Evaluating the Accuracy of Implicit Feedback from Clicks and Query Reformulations in Web Search

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Learning with Humans in the Loop

- **WHILE(forever)**
  - "System" presents "Options" to the user
  - User reacts to the "Options" and gets "Utility"
  - "System" observes the selection and learns from it
- **"System" / "Options" / "Utility" =**
  - Search engine / search results / information
  - Movie recommender system / recommended movies / fun
  - Online shopping site / products to buy / stuff
  - GPS navigation software / route / speed(?)
  - Spelling correction in word processor / word / fewer typos
  - Social network extension / friend / ?
  - Twitter / post / information

Research Questions Learning with Humans in the Loop

- **What does an action mean?**
  - Presentation bias
  - Get accurate training data out of biased feedback
  - Models of how users make decisions
- **How can one measure utility to the user?**
  - System should provide maximum utility
  - How to infer utility from actions
  - Models of how users make decisions
- **How can we learn to best serve the user?**
  - Exploration/exploitation trade-offs
  - Observational vs. experimental data
  - Ability to run interactive experiments with users

Adaptive Search Engines

- **Current Search Engines**
  - One-size-fits-all
  - Hand-tuned retrieval function
- **Hypothesis**
  - Different users need different retrieval functions
  - Different collections need different retrieval functions
- **Machine Learning**
  - Learn improved retrieval functions
  - User Feedback as training data

Implicit Feedback in Web Search

- **Observable actions**
  - Queries / reformulations
  - Clicks
  - Order, dwell time
  - Etc.
- **Implicit feedback**
  - Personalized
  - Democratic
  - Timely
  - Human intelligence
  - Cheap
  - Abundant

Overview of Talk

- **How can we get training data for learning improved retrieval functions?**
  - Explicit vs. implicit feedback
  - User study with eye-tracking and relevance judgments
  - Absolute vs. relative feedback
  - Accuracy of implicit feedback
- **What learning algorithms can use this training data effectively?**
  - Ranking Support Vector Machine
  - User study with meta-search engine

Sources of Feedback

- ~~**Explicit Feedback**~~
  - ~~Overhead for user~~
  - ~~Only few users give feedback~~
    ~~=> not representative~~
- **Implicit Feedback**
  - Queries, clicks, time, mousing, scrolling, etc.
  - No Overhead
  - More difficult to interpret

Feedback from Clickthrough Data

Relative Feedback:
Clicks reflect preference between observed links.

Absolute Feedback:
The clicked links are relevant to the query.

(3 < 2),
(7 < 2),
(7 < 4),
(7 < 5),
(7 < 6)

1. Kernel Machines
   http://svm.first.gmd.de/
2. Support Vector Machine
   http://jbolivar.freeservers.com/
3. SVM-Light Support Vector Machine
   http://ais.gmd.de/~thorsten/svm light/
4. An Introduction to Support Vector Machines
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5. *Support Vector Machine and Kernel ... References*
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6. Archives of SUPPORT-VECTOR-MACHINES ...
   http://www.jiscmail.ac.uk/lists/SUPPORT...
7. Lucent Technologies: SVM demo applet
   *http://svm.*research.bell-labs.com/SVT/SVMsvt.html
8. Royal Holloway Support Vector Machine
   http://svm.dcs.rhbnc.ac.uk

Rel(1),
NotRel(2),
Rel(3),
NotRel(4),
NotRel(5),
NotRel(6),
Rel(7)

Is Implicit Feedback Reliable?

How do users choose where to click?

- How many abstracts do users evaluate before clicking?
- Do users scan abstracts from top to bottom?
- Do users view all abstracts above a click?
- Do users look below a clicked abstract?

How do clicks relate to relevance?

- Absolute Feedback:
  Are clicked links relevant? Are not clicked links not relevant?
- Relative Feedback:
  Are clicked links more relevant than not clicked links?

