11-642:
Search Engines

Search Log Analysis

Jamie Callan
Carnegie Mellon University
callan@cs.cmu.edu

Lecture Outline

- **Introduction to search logs**
- **Users and tasks**
- **Segmenting search logs into sessions**

Search Logs

Most search engines save information about every search

- The query
- A timestamp
- The IP address of the search client
- Possibly an id recorded in a cookie or obtained another way
- Information about the operating system and browser
- …

Search engines can also collect information about which search results are clicked

- Clickthrough information

Tracking Clickthrough

A search result from a commercial search engine

Jamie Callan
www.cs.cmu.edu/~callan/ ▾ Carnegie Mellon University ▾
Jun 2, 2014 - SCS LTI Professor's research, teaching and publications.

This links to a Google service, not Jamie's web page

```
<a href="http://www.google.com/url?...
        url=http%3A%2F%2Fwww.cs.cmu.edu%2F~callan%2F..."
    onmousedown="return rwt(this,",",",'1',
        'AFQjCNEdAfNBUdV9CsucUqfoWBmKAs0zHA',",
        '0CB4QFjAA',",",event)">Jamie Callan</a>
```

It logs the click and returns a page that redirects to Jamie's page

Publicly Available Web Search Logs

There are few publicly available web search logs

- The Excite log (1997)
  - 18,113 users, 51,473 queries
- The AOL log (2006)
  - More than 650,000 users, more than 20 million queries

Why aren't more search logs available?

- Competitive reasons
- Privacy reasons

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Sensitive Information in Web Search Logs: One Individual's Queries

bladder infection	2006-05-13 09:22:53
cleveland ohio jobs	2006-05-15 07:45:51
cleveland plain dealer	2006-05-15 07:47:17
fitness job search	2006-05-15 07:53:46
ymca in cleveland ohio	2006-05-15 08:05:42
ymca jobs in cleveland ohio	2006-05-15 08:14:32
ymca in parma ohio	2006-05-15 08:23:01
united health care	2006-05-15 09:25:37
surgery for bladder	2006-05-15 10:23:07
incontinence surgery	2006-05-15 10:30:43
exercises for legs and abs	2006-05-15 19:26:20
free money for women starting a business	2006-05-16 09:36:40
…	

(AOL search log)

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Web Search Logs: More Detail

gout			2006-03-01 07:38:03
chemotherapy			2006-03-01 07:41:04
chemotherapy side effects			2006-03-01 07:42:36
Click on #1 result ⟶	1	http://www.cancerhelp.org.uk	
chemotherapy causing hearing loss			2006-03-01 07:45:23
	2	http://www.sciencedaily.com	
kenny rogers songs			2006-03-02 06:05:40
kenny rogers' song i cant unlove you			2006-03-02 06:06:58
Click on #4 result ⟶	4	http://www.kennyrogers.com	
kenny rogers' song i cant unlove you			2006-03-02 06:06:58
	3	http://www.cmt.com	
kenny rogers' song i cant unlove you			2006-03-02 06:06:58
	6	http://www.lyricspremium.com	

(From AOL search log, part 9)

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Inaccessible and Less Accessible Web Search Logs

Statistics about some web search logs have been published

- **AltaVista (1999):** 285 million users, about 1 billion queries
- **AltaVista (2001):** Over 7 million queries

Some web search companies make search logs available for research use under a strict license

- These logs allow knowledge to be discovered and disseminated
- But … many researchers cannot get access

