CS 630: Learning from Clickthrough Data in IR

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Cornell University

(Many slides based on those
of Thorsten Joachims)

Consider the Web Search Problem...

- Standard method: PageRank.
  - What are it's assumptions?
  - When can't it work?
  - What else can't it do?
- Can we use Machine Learning to help?

Why Learn a Retrieval Function?

- Faster.
- Personalizable.
- Use of Feedback.
- Can optimize specific cost function.

Web Results **1** - **10** of about **4,530,000** for **michael jordan**. (**0.55** seconds)

News results for **michael jordan** - View today's top stories
Michael Jordan feeling the need for speed - Indianapolis Star - Oct 31, 2004
Jordan sets his eyes on ... motocross? - MSNBC - Oct 30, 2004

Michael Jordan Official Website
... Now that **Michael Jordan** is done with his playing career, take a look back at all his stats, news and photos. Career Highlights Audio Team Stats Photos News. ...
jordan.sportsline.com/ - 32k - Oct 30, 2004 - Cached - Similar pages

NBA.com: **Michael Jordan** Player Info
... **Michael Jordan** | 23. ...
www.nba.com/playerfile/**michael_jordan**/?nav=page - 101k - Cached - Similar pages

www.nba.com/playerfile/michael_jordan.html
1k - Cached - Similar pages
[More results from www.nba.com]

Michael I. **Jordan's** Home Page
Michael I. **Jordan**. ... 9575 catwoman@cs. Grant Administrator: Jane Doyle (510) 642-3001 doyle@cs. **Michael** I. **Jordan**. Publications. Courses. ...
www.cs.berkeley.edu/~**jordan**/ - 8k - Cached - Similar pages

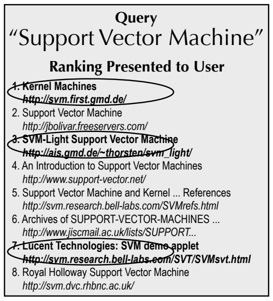
:Jumpman23.com: the official site of the **Jordan** brand.
Jumpman23.com is the place to access the **Jordan** Brand and to find the latest gear inspired by the image and essence of **Michael Jordan**.
www.jumpman23.com/ - 2k - Cached - Similar pages

Michael Jordan Virtual Gallery
The **Michael Jordan** Virtual Gallery was the first and is the last MJ Tribute page on the Internet. It was the first to feature **Michael** ...
www.virtualfans.com/ - 6k - Cached - Similar pages

Michael Jordan Biography

The Problem

- Goal: "Put some relevant documents at the top of the list."
- Input: Query, Click data.
- Output: Ranking function.
- Method: Ranking SVM.



Query
"Support Vector Machine"

Ranking Presented to User

1. **Kernel Machines**
   http://svm.first.gmd.de/
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How does this differ from...

- Classification?

  ranking 1: - - + - - - - - - - - - - -
  ranking 2: - - - - - - - - - - - - - +

⇛ Both return one relevant doc, with same error rate, but one is clearly better rank.

- Regression?

  Regression (estimating a function) needs target values, we don't have them.

How do we Evaluate a Ranking?

- We could count the number of pair flips:

Ranking 1	+ - - + - - - - - - - - -	Cost: 2
Ranking 2	- + + - - - - - - - - - -	Cost: 2
Ranking 3	+ - + - - - - - + - - - -	Cost: 6

- But its hard to optimize over this function.

What Does the Feedback Mean?

- Lets do a simple experiment.
- Let *q* be the query, *d* a document.
- Consider three ranking functions.
- Randomly pick a ranking function for each query.

Bool(q,d)	Boolean Retrieval function
TFIDF(q,d)	Weight query words by TFIDF score
HTML(q,d)	Also look at the HTML

How do we compare two rankings?

- Consider two rankings. Which is better?
  - Are more clicks good or bad?
  - Is the rank of the clicks informative?

