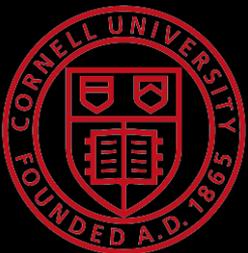


Online Learning from User Interactions through Interventions

CS 7792 - Fall 2016

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Cornell University



Y. Yue, J. Broder, R. Kleinberg, T. Joachims. The K-armed Dueling Bandits Problem. In COLT, 2009.

P. Shivaswamy, T. Joachims. Online Structured Prediction via Coactive Learning, ICML, 2012.

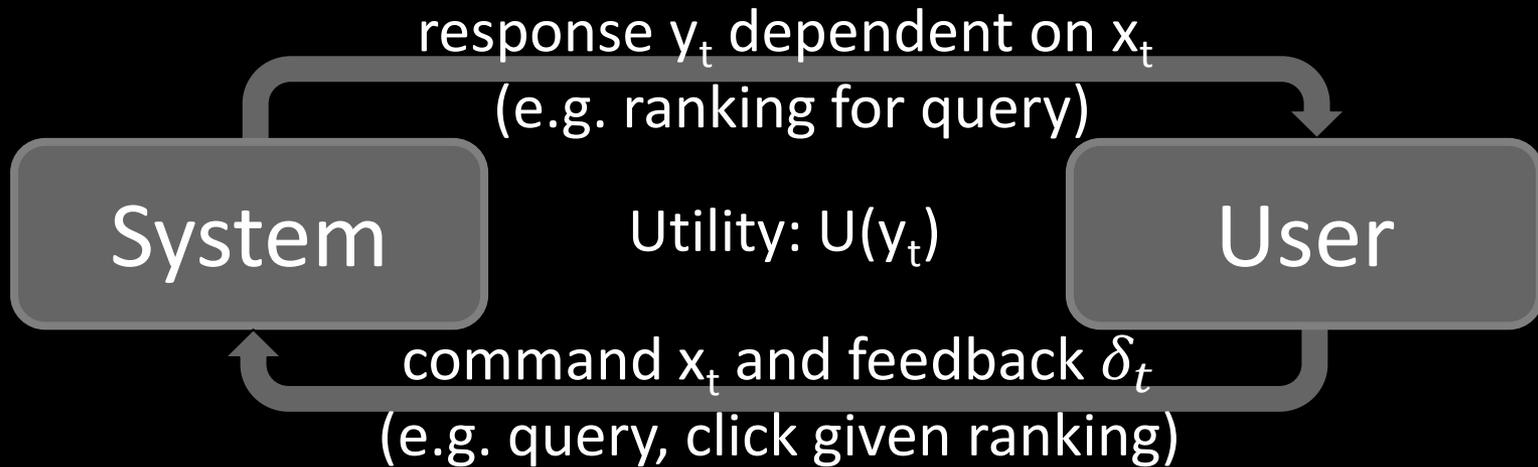
Interactive Learning Systems

- Examples
 - Search engines
 - Entertainment media
 - E-commerce
 - Smart devices
- Learning
 - Gathering and maintenance of knowledge
 - Measure and optimize performance
 - Personalization

Interventions



Interactive Learning System



- Information Elicitation from the User
 - Via generative behavioral model
 - Via information-elicitation interventions
- Online Learning with Interventions
 - Dueling Bandits: Algorithm-driven exploration
 - Coactive Learning: User-driven exploration

Decide between two Ranking Functions

Distribution $P(x)$
of $x=(\text{user, query})$

\vdots
 $(t_j, \text{"SVM"})$
 \vdots

Retrieval Function 1

$$f_1(x) \rightarrow y_1$$

Which one
is better?

Retrieval Function 2

$$f_2(x) \rightarrow y_2$$

1. Kernel Machines
<http://svm.first.gmd.de/>
2. SVM-Light Support Vector Machine
<http://svmlight.joachims.org/>
3. School of Veterinary Medicine at UPenn
<http://www.vet.upenn.edu/>
4. An Introduction to Support Vector Machines
<http://www.support-vector.net/>
5. Service Master Company
<http://www.servicemaster.com/>

\vdots

$U(t_j, \text{"SVM"}, y_1)$

1. School of Veterinary Medicine at UPenn
<http://www.vet.upenn.edu/>
2. Service Master Company
<http://www.servicemaster.com/>
3. Support Vector Machine
<http://jbolivar.freesevers.com/>
4. Archives of SUPPORT-VECTOR-MACHINES
<http://www.jiscmail.ac.uk/lists/SUPPORT...>
5. SVM-Light Support Vector Machine
[http://ais.gmd.de/~thorsten/svm light/](http://ais.gmd.de/~thorsten/svm%20light/)