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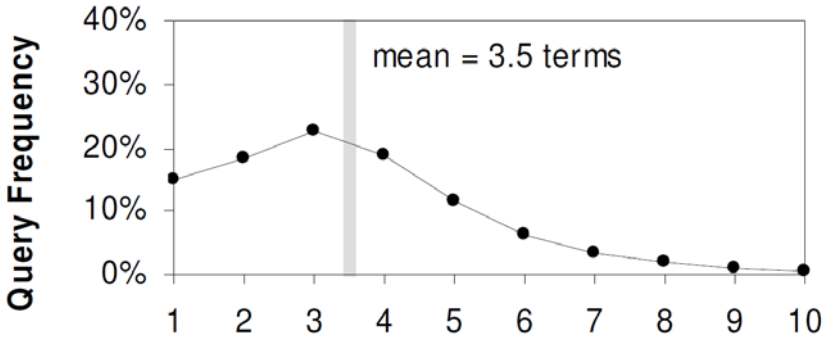
Web Search Query Length

Web queries tend to be short



(Pass, et al., 2006)

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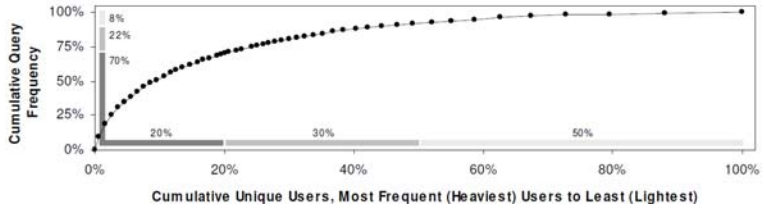
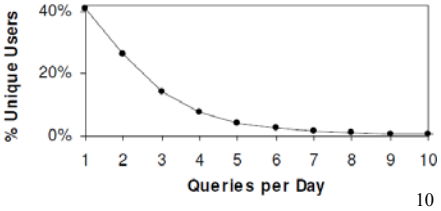
Who Queries?

A few people issue most of the queries



Most people don't search much



(Pass, et al., 2006)

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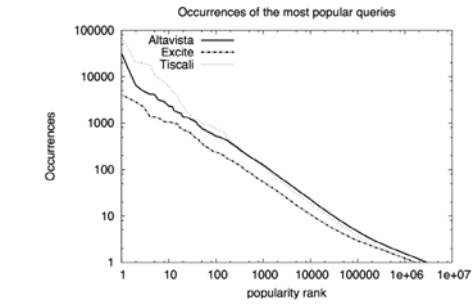
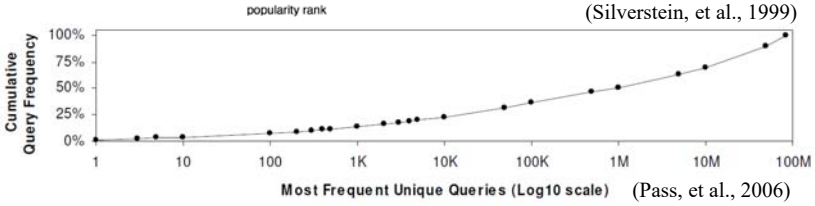
Query Frequency Follows a Power Law



AltaVista log

Freq	Percent
1	63.7%
2	16.2%
3	6.5%
> 3	13.6%

(Fagni, et al., 2006)
(Silverstein, et al., 1999)



(Pass, et al., 2006)

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Query Frequency

Query frequency follows a power law

Frequency(q) = K × Rank(q)$^{-\alpha}$

K: Constant, positive

Rank(q): Popularity rank (r=1 is most popular)

α: Constant, about 2.4 for the Excite query log

Note the similarity to Zipf's law

- Same shape, different slope

Implications

- A small percentage of the (unique) queries are very common
- Most (unique) queries occur very rarely

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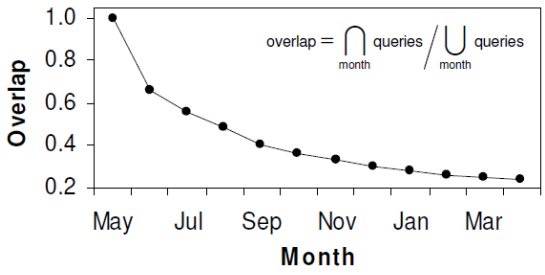
The Most Frequent Queries Vary Over Time

