Fair Ranking with Biased Data

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Ranking in Online Systems

Ranking function π that ranks items for context x.

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	A Support Vector Machine(SVM) is a yet another supervised machine learning algorithm. It	Style FREE shipping	FREE shipping		ormer White House Aide Won't how For Scheduled Impeachment

What is the ideal ranking?

The SMART Information Retrieval Project

C. Buckley, G. Salton, J. Allen

Department of Computer Science Cornell University Bilants, NY 14853

PROJECT GOALS. The primery goal of the IMANT information retrieval project at Consult University remains, as it has for the part 30 years, investigating the effectiveness and effi-many of neutranits multihols of rotational of targ. In resay piece of antend longange text from the user and triking against automatically indexed documents. --

RECENT RESULTS. Under this rather local goal, we're performed a number of investigations this past year. These include:

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Goal: Maximize

utility of rankings

to the users.

 Efficiency and Effectiveness: Trade-offs: A monitor of tradeoffs were also examined at TAHC 1. Major Bossiwal officitions are be very nearaphly transfer to extend efficiency by transmitting the extended taporaganetic).
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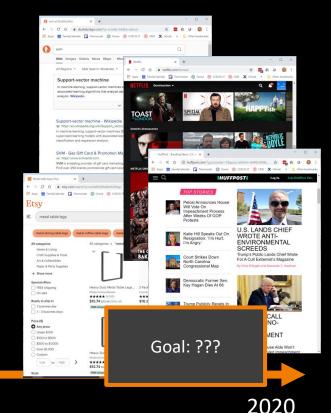
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PLANS FOR THE COMING YEAR.

to antimatically firm a coherent numbery making per-tern for a topic. The SMART system itself will be or

For serious sports fans only! Play Fantasy Football It's amazing where Go Get It will get you. Find: Go Ger II Enhance your search. \$100K New Search - TopNews - Sites by Subject - Top 5% Sites - City Guide - Pictures & Sounds PeopleFind . Point Review . Road Maps . Software . About Lycos . Club Lycos . Help **©**FastCompany







Two-Sided Market

Online Retail

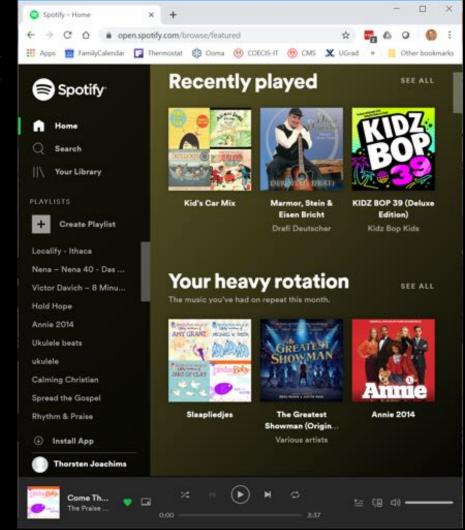
- Utility to Users: Customers find products they want
- Utility to Items: Sellers get revenue

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	\$15.74 \$22.48 (30% off)	\$32.40 \$36.00 (10% off)

Two-Sided Market

Music Streaming

- Utility to Users:
 Customers find music they enjoy
- Utility to Items: Artists get streaming revenue



Two-Sided Market

Research Papers

- Utility to Users: Readers find relevant articles
- Utility to Items:
 Writers get their voice out (and tenure)

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KDD 2020 Accepted Papers

Research Track Papers Applied Data Science Track Papers

Research Track Papers

A Block Decomposition Algorithm for Sparse Optimization

Authors: Ganzhao Yuan: Peng Cheng Laboratory; Li Shen: Tencent Al LAB; Weishi Zheng: Sun Yat-sen University

A causal look at statistical definitions of discrimination Authors: Elias Chalbub Neto: Sage Bionetworks

A Data Driven Graph Generative Model for Temporal Interaction Networks

Authors: Dawei Zhou: University of Illinois at Urbana-Champaign; Lecheng Zheng: University of Illinois at Urbana-Champaign; Jiawei Han: University of Illinois at Urbana-Champaign; Jingrui He: University of Illinois at Urbana-Champaign

A Framework for Recommending Accurate and Diverse Items Using Bayesian Graph Convolutional Neural Networks

Authors: Jianing Sun: Huawei Technologies Canada; Wei Guo: Huawei Noah's Ark Lab; Dengcheng Zhang; Huawei Distributed and Parallel Software Lab; Yingxue Zhang; Huawei Technologies Canada; Florence Robert-Regol: McGill University; Yaochen Hu: Huawei Technologies Canada; Huifeng Guo: Huawei Noah's