	Average Click Rank
Bool(q,d)	6.26
TFIDF(q,d)	6.18
HTML(q,d)	6.04

Impact of Presentation Bias

Average Click Rank		Used for Computing Click Rank		
		Bool	TFIDF	HTML
PRESENTED	Bool	6.26	46.94	28.87
	TFIDF	54.02	6.18	13.76
	HTML	48.52	24.61	6.04

Boyan, Freitag, Joachims, 1996

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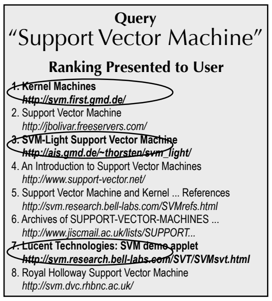
A New Feedback Mechanism

- Assume "clicking" means it might be relevant.
- Assume "not clicking" means its probably not.
- By skipping over something then clicking below, the user is giving us a preference judgment.



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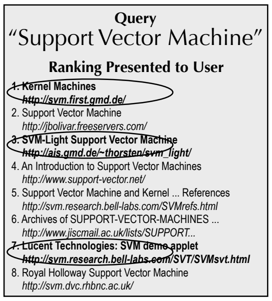
A New Feedback Mechanism

- We don't know about 1.
- 3 is more relevant than 2.
- 7 is more relevant than 2.
- 7 is more relevant than 4.
- 7 is more relevant than 5.
- 7 is more relevant than 6.
- We don't know about 8.



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A problem?

- Consider some query q.
- Assume a deterministic ranking function.
- All results are always in the same order.
- What possible constraints can we generate?
- What happens if the ranking is perfect?
- How do we fix it?

Assumptions

- Assumption 1:

  The user is more likely to click on something if it is relevant.

- Assumption 2:

  There is no bias towards one retrieval strategy except relevance.

Learning to Rank

- User says "d_i better than d_j for query q"

$$w \cdot \phi(q, d_i) \geq 1 + w \cdot \phi(q, d_j)$$

$$\Phi_{qij} = \phi(q, d_i) - \phi(q, d_j)$$

$$w \cdot \Phi_{qij} \geq 1 - \xi_a$$

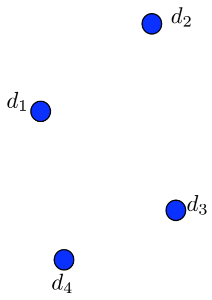
- For each preference we get one constraint.
- We can then run the SVM optimization:

$$\min_{w,\ \xi} \frac{1}{2}|\vec{w}| + C \sum \xi_a$$

Typical features used

$$\phi(q, d) = \begin{bmatrix} \text{PageRank(q, d)} \\ \text{\# of words of q in title of d} \\ \text{d ranked in top 10 of Google} \\ \text{Country code of URL is X} \\ \text{Cosine between URL and q} \\ \text{d clicked on for q} \end{bmatrix}$$

What does it look like?



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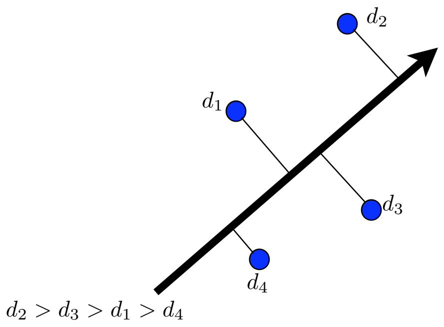

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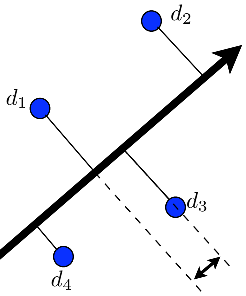

$d_2 > d_3 > d_1 > d_4$

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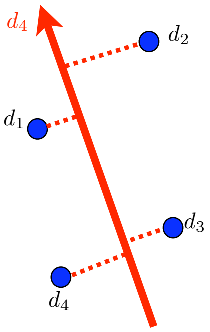

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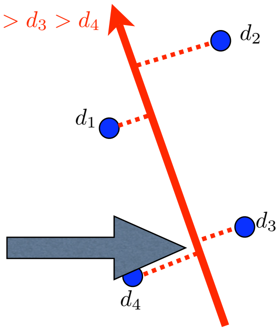
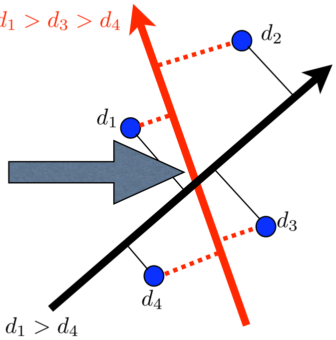


Small margin

What does it look like?