From month to month



From year to year

- Sex much more of a focus in the late 1990s than now

(Pass, et al., 2006)

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Query Frequency

Two interesting statistics

- **20% of all queries seen each day have never been seen before (50% of all unique queries seen each day)**
  - *White, et al., 2007*
  - *Amit Singhal, Google, 2010*

    http://googlepolicyeurope.blogspot.com/2010/02/this-stuff-is-tough.html
- **8% of the queries are names**
  - *Amit Singhal, Google, 2010*

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Queries Vary Geographically

(Pass, et al., 2006)

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Lecture Outline

- Introduction to search logs
- **Users and tasks**
- Segmenting search logs into sessions

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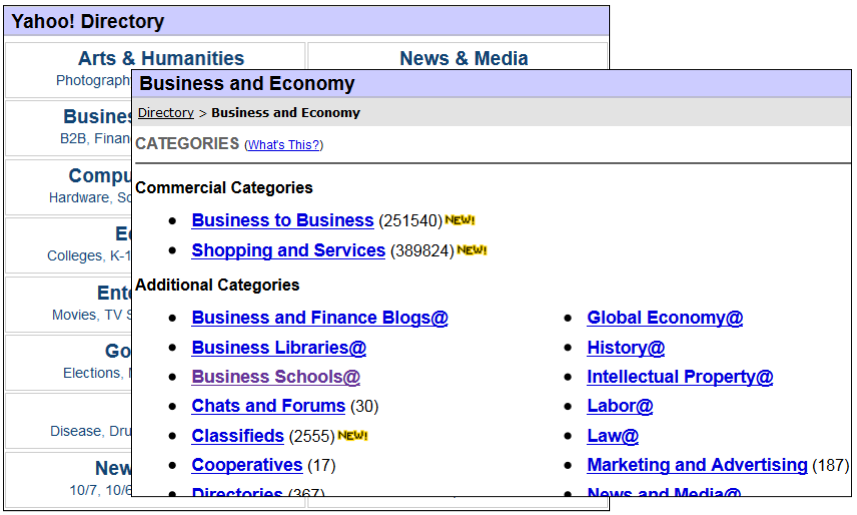
Who Uses Web Search for What? And How?

Web search behavior can be modeled along three dimensions

- **Query topics ("what?")**
  - E.g., topics in the Yahoo! Directory
- **User demographics ("who?")**
  - E.g., provided by the user (age, gender)
  - E.g., inferred from the user's zip code
    - » income, educational level, political party affiliation
- **Session characteristics ("how?")**
  - E.g., Session length, number of queries/session
  - E.g., % of queries with low/high click entropy
    - » Variation in the documents people click on

(Weber and Jaimes, 2011)

The Yahoo! Directory



Who Uses Web Search for What? And How?

Data source:

- A large sample of a Yahoo! search engine query log (2008-2009)
- Registered Yahoo! users
- U.S. users (user-provided information, U.S. search site)
- Active users (> 100 queries during the sample period)
- Not bots (proprietary algorithm)

Data size

- 2.3 million users

Cluster users based on the types of queries they issue

(Weber and Jaimes, 2011)

Who Uses Web Search for What? And How?: Representing Users

Get <$user_i$, $query_j$> pairs from logs

- <jackpgh98, "ingmar weber">
- <jackpgh98, "search log analysis">

Create pseudo documents for users

- **Title:** A user id
- **Contents:** The Yahoo! Directory categories of the top 10 documents for each query

Use your favorite similarity metric

- E.g., Jenson-Shannon Divergence

Pseudo document

<DOC>
<TITLE> jackpgh98 </TITLE>
<BODY>
Computers and Internet / Information Technology,
Computers and Internet / People, Higher Education / College and University Teaching,
Science / Information Architecture and Design,
…
</BODY>
</DOC>

(Weber and Jaimes, 2011)