Maximizing Utility to Users

Probability Ranking Principle [Robertson, 1977]:

- Rank documents by probability of relevance $\rightarrow y^*$
- For virtually any measure U of ranking quality

$$y^* \coloneqq \operatorname{argmax}_y[\operatorname{U}(y|x)]$$

Dynamics of Utility Maximization

Probability Ranking Principle:

- Rank documents by probability of relevance → y* [Robertson, 1977]
- For virtually any measure U of ranking quality

 $y^* \coloneqq \operatorname{argmax}_y[U(y|x)]$

Are rankings fair/desirable?

F		Top News S	Stories
1	Rank	Item	P(read)
2	1	Times 1	50.99
3	2	Times 2	50.98
	3	Times 3	50.97
1			
1	100	Review 1	49.99
1	101	Review 2	49.98
	102	Review 3	49.97
•	•		

Fairness of Exposure

Fair ranking policy π allocates exposure to items based on merit.

Endogenous Factors

How to allocate exposure based on merit in order to

- be fair to the items
- satisfy legal requirements
- shape market dynamics

 (e.g. superstar economics, spam, polarization)

Exogenous Factors

How to estimate merit without biases like

- position bias
- trust bias
- uncertainty bias
- stereotypes

Position-Based Exposure Model

Definition:

Exposure e_j is the probability a users observes the item at position j.

$$Exp(G|x,y) = \sum_{j \in G} e_j$$

How to estimate?

- Eye tracking [Joachims et al. 2007]
- Intervention studies [Joachims et al. 2017]
- Intervention harvesting [Agarwal et al. 2019] [Fang et al. 2019]

Rank	Exposure P(observe)
1	e_1
2	<i>e</i> ₂
3	<i>e</i> ₃
	•••
100	e_{100}
101	e_{101}
102	e_{102}

Fairness Disparity

Goal:
$$Exp(G|x, y) = f(Rel(G|x))$$

Example: Make exposure proportional to relevance (per group) $\frac{Exp(G_0|x,y)}{Exp(G_1|x,y)} = \frac{Rel(G_0|x)}{Rel(G_1|x)}$

Disparity: D(y|x) = |Exp(G|x, y) - f(Rel(G|x))|

[Singh & Joachims, 2018] [Biega et al., 2018]

Learning Fair Ranking Policies

Goal: Policy π that maximizes expected utility U with small disparity D. $\pi^* = \operatorname{argmax}_{\pi} E_x[U(\pi|x)] \quad s.t. \ E_x[D(\pi|x)] \le \delta$

Learning: Empirical Risk Minimization

$$\hat{\pi} = \operatorname{argmax}_{\pi} \frac{1}{n} \sum_{i=1}^{n} U(\pi | x_i) \quad s.t. \frac{1}{n} \sum_{i=1}^{n} D(\pi | x_i) \le \delta$$

 \rightarrow Lagrange multiplier

$$\hat{\pi} = \operatorname{argmax}_{\pi} \frac{1}{n} \sum_{i=1}^{n} U(\pi | x_i) - \lambda \frac{1}{n} \sum_{i=1}^{n} D(\pi | x_i)$$

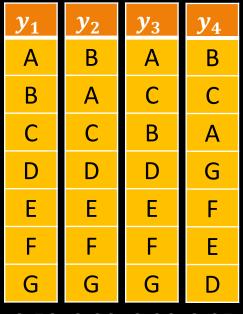
Stochastic Ranking Policies

 π

- Policy:

 π(y|x) is conditional distribution over rankings.
- Utility: $U(\pi|x) = \sum_{y} U(y|x)\pi(y|x)$
- Exposure:

$$\operatorname{Exp}(G|x,\pi) = \sum_{j \in G} \sum_{y} e_{\operatorname{rank}(j|y)} \pi(y|x)$$



0.52 0.23 0.20 0.05

Policy Training

Training objective:

$$\hat{\pi} = \operatorname{argmax}_{\pi} \frac{1}{n} \sum_{i=1}^{n} U(\pi | x_i) - \lambda \frac{1}{n} \sum_{i=1}^{n} D(\pi | x_i)$$

Policy class:

- Plackett-Luce $\pi_w(y|x) = PL(s_1, ..., s_k)$ with per-item scoring model $s_j = s(y_j|x, w)$

Training algorithm:

- Policy gradient with Monte-Carlo estimates of gradient.
- Entropy regularization.
- Variance reduction.