$d_2 > d_1 > d_3 > d_4$



Larger margin

$d_2 > d_3 > d_1 > d_4$

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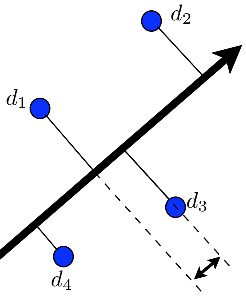

$d_2 > d_3 > d_1 > d_4$

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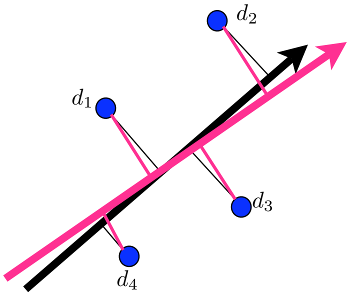

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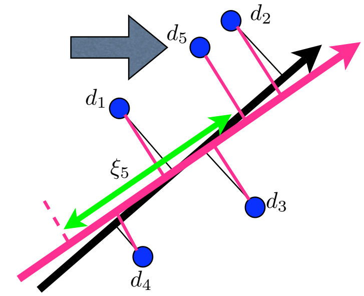

$$d_2 > d_3 > d_1 > d_4 > d_5(?)$$

Evaluation

- We have a new ranking function. Is it better?

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OLD Ranking

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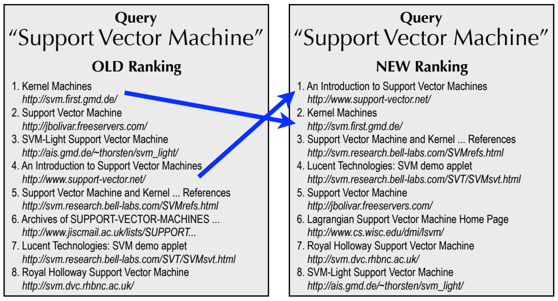

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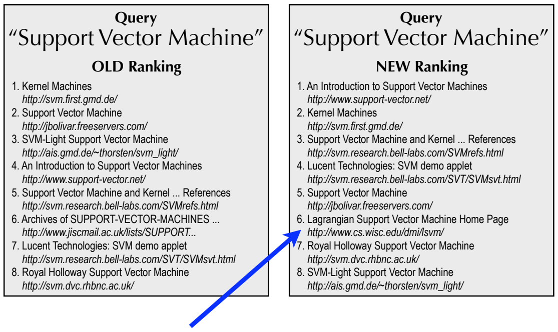

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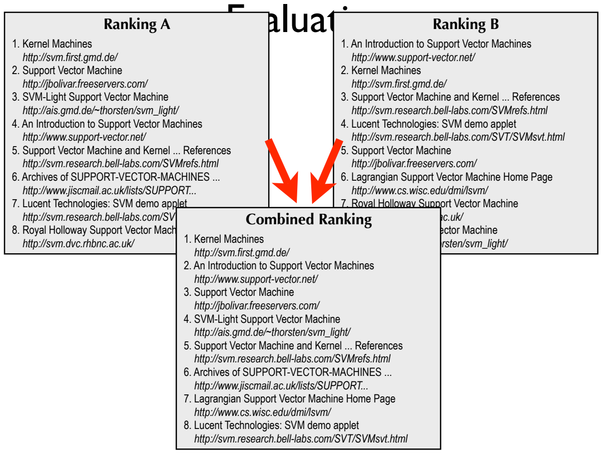

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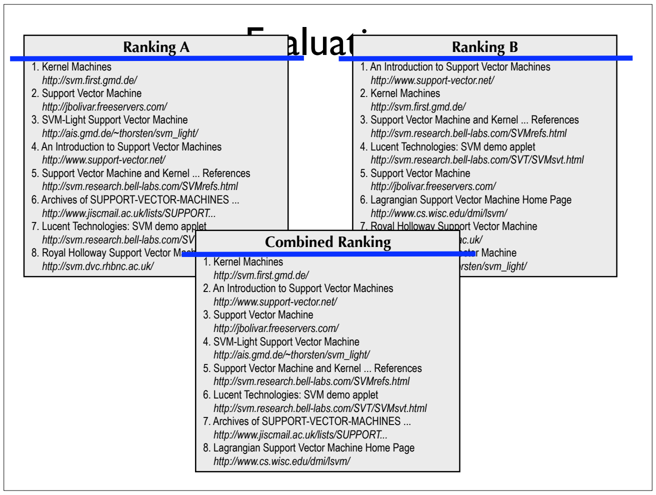
Property of Combined Ranking