\vdots

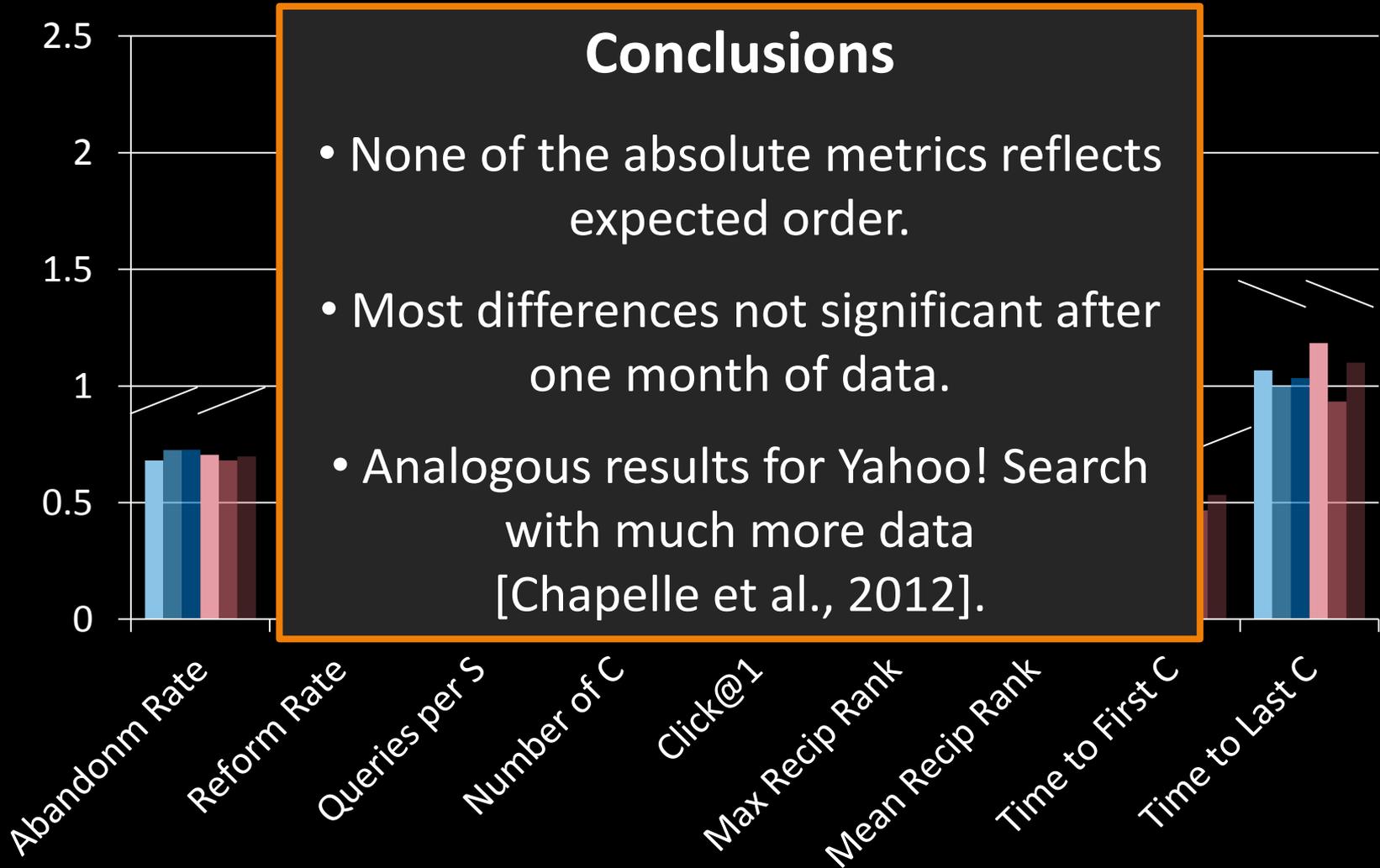
$U(t_j, \text{"SVM"}, y_2)$

Measuring Utility

Name	Description	Aggregation	Hypothesized Change with Decreased Quality
Abandonment Rate	% of queries with no click	N/A	Increase
Reformulation Rate	% of queries that are followed by reformulation	N/A	Increase
Queries per Session	Session = no interruption of more than 30 minutes	Mean	Increase
Clicks per Query	Number of clicks	Mean	Decrease
Click@1	% of queries with clicks at position 1	N/A	Decrease
Max Reciprocal Rank*	1/rank for highest click	Mean	Decrease
Mean Reciprocal Rank*	Mean of 1/rank for all clicks	Mean	Decrease
Time to First Click*	Seconds before first click	Median	Increase
Time to Last Click*	Seconds before final click	Median	Decrease

(*) only queries with at least one click count

Arxiv.org: Results



A Model of how Users Click in Search

- Model of clicking:
 - Users explore ranking to position k
 - Users click on most relevant (looking) links in top k
 - Users stop clicking when time budget up or other action more promising (e.g. reformulation)
 - Empirically supported by [Granka et al., 2004]

Google Search: svm - Microsoft Internet Explorer

Address: <http://www.google.com/search?sourceid=navclient&ie=UTF-8&oe=UTF-8&q=svm>

Google Search

Searched the web for **svm**. Results 1 - 10 of about 329,000. Search took 0.29 seconds.

Categories: [Computers > Artificial Intelligence > Machine Learning](#)
[Computers > Artificial Intelligence > Neural Networks > Software](#)

[Show stock quotes for SVM \(ServiceMaster Company The\)](#)

[Bienvenue sur svm.vnunet.fr !](#) - [Translate this page]
... Les forums de SVM. Participez aux grands débats de la rédaction. De vous à vous. Les meilleures réponses sélectionnées sur le forum de SVM. ...
svm.vnunet.fr/ - 39k - Mar 1, 2004 - Cached - Similar pages

[SVM-Light Support Vector Machine](#)
SVM-Light Support Vector Machine. Hier finden Sie Informationen zu den folgenden Themen: Thorsten Joachims, SVMlight, Support Vector ...
Description: Training software for SVMs. [Free for non-commercial use]
Category: [Computers > Artificial Intelligence > Software](#)
svm.light.joachims.org/ - 3k - Mar 1, 2004 - Cached - Similar pages

[Support Vector Machine](#)
... Support Vector Machine. The most recent SVM light page can now be found at <http://svmlight.joachims.org/>. Older versions are still available from here. ...
www.ai.cs.uni-dortmund.de/SOFTWARE/SVM_LIGHT/svm_light.html - 6k - Cached - Similar pages

[ServiceMaster -- We Are Home](#)
ServiceMaster Issues Information on Tax Treatment of Dividends. ServiceMaster Reports 2003 Fourth Quarter Revenues and Profits. ServiceMaster ...
www.svm.com/ - 13k - Mar 1, 2004 - Cached - Similar pages

[Kernel Machines](#)
Description: A central source of information on kernel based methods, including support vector machines, Gaussian...
Category: [Computers > Artificial Intelligence > Support Vector Machines](#)
www.kernel-machines.org/ - 1k - Cached - Similar pages

[SVM Application List](#)
SVM Application List. This list of Support Vector Machine applications grows thanks to visitors like you who ADD new entries. ... svm learning. ...

$$\operatorname{argmax}_{y \in \text{Top } k} U(y)$$

Balanced Interleaving

$$x=(u=tj, q="svm")$$

$$f_1(x) \rightarrow y_1$$

$$f_2(x) \rightarrow y_2$$

1. Kernel Machines
<http://svm.first.gmd.de/>
2. Support Vector Machine
<http://jbolivar.freesevers.com/>
3. An Introduction to Support Vector Machines
<http://www.support-vector.net/>
4. Archives of SUPPORT-VECTOR-MACHINES ...
<http://www.jiscmail.ac.uk/lists/SUPPORT...>
5. SVM-Light Support Vector Machine
http://ais.gmd.de/~thorsten/svm_light/

1. Kernel Machines
<http://svm.first.gmd.de/>
2. SVM-Light Support Vector Machine
http://ais.gmd.de/~thorsten/svm_light/
3. Support Vector Machine and Kernel ... References
<http://svm.research.bell-labs.com/SVMrefs.html>
4. Lucent Technologies: SVM demo applet
<http://svm.research.bell-labs.com/SVT/SVMsvt.html>
5. Royal Holloway Support Vector Machine
<http://svm.dcs.rhnc.ac.uk>

Interleaving(y_1, y_2)

- | | |
|--|---|
| 1. Kernel Machines
http://svm.first.gmd.de/ | 1 |
| 2. Support Vector Machine
http://jbolivar.freesevers.com/ | 2 |
| 3. SVM-Light Support Vector Machine
http://ais.gmd.de/~thorsten/svm_light/ | 2 |
| 4. An Introduction to Support Vector Machines
http://www.support-vector.net/ | 3 |
| 5. Support Vector Machine and Kernel ... References
http://svm.research.bell-labs.com/SVMrefs.html | 3 |
| 6. Archives of SUPPORT-VECTOR-MACHINES ...
http://www.jiscmail.ac.uk/lists/SUPPORT... | 4 |
| 7. Lucent Technologies: SVM demo applet
http://svm.research.bell-labs.com/SVT/SVMsvt.html | 4 |

Model of User:

Better retrieval functions
is more likely to get more
clicks.

Invariant:

For all k , top k of
balanced interleaving is
union of top k_1 of r_1 and
top k_2 of r_2 with $k_1=k_2 \pm 1$.