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User Study: Eye-Tracking and Relevance

- **Scenario**
  - WWW search
  - Google search engine
  - Subjects were not restricted
  - Answer 10 questions
- **Eye-Tracking**
  - Record the sequence of eye movements
  - Analyze how users scan the results page of Google
- **Relevance Judgements**
  - Ask relevance judges to explicitly judge the relevance of all pages encountered
  - Compare implicit feedback from clicks to explicit judgments

Experiment Setup

- **Study (Phase I)**
  - 36 subjects
  - Undergraduate students
  - Familiar with Google
- **10 Questions**
  - Balanced informational and navigational
- **Task**
  - Answer questions
  - Start with Google search, no restrictions
  - Users unaware of study goal

Who discovered the first modern antibiotic?
Find the homepage of Emeril - the chef who has a TV cooking program.
What actor starred as the main character in the original 'Time Machine' movie?
Find the page displaying the routemap for Greyhound buses.
You are excited to cast your vote in the democratic presidential primary - when can you do so in NY?
Find the homepage of Michael Jordan, the statistician.
Where is the tallest mountain in NY located?
Find the homepage for graduate housing at Carnegie Mellon University.
A friend told you that Mr. Cornell used to live close to campus - between University and Stewart Aves - does anyone live in his house now; if so, who?
Find the homepage of the 1,000 Acres Dude Ranch.

What is Eye-Tracking?

Eye tracking device

"Scanpath" output depicts pattern of movement throughout screen. Black markers represent fixations.

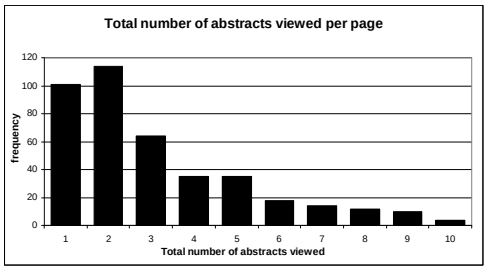
Device to detect and record where and what people look at

- **Fixations**: ~200-300ms; information is acquired
- **Saccades**: extremely rapid movements between fixations
- **Pupil dilation**: size of pupil indicates interest, arousal

Eye Tracking Measurements

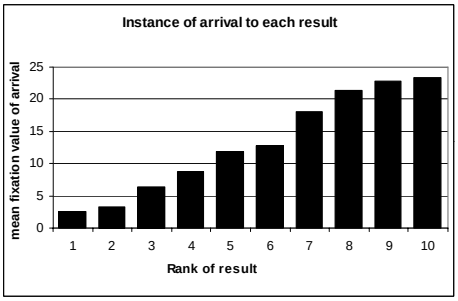
- **Lookzone for each result**
- **Data capture**
  - Eyetracker:
    - Fixations per lookzone
    - Clicks
    - Typing
  - HTTP-Proxy
    - Remove ads
    - All pages viewed
    - All pages in results list

How Many Links do Users View?



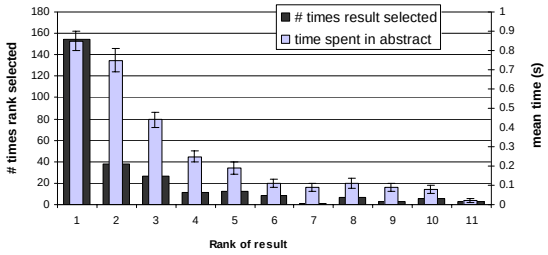
Mean: 3.07 Median/Mode: 2.00

In Which Order are the Results Viewed?



=> Users tend to read the results in order

Looking vs. Clicking



=> Users view links one and two more thoroughly / often

=> Users click most frequently on link one

Do Users Look Below the Clicked Link?

Viewed Rank	Clicked Rank 1	2	3	4	5	6
1	90.6%	76.2%	73.9%	60.0%	54.5%	45.5%
2	56.8%	90.5%	82.6%	53.3%	63.6%	54.5%
3	30.2%	47.6%	95.7%	80.0%	81.8%	45.5%
4	17.3%	19.0%	47.8%	93.3%	63.6%	45.5%
5	8.6%	14.3%	21.7%	53.3%	100.0%	72.7%
6	4.3%	4.8%	8.7%	33.3%	18.2%	81.8%

=> Users typically do not look at links below before they click (except maybe the next link)

Conclusion: Decision Process

- Users most frequently view two abstracts
- Users typically view results in order from top to bottom
- Users view links one and two more thoroughly and often
- Users click most frequently on link one
- Users typically do not look at links below before they click (except maybe the next link)

=> **Design strategies for interpreting clickthrough data that respect these properties!**

How do Clicks Relate to Relevance?