Who Uses Web Search for What? And How?: Finding Similar Users

Each user is represented by a pseudo document

jackpgh98

<DOC>
<TITLE> jackpgh98 </TITLE>
<BODY>
Computers and Internet / Information Technology, Computers and Internet / People,
Higher Education / College and University Teaching,
Science / Information Architecture and Design,
…
</BODY>
</DOC>

irguy214

<DOC>
<TITLE> irguy214 </TITLE>
<BODY>
Higher Education / College and University Teaching,
Computers and Internet / Object-Oriented Programming,
Science / Information Architecture and Design,
Computers and Internet / Linguistics,
…
</BODY>
</DOC>

kimfan1893

<DOC>
<TITLE> kimfan1893 </TITLE>
<BODY>
Television Shows / Reality Television,
Television Shows / Society and Culture,
Television Shows / Comedy,
Television Shows / Reality Television,
…
</BODY>
</DOC>

. . .

Use your favorite similarity metric to find similar users

- E.g., Jenson-Shannon Divergence, cosine correlation, ….

These ideas are used repeatedly in search engines

- Product search, company search, people search, …

Who Uses Web Search for What? And How?: Finding Similar Users

Cluster users in the "what" dimension

- Topics
  - Representations are based on Yahoo Directory categories (i.e., controlled vocabulary terms)

Use the other two dimensions to investigate the groups

- "Who": Demographic information
- "How": How people search

Manually label groups based on distinctive characteristics

(Weber and Jaimes, 2011)

Who Uses Web Search for What? And How?: Informational Users

What

- Wide range of topics
  - Little interest in adult content

How

- More likely to issue non-navigational queries
- Less likely to have single-click sessions
- More likely to use query suggestions

Who

- More likely to be well-educated
- More likely to have above-average income

(Weber and Jaimes, 2011)

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Who Uses Web Search for What? And How?: Navigational Users

What

- Dominated by popular websites (Facebook, YouTube, Craigslist)

How

- More likely to issue navigational queries
- More likely to have single-click sessions
- Less likely to use query suggestions

Who

- Mostly representative of the entire population

(Weber and Jaimes, 2011)

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Who Uses Web Search for What? And How?: Transactional Users

What

- Shopping, adult content, gaming

How

- Somewhat similar to navigational users
  - But, multiple sites can perform the transaction
  - Diverse clicks
- Short interaction with search engine

Who

- Depends heavily on the type of transaction
- Topic "recreation/games" associated with low income & education

(Weber and Jaimes, 2011)

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Who Uses Web Search for What? And How?: Selected Groups

Baby boomers

- 50 years old
- Interested in finance
- Simple navigational queries related to online banking

Challenged youth

- Average age of 34
- Low-income neighborhoods with low-level of education
- Interested in music
- Navigational sessions

(Weber and Jaimes, 2011)

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Who Uses Web Search for What? And How?: Selected Groups

Liberal females

- Mostly female from areas that voted Democratic
- Shopping queries
- Long sessions (browsing and comparison)

White conservatives

- Mostly male from areas that voted Republican
- Interested in automotive, business, home & garden

(Weber and Jaimes, 2011)

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Who Uses Web Search for What? And How?: Selected Groups

Older users: Health / diseases & conditions, gambling, travel

People in their late 20s: Health / fitness, reproductive health

Younger people: Games, education

Low income: Music, comics & animation, military

Asian descent: Computers & internet, programming & development

Is any of this surprising or useful?

(Weber and Jaimes, 2011)

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Who Uses Web Search for What? And How?: Interplay Between What and How

Some topics typically receive few clicks

- News & media, society & culture, computers & internet

People are more likely to click on suggestions for some topics

- Health, science, arts

People with higher educational levels…

- Tend to have shorter sessions
- Click on query suggestions less often
- Are more likely to submit tail queries

(Weber and Jaimes, 2011)

Who Uses Web Search for What? And How?