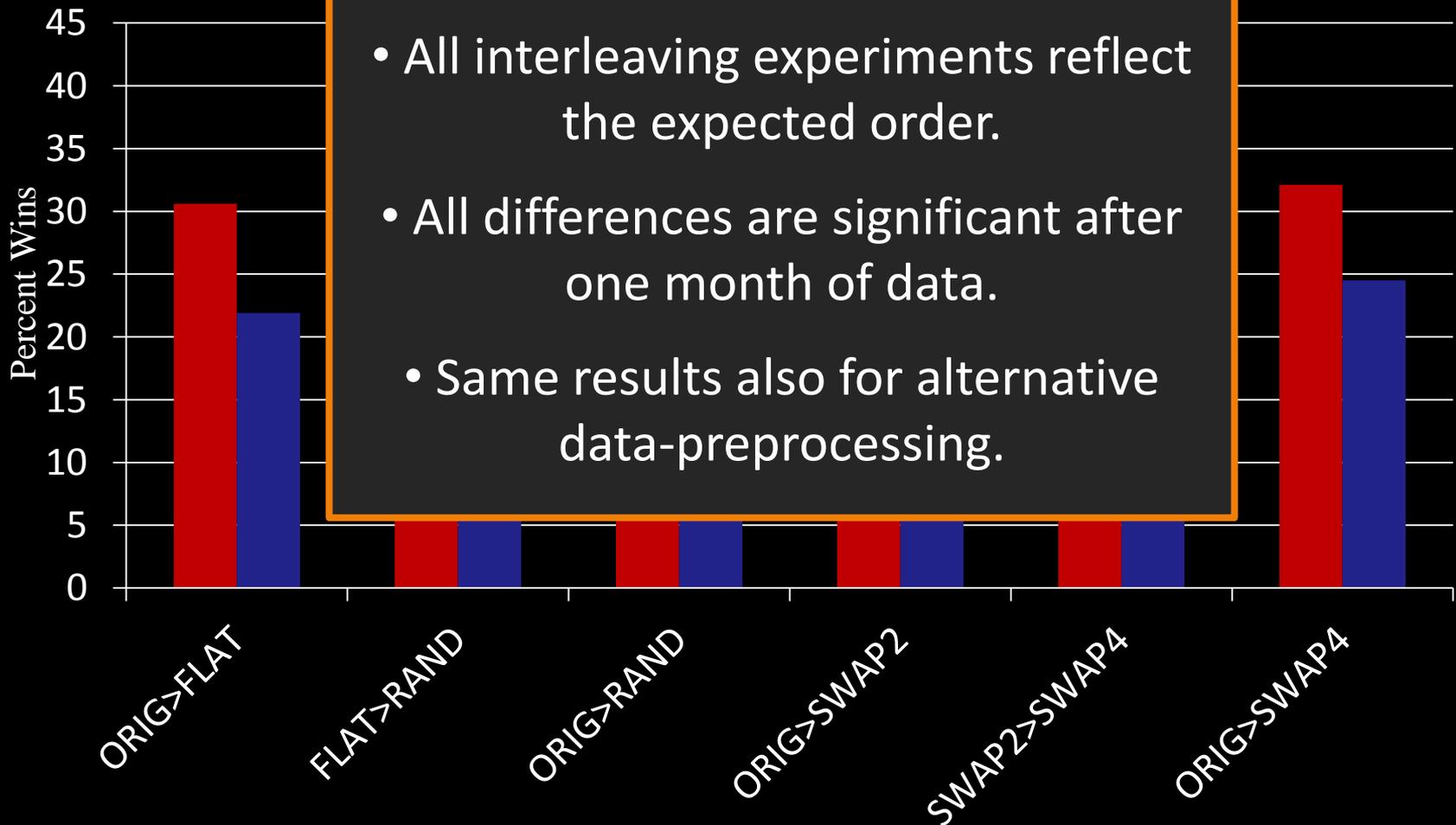
Interpretation: $(y_1 \succ y_2) \Leftrightarrow \text{clicks}(\text{topk}(y_1)) > \text{clicks}(\text{topk}(y_2))$

\rightarrow see also [Radlinski, Craswell, 2012] [Hofmann, 2012]

Arxiv.org: Interleaving Results

Conclusions

- All interleaving experiments reflect the expected order.
- All differences are significant after one month of data.
- Same results also for alternative data-preprocessing.



Yahoo and Bing: Interleaving Results

- Yahoo Web Search [Chapelle et al., 2012]
 - Four retrieval functions (i.e. 6 paired comparisons)
 - Balanced Interleaving
 - All paired comparisons consistent with ordering by NDCG.
- Bing Web Search [Radlinski & Craswell, 2010]
 - Five retrieval function pairs
 - Team-Game Interleaving
 - Consistent with ordering by NDGC when NDCG significant.

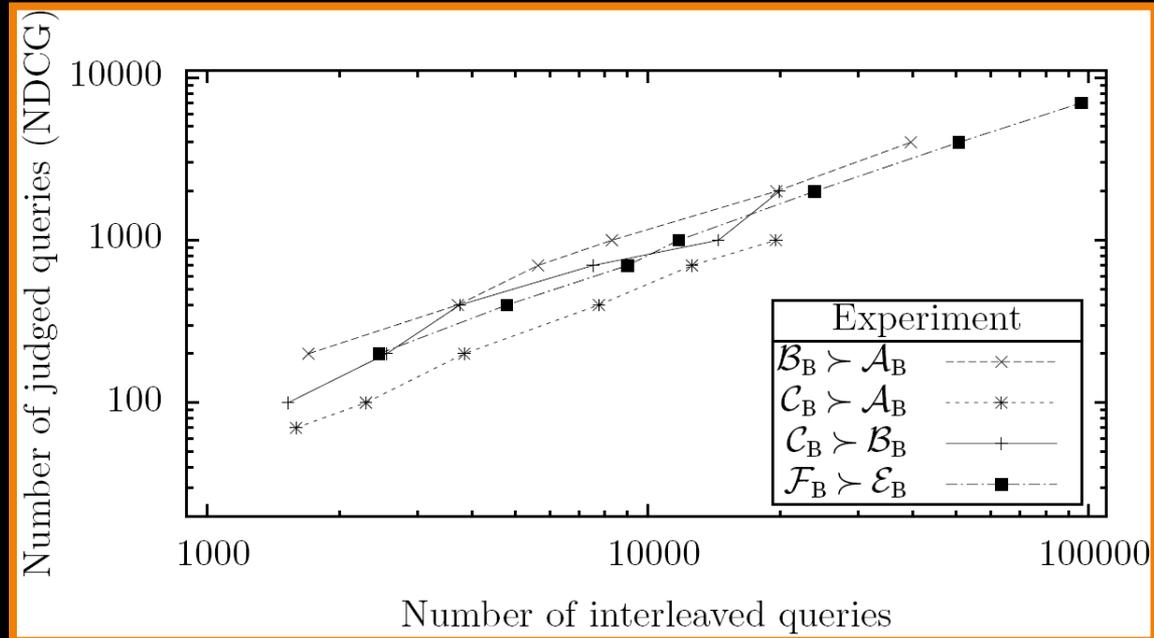
Efficiency: Interleaving vs. Explicit

- Bing Web Search
 - 4 retrieval function pairs
 - ~12k manually judged queries
 - ~200k interleaved queries