- Combine two rankings A and B so that user scanning from top to bottom always sees the same number of hits from each:

$$A = \{a_1,\ a_2,\ \ldots\} \qquad B = \{b_1,\ b_2,\ \ldots\}$$

$$\{c_1,\ \ldots,\ c_n\} = \{a_1,\ \ldots,\ a_\alpha\} \cup \{b_a,\ \ldots,\ b_\beta\}$$

Such that $\beta \leq \alpha \leq \beta + 1$



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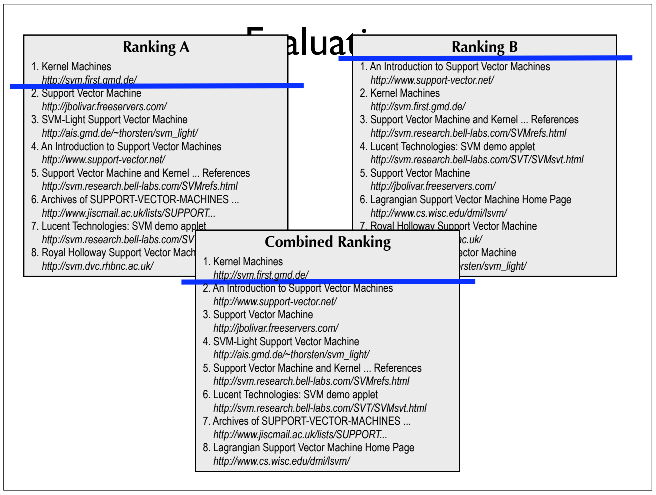

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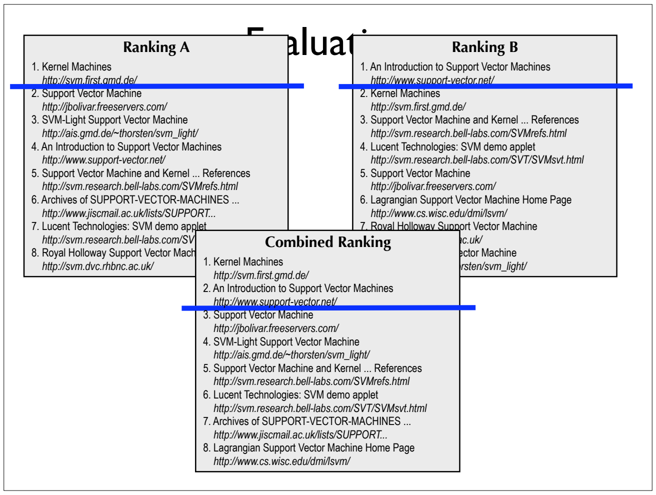

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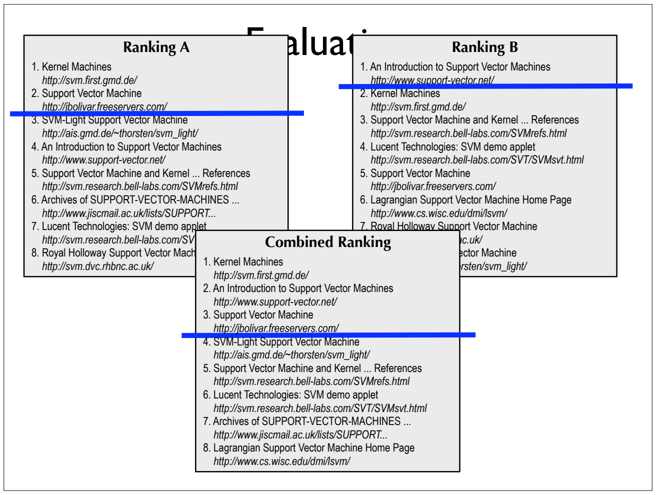

