Learning Ranking Functions with SVMs

CS4780 – Machine Learning
Fall 2009

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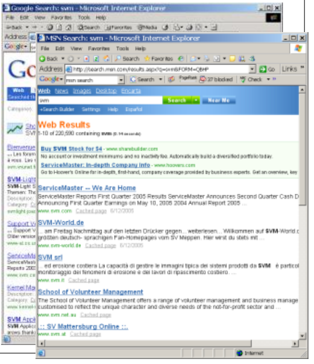
T. Joachims, Optimizing Search Engines Using Clickthrough Data, Proceedings of the ACM Conference on Knowledge Discovery and Data Mining (KDD), ACM, 2002.

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



Overview

- **How can we get training data for learning improved retrieval functions?**
  - Explicit vs. implicit feedback
  - Absolute vs. relative feedback
  - User study with eye-tracking and relevance judgments
- **What learning algorithms can use this training data?**
  - 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
   http://www.support-vector.net/
5. *Support Vector Machine and Kernel ... References*
   http://svm.research.bell-labs.com/SVMrefs.html
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)

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

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

Conclusion: Viewing Behavior

- 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!**

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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   http://ais.gmd.de/~thorsten/svm light/
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5. *Support Vector Machine and ...*
   http://svm.bell-labs.com/SVMrefs.html
6. Archives of SUPPORT-VECTOR...
   http://www.jisc.ac.uk/lists/SUPPORT...
7. Lucent Technologies: SVM demo applet
   http://svm.bell-labs.com/SVMsvt.html
8. Royal Holloway SVM
   http://svm.dcs.rhbnc.ac.uk
9. SVM World
   http://www.svmworld.com
10. Fraunhofer FIRST SVM page
    http://svm.first.gmd.de

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

Learning Retrieval Functions from Pairwise Preferences

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

Form of Ranking Function: sort by

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

Training: Select w so that

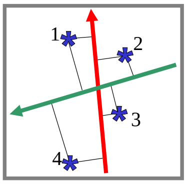
if user prefers d_i to d_i for query q,
then
$rsv(q, d_i) > rsv(q, d_j)$

Ranking Support Vector Machine

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

$$
\begin{aligned}
min \quad & \frac{1}{2}\vec{w}\cdot\vec{w} + C\sum_{i,j,k}\xi_{kij} \\
s.t. \quad & \vec{w}\cdot\Phi(q_1,d_i) \geq \vec{w}\cdot\Phi(q_1,d_j) + 1 - \xi_{1ij} \\
& \ldots \\
& \vec{w}\cdot\Phi(q_n,d_i) \geq \vec{w}\cdot\Phi(q_n,d_j) + 1 - \xi_{nij}
\end{aligned}
$$

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

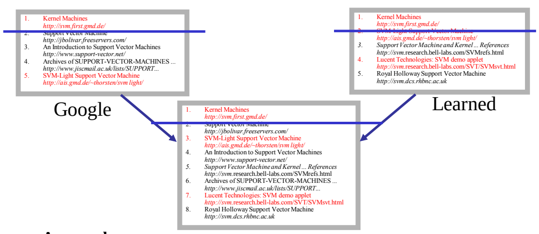


Experiment

Meta-Search Engine "Striver"
- Implemented meta-search engine on top of Google, MSNSearch, Altavista, Hotbot, Excite
- Retrieve top 100 results from each search engine
- Re-rank results with learned ranking functions

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

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
- **Current and future work**
  - Exploiting query chains
  - Adapting intranet search for Cornell Library Web Collection and Physics E-Print ArXiv
  - Implementation of methods in Osmot Search Engine
  - Robustness to "click-spam"
  - Learning theory for interactive learning with preference
  - Further user studies to get more operational model of user behavior
- **Info and Papers**
  - `http://www.joachims.org`