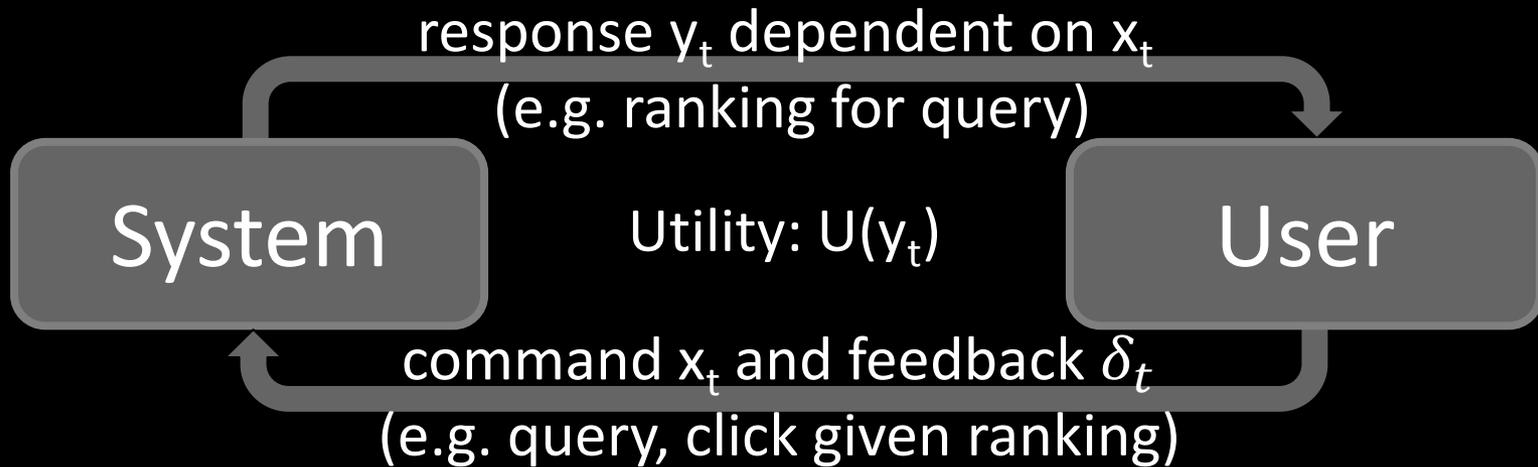
- Experiment

- p = probability that NDCG is correct on subsample of size y
- x = number of queries needed to reach same p -value with interleaving

➔ Ten interleaved queries are equivalent to one manually judged query.



Interactive Learning System



- Information Elicitation from the User
 - Via generative behavioral model
 - Via information-elicitation interventions ✓
- Online Learning with Interventions
 - Dueling Bandits: Algorithm-driven exploration
 - Coactive Learning: User-driven exploration

Learning on Operational System

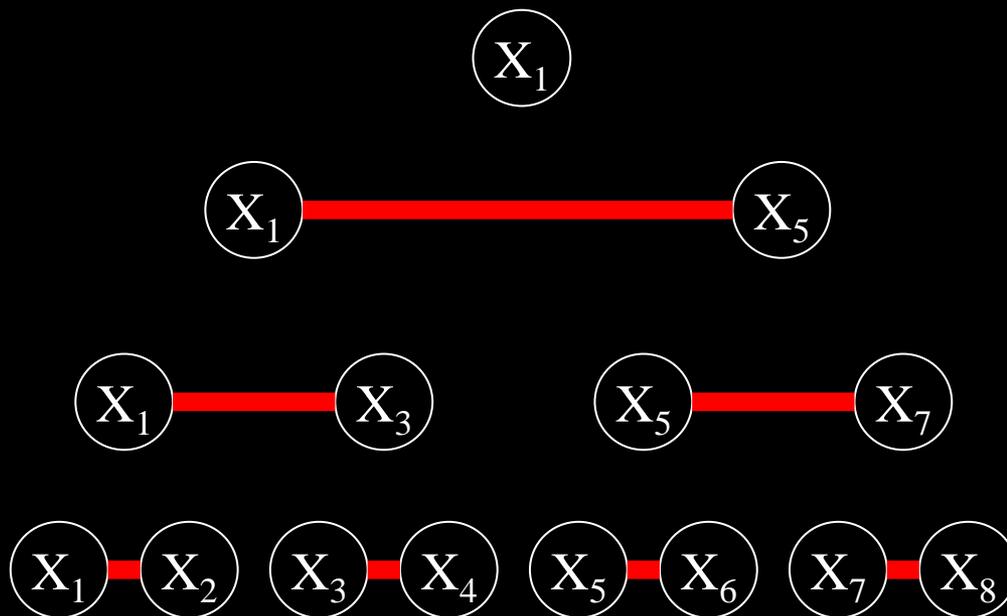
- Example: 4 retrieval functions: $A > B \gg C > D$
 - 10 possible pairs for interactive experiment
 - (A,B) \rightarrow low cost to user
 - (A,C) \rightarrow medium cost to user
 - (C,D) \rightarrow high cost to user
 - (A,A) \rightarrow zero cost to user
 - ...
- Minimizing Regret
 - Don't present "bad" pairs more often than necessary
 - Trade off (long term) informativeness and (short term) cost
 - Definition: Probability of (f_t, f'_t) losing against the best f^*

$$R(A) = \sum_{t=1}^T [P(f^* \succ f_t) - 0.5] + [P(f^* \succ f'_t) - 0.5]$$

\rightarrow Dueling Bandits Problem

First Thought: Tournament

- Noisy Sorting/Max Algorithms:
 - [Feige et al.]: Triangle Tournament Heap $O(n/\varepsilon^2 \log(1/\delta))$ with prob $1-\delta$
 - [Adler et al., Karp & Kleinberg]: optimal under weaker assumptions



Algorithm: Interleaved Filter 2

- Algorithm

InterleavedFilter1($T, W = \{f_1 \dots f_K\}$)

- Pick random f' from W
- $\delta = 1/(TK^2)$
- WHILE $|W| > 1$
 - FOR $b \in W$ DO
 - » duel(f', b)
 - » update P_f
 - $t = t + 1$
 - $c_t = (\log(1/\delta)/t)^{0.5}$
 - Remove all f from W with $P_f < 0.5 - c_t$ [WORSE WITH PROB $1 - \delta$]
 - IF there exists f'' with $P_{f''} > 0.5 + c_t$ [BETTER WITH PROB $1 - \delta$]
 - » Remove f' from W
 - » Remove all f from W that are empirically inferior to f'
 - » $f' = f''$; $t = 0$
- UNTIL T : duel(f', f')

f_1	f_2	$f' = f_3$	f_4	f_5
0/0	0/0		0/0	0/0

f_1	f_2	$f' = f_3$	f_4	f_5
8/2	7/3		4/6	1/9

f_1	f_2	$f' = f_3$	f_4	
13/2	11/4		7/8	XX

$f' = f_1$	f_2		f_4	
0/0	0/0	XX	XX	XX

Assumptions

- Preference Relation: $f_i \succ f_j \Leftrightarrow P(f_i \succ f_j) = 0.5 + \varepsilon_{i,j} > 0.5$
- Weak Stochastic Transitivity: $f_i \succ f_j$ and $f_j \succ f_k \rightarrow f_i \succ f_k$