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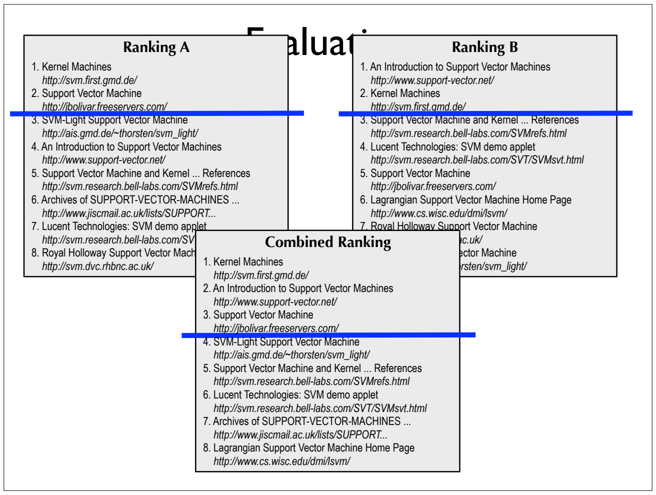

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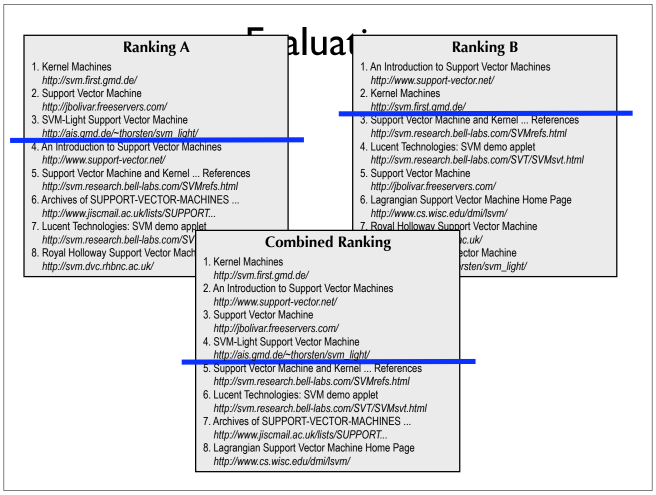

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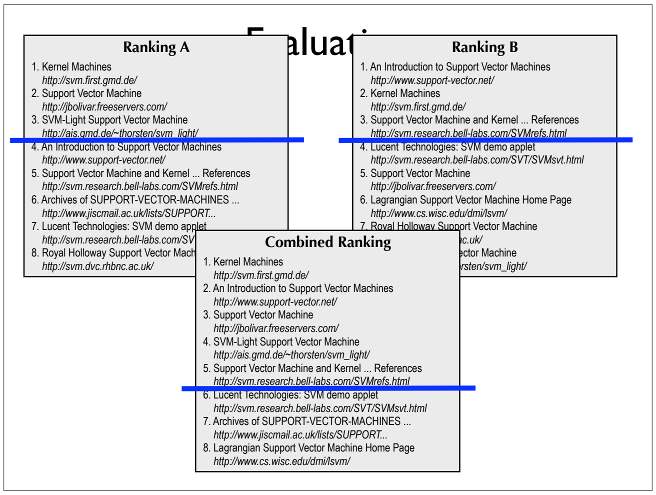

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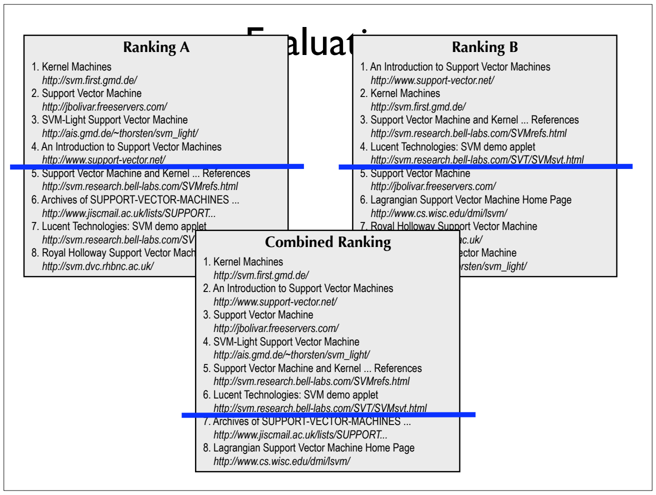