- **Experiment (Phase II)**
  - Additional 16 subjects
  - Manually judged relevance
    - Abstract
    - Page
- **Manipulated Rankings**
  - **Normal**: Google's ordering
  - **Swapped**: Top Two Swapped
  - **Reversed**: Ranking reversed
- **Experiment Setup**
  - Same as Phase I
  - Manipulations not detectable

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Presentation Bias

~~**Hypothesis: Order of presentation influences where users look, but not where they click!**~~

"normal"	l_1^-, l_2^-	l_1^+, l_2^-	l_1^-, l_2^+	l_1^+, l_2^+	total
$rel(l_1) > rel(l_2)$	15	19	1	1	36
$rel(l_1) < rel(l_2)$	11	5	2	2	20
$rel(l_1) = rel(l_2)$	19	9	1	0	29
total	45	33	4	3	85

"swapped"	l_1^-, l_2^-	l_1^+, l_2^-	l_1^-, l_2^+	l_1^+, l_2^+	total
$rel(l_1) > rel(l_2)$	11	15	1	1	28
$rel(l_1) < rel(l_2)$	17	10	7	2	36
$rel(l_1) = rel(l_2)$	36	11	3	0	50
total	64	36	11	3	114

Quality-of-Context Bias

~~**Hypothesis: Clicking depends only on the link itself, but not on other links.**~~

	Rank of clicked link as sorted by relevance judges
Normal + Swapped	**2.67**
Reversed	**3.27**

=> Users click on less relevant links, if they are embedded between irrelevant links.

Are Clicks Absolute Relevance Judgments?

- **Clicks depend not only on relevance of a link, but also**
  - On the position in which the link was presented
  - The quality of the other links

=> Interpreting Clicks as absolute feedback extremely difficult!

Strategies for Generating Relative Feedback

Strategies

- "Click > Skip Above"
  - **(3>2), (5>2), (5>4)**
- "Last Click > Skip Above"
  - **(5>2), (5>4)**
- "Click > Earlier Click"
  - **(3>1), (5>1), (5>3)**
- "Click > Skip Previous"
  - **(3>2), (5>4)**
- "Click > Skip Next"
  - **(1>2), (3>4), (5>6)**

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Comparison with Explicit Feedback

Explicit Feedback Data Strategy	Abstracts Phase I "normal"
Inter-Judge Agreement	89.5
Click > Skip Above	80.8 ± 3.6
Last Click > Skip Above	83.1 ± 3.8
Click > Earlier Click	67.2 ± 12.3
Click > Skip Previous	82.3 ± 7.3
Click > No Click Next	84.1 ± 4.9

=> All but "Click > Earlier Click" appear accurate

Is Relative Feedback Affected by Bias?

Explicit Feedback Data Strategy	Abstracts Phase II "normal"	 "swapped"	 "reversed"
Click > Skip Above	88.0 ± 9.5	79.6 ± 8.9	83.0 ± 6.7
Last Click > Skip Above	89.7 ± 9.8	77.9 ± 9.9	84.6 ± 6.9
Click > Earlier Click	75.0 ± 25.8	36.8 ± 22.9	28.6 ± 27.5
Click > Skip Previous	88.9 ± 24.1	80.0 ± 18.0	79.5 ± 15.4
Click > No Click Next	75.6 ± 14.5	66.7 ± 13.1	70.0 ± 15.7

⇒**Significantly better than random in all conditions, except "Click > Earlier Click"**

How Well Do Users Judge Relevance Based on Abstract?

Explicit Feedback Data Strategy	Abstracts Phase II all	Pages all
Inter-Judge Agreement	82.5	86.4
Click > Skip Above	83.1 ± 4.4	78.2 ± 5.6
Last Click > Skip Above	83.8 ± 4.6	80.9 ± 5.1
Click > Earlier Click	46.9 ±13.9	64.3 ±15.4
Click > Skip Previous	81.6 ± 9.5	80.7 ± 9.6
Click > No Click Next	70.4 ± 8.0	67.4 ± 8.2

⇒**clicks based on abstracts reflect relevance of the page well**

Conclusions: Implicit Feedback

- **Interpreting clicks as absolute feedback is difficult**
  - Presentation Bias
  - Quality-of-Context Bias
- **Relative preferences derived from clicks are accurate**
  - "Click > Skip Above"
  - "Last Click > Skip Above"
  - "Click > Skip Previous"

Overview of Talk

- **How can we get training data for learning improved retrieval functions?**
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Learning Retrieval Functions from Pair-wise Preferences

Idea: Learn a ranking function, so that number of violated pair-wise training preferences is minimized.