Theorem: IF2 incurs expected average regret bounded by

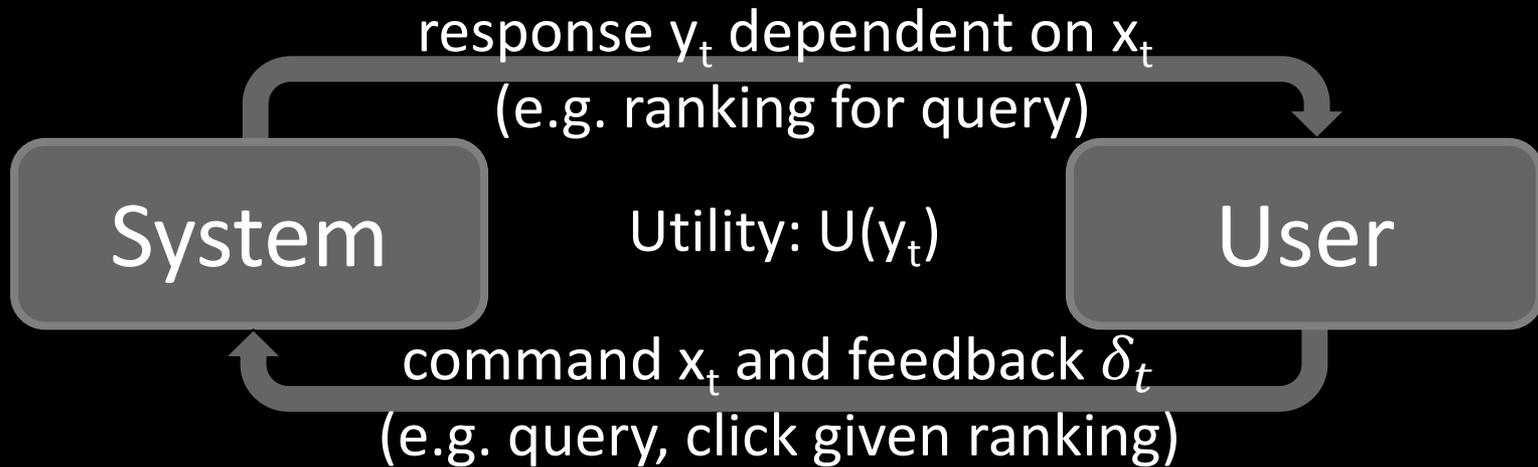
- $$\frac{1}{T} E(R_T) \leq O\left(\frac{K \log T}{\varepsilon_{1,2} T}\right)$$

- Stochastic Triangle Inequality: $f_i \succ f_j \succ f_k \rightarrow \varepsilon_{i,k} \leq \varepsilon_{i,j} + \varepsilon_{j,k}$

$$\varepsilon_{1,2} = 0.01 \text{ and } \varepsilon_{2,3} = 0.01 \rightarrow \varepsilon_{1,3} \leq 0.02$$

- ε -Winner exists: $\varepsilon = \max_i \{ P(f_1 \succ f_i) - 0.5 \} = \varepsilon_{1,2} > 0$

Interactive Learning System



- Information Elicitation from the User
 - Via generative behavioral model
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- Online Learning with Interventions
 - Dueling Bandits: Algorithm-driven exploration ✓
 - Coactive Learning: User-driven exploration

Who does the exploring? Example 1

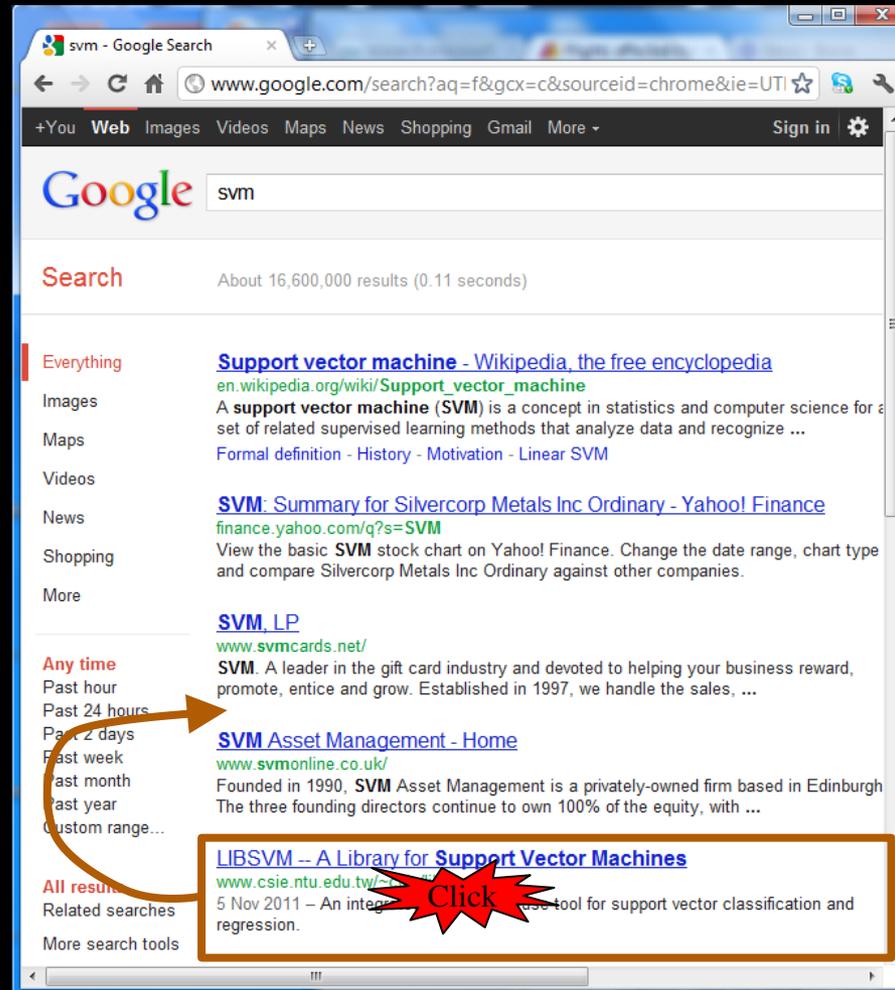
The image shows a screenshot of a web browser displaying the Netflix website. The browser window has a single tab titled "Netflix" and the address bar shows "movies.netflix.com/WiHome". The page content includes the Netflix logo, navigation links for "Watch Instantly" and "Just for Kids", and a search bar. Below the navigation, there are sections for "Recently Watched" (featuring "TALLER PARK BOYS" and "AZIZ ANSARI") and "My List". A "Top Picks for Thorsten" section is also visible, featuring "IN GOD WE TRUST" and "DO FRIES AS YOUR MO".