Observations from query log analysis are useful for designing personalization strategies

- However, you have to figure out how to turn observations into useful strategies

(Weber and Jaimes, 2011)

Lecture Outline

- Introduction to search logs
- Users and tasks
- **Segmenting search logs into sessions**

Information Seeking in the Real World

Interpreting search logs is an open research problem

- d_1 is clicked at steps 2 and 4 … is it relevant to q_1?
- Are q_1, q_2, and q_3 about the same information need?
- Was the user satisfied with any of the search results?

How do we think about this sequence of interactions?

Search log

q_1
d_1
d_2
d_1
q_2
q_3
d_3
email site
:

q_i: Query
d_j: Clicked page

Information Seeking is a Dialogue Between a Person and a Search Engine

Ad-hoc search can be viewed as a *dialogue* about an information need

Person: query	Initial description
Engine: search results	Initial attempt to satisfy it
Person: reformulated query	Revised description
Engine: new search results	Revised attempt to satisfy it
…	

Viewing Search Logs as a Dialogue

Timeline (mm:ss)		Query
00:00	◯	nursing registry
04:18	c	certified nursing assistant 1
08:48	c	nursing assistant registry
09:48	c	license look up for nursing assistants
10:06	c	nursing assistant 1 certification
11:42	c	nursing assistant 1 license look ups
12:18	c	nursing assistant 1 expiration look up
12:30	c	nursing registry in Raleigh
13:24	c	nursing aide registry of Raleigh
15:00	+	nursing aide registry of Raleigh website
16:06	<	nursing aide registry of Raleigh
19:48	c	north carolina board of nursing information for nursing assistant 1
22:24	c	license look up for nursing assistant 1
24:36	c	license information for nursing assistant 1 expiration
28:30	c	north carolina nursing assistant 1 license information

(Pass, et al., 2006)

Viewing Search Logs as a Dialogue

The first task is to distinguish the different dialogues

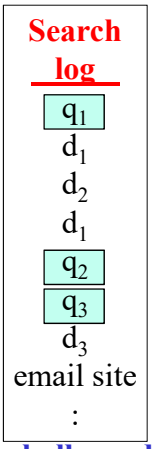
- Which queries address the same information need?

Originally, information need ≈ a search session

- **Session:** A sequence of user actions within a timespan
  - E.g., 30 minutes
- Perhaps an artifact of the experimental conditions
  - Much of the early work was done in a lab

Information need ≈ a search session is beginning to be challenged

- However, we start here because it is still the dominant view



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Viewing Search Logs as a Dialogue

gout	2006-03-01 07:38:03	**How would**
chemotherapy side effects	2006-03-01 07:42:36	**you segment**
chemotherapy causing hearing loss	2006-03-01 07:45:23	**this log into**
kenny rogers songs	2006-03-02 06:05:40	**sessions?**
commerce on line	2006-03-03 04:54:11	
broadband internet	2006-03-06 05:32:28	
middlesex county college nj	2006-03-06 16:55:56	
kean college	2006-03-06 17:02:32	
montclair college	2006-03-06 17:10:45	
union county college	2006-03-07 04:49:23	
rutgers	2006-03-07 05:10:17	
kean college	2006-03-07 05:19:22	
migraine headache	2006-03-10 06:02:55	
new jersey income tax	2006-04-12 06:09:44	

(From AOL search log, part 9)

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Segmenting Search Logs into Sessions: Simple Heuristics

Δ Time: Same session iff $|\text{timestamp}(q_2) - \text{timestamp}|(q_1) < \Delta$

- Often $\Delta = 30$ minutes, but many values have been tried
- Radlinski found 30 minutes to be effective in a library setting
- Jones found no value that is better than random on the web