Form of Ranking Function: sort by

$f(q,d_i) = w_1 * (\#\text{of query words in title of } d_i) + w_2 * (\#\text{of query words in anchor}) + \ldots + w_n * (\text{page-rank of } d_i) = w * \Phi(q,d_i)$

Training: Select w so that

IF user prefers d_i to d_j for query q, THEN $f(q, d_i) > f(q, d_j)$

Ranking Support Vector Machine

- **Find ranking function with low error and large margin**

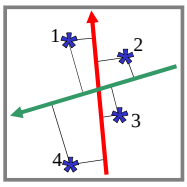
$$\min \quad \frac{1}{2}\vec{w}\cdot\vec{w} + C\sum_{i,j,k}\xi_{kij}$$

$$s.t. \quad \vec{w}\cdot\Phi(q_1,d_i) \geq \vec{w}\cdot\Phi(q_1,d_j) + 1 - \xi_{1ij}$$

$$\ldots$$

$$\vec{w}\cdot\Phi(q_n,d_i) \geq \vec{w}\cdot\Phi(q_n,d_j) + 1 - \xi_{nij}$$

- **Properties**
  - Convex quadratic program
  - Non-linear functions using Kernels
  - Implemented as part of SVM-light
  - `http://svmlight.joachims.org`



Experiment

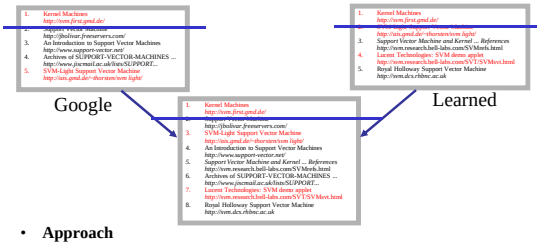
Meta-Search Engine "Striver"

- Implemented meta-search engine on top of Google, MSNSearch, Altavista, Hotbot, and Excite
- Retrieve top 100 results from each search engine
- Re-rank results with learned ranking functions based on "Click > Skip Above" preferences

Experiment Setup

- User study on group of ~20 German machine learning researchers and students
  => homogeneous group of users
- Asked users to use the system like any other search engine
- Train ranking SVM on 3 weeks of clickthrough data
- Test on 2 following weeks

Which Ranking Function is Better?



- **Approach**
  - Experiment setup generating "unbiased" clicks for fair evaluation.
- **Validity**
  - Clickthrough in combined ranking gives same results as explicit feedback under mild assumptions [Joachims, 2003].

Results

Ranking A	Ranking B	A better	B better	Tie	Total
Learned	Google	29	13	27	69
Learned	MSNSearch	18	4	7	29
Learned	Toprank	21	9	11	41

Result:

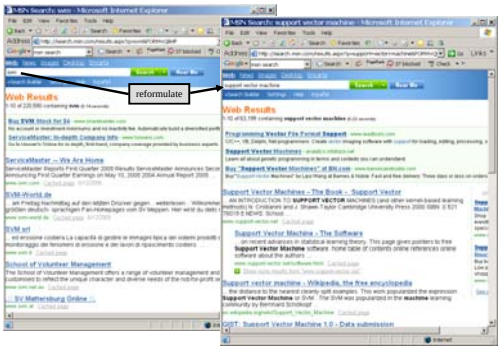
- Learned > Google
- Learned > MSNSearch
- Learned > Toprank

Toprank: rank by increasing minimum rank over all 5 search engines

Learned Weights

Weight	Feature
0.60	cosine between query and abstract
0.48	ranked in top 10 from Google
0.24	cosine between query and the words in the URL
0.24	doc ranked at rank 1 by exactly one of the 5 engines
...	
0.22	host has the name "citeseer"
...	
0.17	country code of URL is ".de"
0.16	ranked top 1 by HotBot
...	
-0.15	country code of URL is ".fi"
-0.17	length of URL in characters
-0.32	not ranked in top 10 by any of the 5 search engines
-0.38	not ranked top 1 by any of the 5 search engines

Feedback across Query Chains [KDD 2005]



Conclusions

- **Clickthrough data can provide accurate feedback**
  - Clickthrough provides relative instead of absolute judgments
- **Ranking SVM can learn effectively from relative preferences**
  - Improved retrieval through personalization in meta search
- **Other issues**
  - Exploiting query chains
  - Online learning algorithms for preference data
  - Implementation of methods in Osmot Search Engine
  - Robustness to noise, varying user behavior, and "click-spam"
  - Learning theory for interactive learning with preferences
  - Further user studies to get more operational model of user behavior