The second browser window is titled "Watch Lie to Me Onli" and shows the movie page for "Lie to Me". The address bar displays "movies.netflix.com/WiMovie/Lie_to_Me/70140406?trkid=13462049". The page features the Netflix navigation bar with a search bar containing "Movies, TV shows, actors, directors, genres" and a user profile for "Thorsten". Below the navigation, there is a pagination control showing "1" selected out of "75" items. A section titled "More Like Lie to Me" displays a row of movie posters: "NUMB3RS", "BONES", "FLASHPOINT", "AWAKE", "CSI: NY", and "KEEPER".

At the bottom of the page, there is a footer with copyright information: "© 2013 Netflix, Inc." and a list of links including "Membership", "Subtitles & Captions", "Test Participation", "Gifts: Buy / Redeem", "Support", "Company", "About Us", "Affiliates", "Investor Relations", "Media Center", "Jobs", "Contact Us", and "Blog". A "Service Code" section at the bottom right states: "Use of the Netflix service and this Web site constitutes acceptance of our Terms of Use and Privacy Policy. All rights reserved. About Cookies and Internet Advertising (1-ef8b98a)".

Who does the exploring?

Example 2



The image shows a screenshot of a Google search for "svm". The search results are displayed in a browser window. The search bar contains "svm" and the results show "About 16,600,000 results (0.11 seconds)".

The search results are categorized by type:

- Everything**: [Support vector machine - Wikipedia, the free encyclopedia](#) (en.wikipedia.org/wiki/Support_vector_machine). A support vector machine (SVM) is a concept in statistics and computer science for a set of related supervised learning methods that analyze data and recognize ...
[Formal definition - History - Motivation - Linear SVM](#)
- News**: [SVM: Summary for Silvercorp Metals Inc Ordinary - Yahoo! Finance](#) (finance.yahoo.com/q?s=SVM). View the basic SVM stock chart on Yahoo! Finance. Change the date range, chart type and compare Silvercorp Metals Inc Ordinary against other companies.
- Shopping**: [SVM, LP](#) (www.svmcards.net/). SVM. A leader in the gift card industry and devoted to helping your business reward, promote, entice and grow. Established in 1997, we handle the sales, ...
- More**: [SVM Asset Management - Home](#) (www.svmonline.co.uk/). Founded in 1990, SVM Asset Management is a privately-owned firm based in Edinburgh. The three founding directors continue to own 100% of the equity, with ...
- Any time**: [LIBSVM -- A Library for Support Vector Machines](#) (www.csie.ntu.edu.tw/~cjlin/libsvm/). 5 Nov 2011 - An integrated software tool for support vector classification and regression.

Annotations on the screenshot include:

- A red starburst with the word "Click" pointing to the LIBSVM link.
- An orange arrow pointing from the "Past 24 hours" filter to the SVM Asset Management link.
- An orange arrow pointing from the "Past 24 hours" filter to the LIBSVM link.
- An orange box around the LIBSVM link and its description.

Who does the exploring? Example 3

The image displays two browser windows side-by-side, illustrating a search process. The left window shows a Google search for 'svm' with approximately 16,600,000 results. The right window shows a search for 'sv meppen' with approximately 939,000 results. An orange arrow points from the 'SV Meppen 1912 e.V. - Offizielle Webseite' link in the right window to the search bar of the left window. A red starburst with the word 'Click' is positioned over the 'SV Meppen 1912 e.V. - Offizielle Webseite' link in the right window.

Left Window: svm - Google Search

Search: svm
About 16,600,000 results (0.11 seconds)

Everything

- [Support vector machine - Wikipedia, the free encyclopedia](#)
en.wikipedia.org/wiki/Support_vector_machine
A support vector machine (SVM) is a concept in statistics and computer science that is used for classification and regression analysis.
Formal definition - History - Motivation - Linear SVM
- [SVM: Summary for Silvercorp Metals Inc Ordinary - Yahoo! Finance](#)
finance.yahoo.com/q?s=SVM
View the basic SVM stock chart on Yahoo! Finance. Change the data and compare Silvercorp Metals Inc Ordinary against other companies.
- [SVM LP](#)
www.svmcards.net/
SVM. A leader in the gift card industry and devoted to helping your business promote, entice and grow. Established in 1997, we handle the sales, distribution and marketing of gift cards.
- [SVM Asset Management - Home](#)
www.svmonline.co.uk/
Founded in 1990, SVM Asset Management is a privately-owned firm. The three founding directors continue to own 100% of the equity, with a focus on long-term value creation.
- [LIBSVM -- A Library for Support Vector Machines](#)
www.csie.ntu.edu.tw/~cjlin/libsvm/
5 Nov 2011 -- An integrated and easy-to-use tool for support vector classification and regression.

Any time

- Past hour
- Past 24 hours
- Past 2 days
- Past week
- Past month
- Past year
- Custom range...

All results

- Related searches
- More search tools

Right Window: sv meppen - Google Search

Search: sv meppen
About 939,000 results (0.09 seconds)

