal metadata extraction
  - Enables richer understanding of the evolution (and prediction) of key ideas, relations, and trends over time
- Time is one important example of context and IR
  - Others include: location, individuals, tasks ...
Think Outside the (Search) Boxes

User Context

Task/Use Context

Query Words

Document Context

Ranked List
Thank You!

- Questions/Comments...

More info, http://research.microsoft.com/~sdumais

Diff-IE ... try it!