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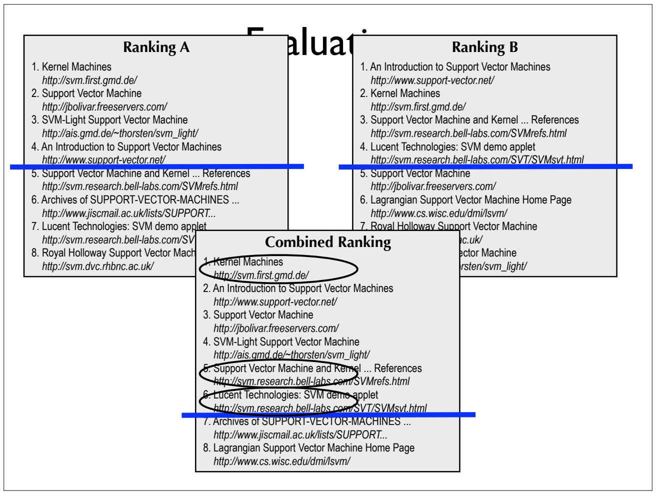

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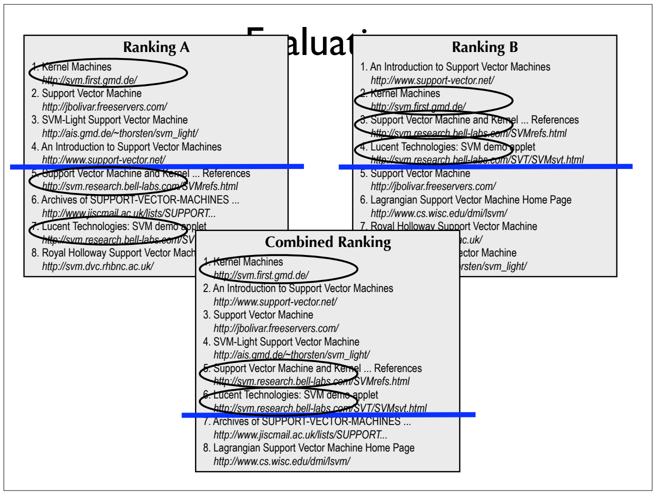

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Specific Experiment

- Used a combination of current search engines.
- Displayed URL and title of documents.
- Asked users to use it for a while, recording use.
- Then learned weights for new retrieval function.
- Interleaved with other rankings to test results.

Joachims, 2002

Feature Weights Learned

Weight	Feature
0.60	Cosine between query and abstract
0.48	Ranked in top 10 by Google
0.24	Cosine between query and URL
0.24	Ranked top 1 by exactly one SE
...	
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 in top 10 in any SE
-0.38	Not top 1 for any SE

Evaluation

Ranking A	**Ranking B**	**A Better**	**B Better**	**Tie**	**Total**
Learned	Google	29	13	27	69
Learned	MSN Search	18	4	7	29
Learned	Toprank	21	9	11	41

- Are these results significant?

Are these significant?

- How likely are we to say A is better 29 out of 42 times they differ, B is better 13 times?
- Use McNemar's Test (Paired t-test):

$$P(N_A > n_A | p, n) = \sum_{i=0}^{n_A} \frac{n!}{i!(n-i)!} p^n$$

Result: Learned Ranking is Better

What about the Assumptions?

- Assumption 1:

  The user is more likely to click on something if it is relevant.

$$P(C|R) = P(R|C)\frac{P(C)}{P(R)} \approx \frac{C_R}{C}\frac{C}{R}$$

$$P(C|N) = P(N|C)\frac{P(C)}{P(N)} \approx \frac{C_N}{C}\frac{C}{N}$$

What about the Assumptions?

- Assumption 2:

  There is no bias towards one retrieval strategy except relevance.

$$E[C_{R,A}] = E\left[C_R \frac{R_A}{R}\right] \qquad E[C_{N,A}] = E\left[C_N \frac{N_A}{N}\right]$$

$$E[C_{R,B}] = E\left[C_R \frac{R_B}{R}\right] \qquad E[C_{N,B}] = E\left[C_N \frac{N_B}{N}\right]$$