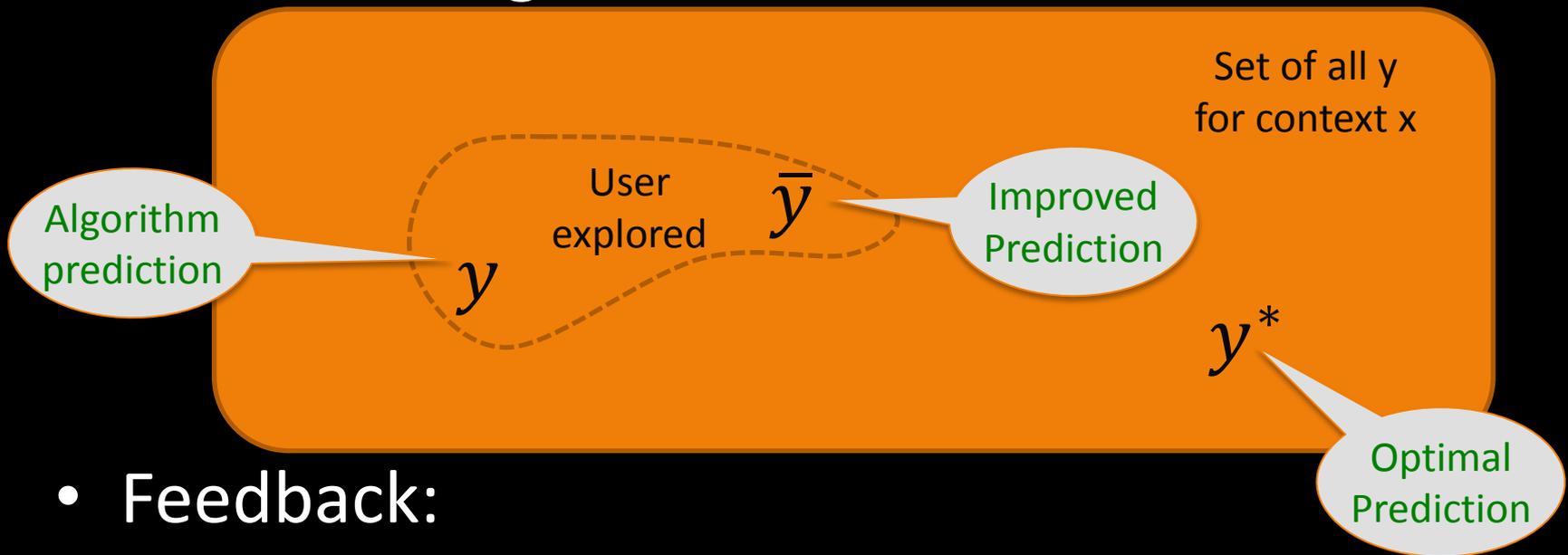
Everything

- [SV Meppen 1912 e.V. - Offizielle Webseite](#)
www.svmeppen.de/
Die offizielle Homepage des am 29. November 1912 gegründeten Fußballvereins präsentiert einen Live-Ticketverkauf und informiert über die Mannschaft.
- [Willkommen auf www.svmeppen.de - SV Meppen 1912 e.V. ...](#)
1912.svmeppen.de/ - Translate this page
SV Meppen e.V. 1912 - Offizielle Website- ... SV Meppen, meppen, emsland, oberliga, oberliga nord, fussball, fußball, lingen, steve haensel, webcomtech.net, ...
- [SV Meppen - Wikipedia, the free encyclopedia](#)
en.wikipedia.org/wiki/SV_Meppen
SV Meppen is a German association football club playing in Meppen, Lower Saxony. The club was founded on 29 November 1912 as Amisia Meppen and ...
History - Stadium - Records - Literature
- [SV Meppen - Nachrichten, Liveticker, Bilder vom SV Meppen in der ...](#)
www.noz.de/sport/sv-meppen - Translate this page
Berichte, Liveticker, Bilder und Audios vom SV Meppen, mehr zur Mannschaft sowie Analysen der Gegner in der Fußball-Regionalliga.
- [SV Meppen - Fußballverein - transfermarkt.de](#)
www.transfermarkt.de/.../sv-meppen/.../verein_24... - Translate this page
Mit dieser Nachricht hatte Stephen Famewo (Foto) nicht gerechnet. Als unumstrittener Stammspieler trug er dazu bei, dass der SV Meppen in die Regionalliga ...

Show search tools

Coactive Feedback Model

- Interaction: given x



- Feedback:

– Improved prediction \bar{y}_t

$$U(\bar{y}_t | x_t) > U(y_t | x_t)$$

– Supervised learning: optimal prediction y_t^*

$$y_t^* = \operatorname{argmax}_y U(y | x_t)$$

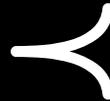
Machine Translation

x_t

We propose Coactive Learning as a model of interaction between a learning system and a human user, where both have the common goal of providing results of maximum utility to the user.

y_t

Wir schlagen vor, koaktive Learning als ein Modell der Wechselwirkung zwischen einem Lernsystem und menschlichen Benutzer, wobei sowohl die gemeinsame Ziel, die Ergebnisse der maximalen Nutzen für den Benutzer.



Wir schlagen ~~vor~~, koaktive Learning als ein Modell ~~der Wechselwirkung des Dialogs~~ zwischen einem Lernsystem und menschlichen Benutzer, wobei ~~sowohl die beide das~~ gemeinsame Ziel ~~haben~~, die Ergebnisse der maximalen Nutzen für den Benutzer ~~zu liefern~~.

\bar{y}_t

Coactive Preference Perceptron

- Model
 - Linear model of user utility: $U(y|x) = w^T \phi(x,y)$
- Algorithm
 - FOR $t = 1$ TO T DO
 - Observe x_t
 - Present $y_t = \operatorname{argmax}_y \{ w_t^T \phi(x_t, y) \}$
 - Obtain feedback \bar{y}_t from user
 - Update $w_{t+1} = w_t + \phi(x_t, \bar{y}_t) - \phi(x_t, y_t)$
- This may look similar to a multi-class Perceptron, but
 - Feedback \bar{y}_t is different (not get the correct class label)
 - Regret is different (misclassifications vs. utility difference)

$$R(A) = \frac{1}{T} \sum_{t=1}^T [U(y_t^*|x) - U(y_t|x)]$$

Never revealed:
• cardinal feedback
• optimal y^*

Coactive Perceptron: Regret Bound

- Model

$U(\mathbf{y}|\mathbf{x}) = \mathbf{w}^\top \phi(\mathbf{x}, \mathbf{y})$, where w is unknown

- Feedback: ξ -Approximately α -Informative

$$E[U(x_t, \bar{y}_t)] \geq U(x_t, y_t) + \alpha(U(x_t, y_t^*) - U(x_t, y_t)) - \xi_t$$

- Theorem

user feedback

system prediction

gap to optimal

model error

For user feedback \bar{y} that is α -informative in expectation, the expected average regret of the Preference Perceptron is bounded by

$$E \left[\frac{1}{T} \sum_{t=1}^T U(y_t^* | x) - U(y_t | x) \right] \leq \frac{1}{\alpha T} \sum_{t=1}^T \xi_t + \frac{2R ||w||}{\alpha \sqrt{T}}$$

→ zero

model error

Preference Perceptron: Experiment

Experiment:

- Automatically optimize Arxiv.org Fulltext Search

Analogous
to DCG

Model

- Utility of ranking y for query x : $U_t(y|x) = \sum_i \gamma_i w_t^\top \phi(x, y^{(i)})$ [~ 1000 features]
→ Computing argmax ranking: sort by $w_t^\top \phi(x, y^{(i)})$

Feedback

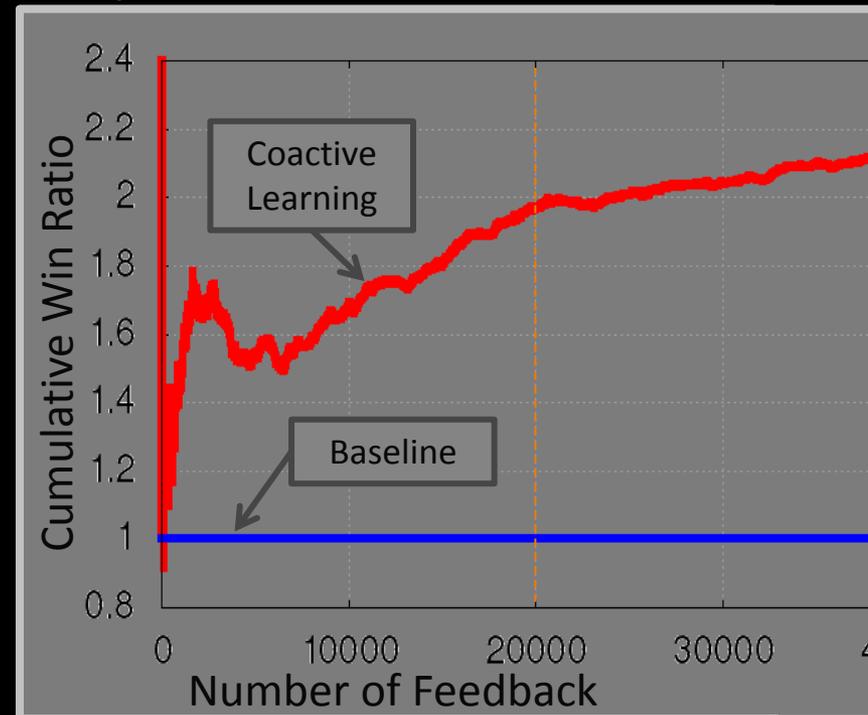
- Construct \bar{y}_t from y_t by moving clicked links one position higher.
- Perturbation [Raman et al., 2013]