Common term: Same session iff $q_1 \cap q_2 \neq \emptyset$

- Probably high Precision, low Recall

Rewrite classes: Common reformulation patterns

- E.g., term added, deleted, or replaced
- Probably high Precision, low Recall

Segmenting Search Logs into Sessions: Simple Heuristics

gout	2006-03-01 07:38:03	CT, RC
chemotherapy side effects	2006-03-01 07:42:36	
chemotherapy causing hearing loss	2006-03-01 07:45:23	ΔT, CT, RC
kenny rogers songs	2006-03-02 06:05:40	ΔT, CT, RC
commerce on line	2006-03-03 04:54:11	ΔT, CT, RC
broadband internet	2006-03-06 05:32:28	ΔT, CT, RC
middlesex county college nj	2006-03-06 16:55:56	
kean college	2006-03-06 17:02:32	
montclair college	2006-03-06 17:10:45	ΔT
union county college	2006-03-07 04:49:23	CT, RC
rutgers	2006-03-07 05:10:17	CT, RC
kean college	2006-03-07 05:19:22	ΔT, CT, RC
migraine headache	2006-03-10 06:02:55	ΔT, CT, RC
new jersey income tax	2006-04-12 06:09:44a	

(From AOL search log, part 9)

Segmenting Search Logs into Sessions: Other Features

gout	2006-03-01 07:38:03	
chemotherapy side effects	2006-03-01 07:42:36	--- CT, RC
chemotherapy causing hearing loss	2006-03-01 07:45:23	
kenny rogers songs	2006-03-02 06:05:40	ΔT, CT, RC
commerce on line	2006-03-03 04:54:11	ΔT, CT, RC

What other features could be used to segment a log?

- Edit distance between queries
- Co-occurrence (e.g., PMI, χ^2) of queries in a query log
- Queries have co-occurring clicks in a query log
- ODP or Yahoo page category overlap of top 10 results
- JSD similarity of top 10 results
- …

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Challenges to Recognizing Information Needs In Search Engine Logs

A person's information need may span days or weeks

- E.g., writing a paper, searching for colleges, medical problems

People routinely interleave tasks

- E.g., writing a paper, but take a break to make dinner plans

Typical search behavior reflects tasks and subtasks

- The subtasks may appear distinct when they are actually related

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Missions and Goals (Tasks and Subtasks)

An information need is a single, well-defined goal

- It is represented by a group of queries

A mission is a set of related information needs

- An extended or higher-level information need

Example:

- **Mission:** Find information on hiking in the Pittsburgh area
- **Goal:** Getting to the Laurel Highlands Hiking Trail
- **Goal:** Getting to the Rachel Carson Trail

(Jones and Klinker, 2006)

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Challenges to Recognizing Information Needs In Search Engine Logs

Can queries from the same information need or mission be identified automatically?

- **Boundary task:** Given a pair of sequential queries
  - Are they from the same information need ("goal")?
  - Are they from the same information seeking mission?
- **Same task:** Given a pair of queries
  - Are they from the same information need ("goal")?
  - Are they from the same information seeking mission?
- **Note:** We do not know what the goals or missions are … but we can still recognize queries that belong together

(Jones and Klinker, 2006)

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Missions and Goals (Tasks and Subtasks)

	the who, wikipedia	Boundary (mission)	Mission: Old music. Goal: The Who
Same mission	toronto		Mission: Toronto. Goal: ?
	toronto tourism		Mission: Toronto. Goal: Things to do
	toronto blue jays		Mission: Toronto. Goal: Things to do
	toronto zoo	Boundary (goal)	Mission: Toronto. Goal: Things to do
	toronto hotels		Mission: Toronto. Goal: Hotels
	usair 2130		
Same goal	toronto hotel deals		Mission: Toronto. Goal: Hotels
	toronto hotels downtown		Mission: Toronto. Goal: Hotels
	sigir 2014		
	toronto restaurants		Mission: Toronto. Goal: Restaurants
	toronto second city		Mission: Toronto. Goal: Things to do
	toronto yorkville		Mission: Toronto. Goal: Things to do
	toronto yorkville hotels		Mission: Toronto. Goal: Hotels
	toronto yorkville restaurants		Mission: Toronto. Goal: Restaurants