Baseline

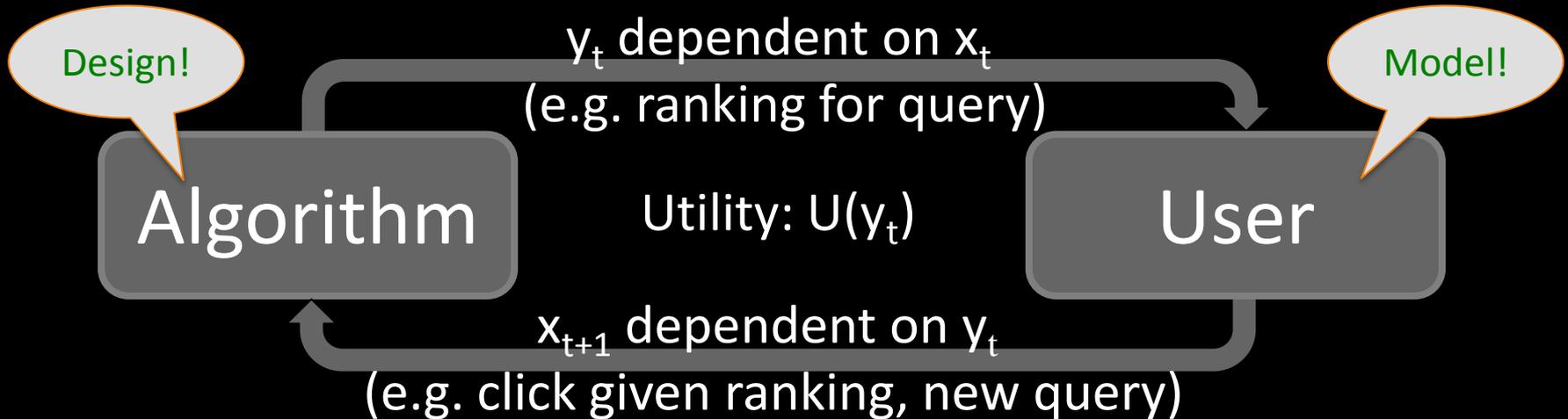
- Handtuned w_{base} for $U_{\text{base}}(y|x)$

Evaluation

- Interleaving of ranking from $U_t(y|x)$ and $U_{\text{base}}(y|x)$



Interactive Learning System



- Information Elicitation Interventions
- Decisions \rightarrow Feedback \rightarrow Learning Algorithm
 - Dueling Bandits
 - \rightarrow Model: Pairwise comparison test $P(y_i \succ y_j \mid U(y_i) > U(y_j))$
 - \rightarrow Algorithm: Interleaved Filter 2, $O(|Y| \log(T))$ regret
 - Coactive Learning
 - \rightarrow Model: for given y , user provides \bar{y} with $U(\bar{y} \mid x) > U(y \mid x)$
 - \rightarrow Algorithm: Preference Perceptron, $O(\|w\| T^{0.5})$ regret

Running Interactive Learning Experiments

~~1) Build your own system and provide service~~

~~→ a lot of work~~

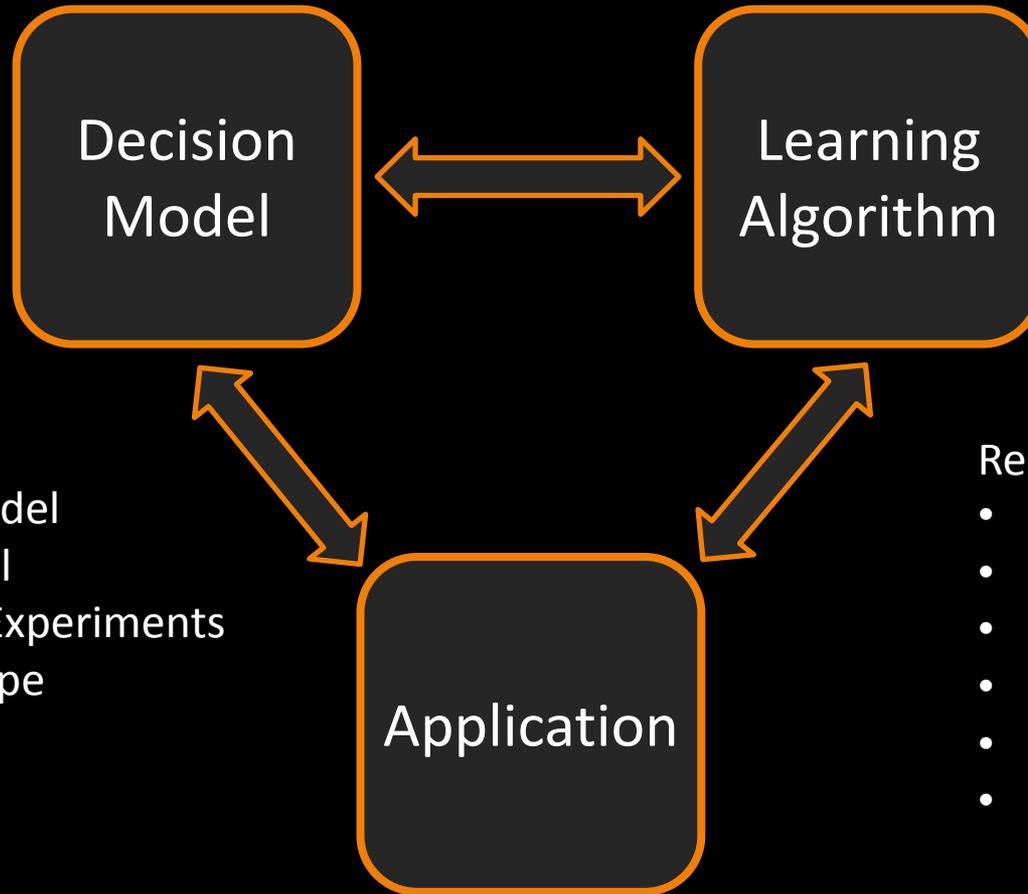
~~→ too little data~~

~~2) Convince others to run your experiments on
commercial system~~

~~→ good luck with that~~

3) Use large-scale historical log data from
commercial system

Learning from Human Decisions



Design Space:

- Decision Model
- Utility Model
- Interaction Experiments
- Feedback Type
- Regret
- Applications

Related Fields:

- Micro Economics
- Decision Theory
- Econometrics
- Psychology
- Communications
- Cognitive Science

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