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A Classification-Based Approach to Detecting Pairs of Related Queries

Heuristics work surprisingly well

Sequential queries ↓ **Pairs of queries** ↓

Features	Goals		Missions	
	Boundary	Same	Boundary	Same
Baseline	63.1%	94.8%	59.9%	70.5%
30 minute	57.2%	90.9%	73.8%	74.4%
Trained time	69.5%	92.6%	75.8%	74.4%
commonw	80.7%	94.9%	79.3%	78.9%
commonw+prisma+time	84.0%		82.1%	

- **Baseline:** Always predicts 'no boundary' or 'different goal'
- **Trained time, goals:** 1.5 min for boundary, 17.2 min for same
- **Trained time, missions:** 6 min for boundary, 47 min for same

(Jones and Klinker, 2006)

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A Classification-Based Approach to Detecting Pairs of Related Queries

Features

- **Temporal**
  - ≤ {5, 30, 60, 120} minutes, Δ time, are_sequential
- **Edit distance**
  - Several character and token-based metrics
- **Query log**
  - Various types of $<q_1, q_2>$ co-occurrence in a larger query log
- **Web search**
  - Cosine distance of top 50 search results for each query ("prisma")

(Jones and Klinker, 2006)

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A Classification-Based Approach to Detecting Pairs of Related Queries

A trained classifier is somewhat more effective than heuristics

Features	Goals		Missions	
	Boundary	Same	Boundary	Same
Baseline	63.1%	94.8%	59.9%	70.5
Commonw+cosine+time	84.0%		82.1%	
All features	87.3%	97.1%	84.4%	88.4%
Levenshtein distance	85.0%	95.2%	78.2%	77.0%
commonw+time	81.5%	95.3%	79.3%	78.9%

Metric: Classifier accuracy. Differences are statistically significant.

(Jones and Klinker, 2006)

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Segmenting and Organizing Query Logs

There is more recent work, but the main message hasn't changed

- **Predict whether two queries are for the same information need**
  - Adjacent queries: 85-90% accuracy
  - Any pair of queries: 95-97% accuracy
    - » Higher because the negative class is very common
- **Classifiers are best, but the best heuristics aren't far behind**
  - Edit distance is very effective
  - Cosine distance among results is effective
  - Time alone is primitive
    - » But effective in combination with other heuristics
    - » Still a very commonly-used heuristic

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Lecture Outline

- **Introduction to search logs**
- **Users and tasks**
- **Segmenting search logs into sessions**

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For More Information

- T. Fagni, R. Perego F. Silvestri, and S. Orlando. "Boosting the performance of Web search engines: Caching and prefetching query results by exploiting historical usage." *ACM Transactions on Information Systems (TOIS)*, 24(1), pp 51-78. 2006.
- R. Jones and K.L. Klinker. "Beyond the session timeout: Automatic hierarchical segmentation of search topics in query logs." In *Proceedings CIKM '08*. 2008.
- R. Jones, B. Rey, O. Madani, and W. Greiner. "Generating query substitutions." WWW 2006.
- G. Pass, A. Chowdhury, and C. Torgeson. A picture of search. In *InfoScale '06: Proceedings of the 1st International Conference on Scalable Information Systems.* 2006.
- F. Radlinski, M. Szummer, and N. Craswell. "Inferring query intent from reformulations and clicks." WWW 2010.
- C. Silverstein, H. Marais, M. Henzinger, and M. Moricz. "Analysis of a very large web search engine query log." *SIGIR Forum*, 33(1), pp 6-12. 1999.
- I. Weber and A. Jaimes. Who uses web search for what: and how. WSDM 2011. 2011.
- R. White, M. Bilenko, and S. Cucerzan. "Studying the use of popular destinations to enhance web search interaction." *Proceedings of SIGIR 2007*. 2007.