Experiment

Data

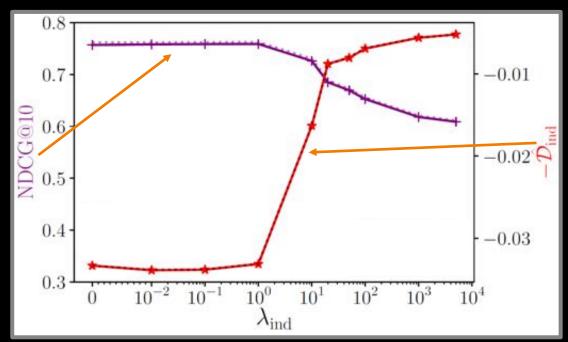
Yahoo LTR Challenge

Fairness

- Proportional exposure
- Individual fairness

Ranking policy

- Plackett-Luce
- Deep network scorer



 \rightarrow Generalizes to be fair on test data.

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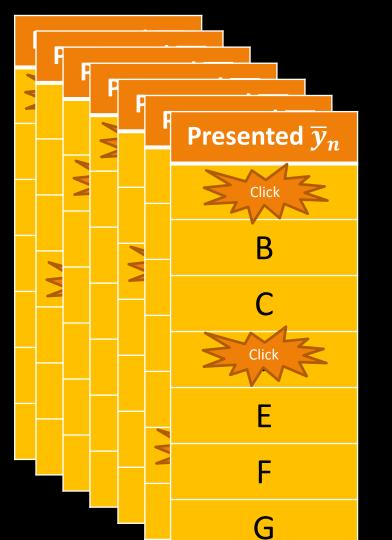
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Exogenous Factors -

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Interaction Feedback

Data

- Query distribution: $x_j \sim P(X)$
- Deployed ranker: $\overline{y}_j \sim \boldsymbol{\pi_0}(y|x_j)$
- Feedback: clicks, purchases, plays, reads

 \rightarrow Feedback is biased!

Modeling Position Bias

• Assume:

– Click implies observed and relevant:

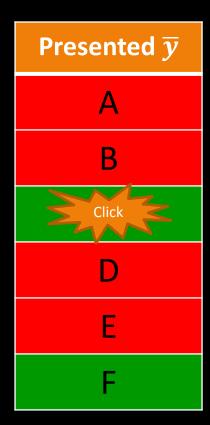
 $(click_i = 1) \leftrightarrow (obs_i = 1) \land (rel_i = 1)$

• Problem:

No click can mean not relevant OR not observed

$$(click_i = 0) \leftrightarrow (obs_i = 0) \lor (rel_i = 0)$$

 \rightarrow Understand observation mechanism



Inverse Propensity Score Estimators

- Observation Propensities
 - $Q(obs_j = 1|x, \bar{y})$
 - − Random variable $obs_j \in \{0,1\}$ indicates whether relevance label rel_j is observed.
 - Can use position-based exposure $Q(obs_j = 1|x, \overline{y}) = e_j$
- Inverse Propensity Score (IPS) Weighting
 - $\text{Utility:} \,\widehat{\mathbb{U}}(y|x) = \sum_{j} g(rank(j|y)) \frac{click(j|x)}{e_{j}} \quad (\text{e.g. DCG})$

- Relevance:
$$\widehat{Rel}(G|x) = \sum_{j \in G} \frac{click(j|x)}{e_j}$$

Unbiased! In expectation independent of past rankings.

Presented \overline{y}	Q
А	1.0
В	0.8
С	0.5
D	0.2
Е	0.2
F	0.2

[Joachims et al., 2017] [Yadav et al., 2020]

Fair Policy Training

Training objective:

$$\hat{\pi} = \operatorname{argmax}_{\pi} \frac{1}{n} \sum_{i=1}^{n} \widehat{U}(\pi | x_i) - \lambda \frac{1}{n} \sum_{i=1}^{n} \widehat{D}(\pi | x_i)$$

Utility

– Unbiased $\widehat{U}(y|x)$ gives unbiased $\widehat{U}(\pi|x_i)$

Disparity

- Average relevance $\widehat{Rel}(G) = \sum_{x} \widehat{Rel}(G|x)$
- Amortized group disparity (similar to [Biega et al., 2018]) $\widehat{D}(y|x) = \widehat{Rel}(G_1)Exp(G_0|x) - \widehat{Rel}(G_0)Exp(G_1|x)$

Experiment

Data

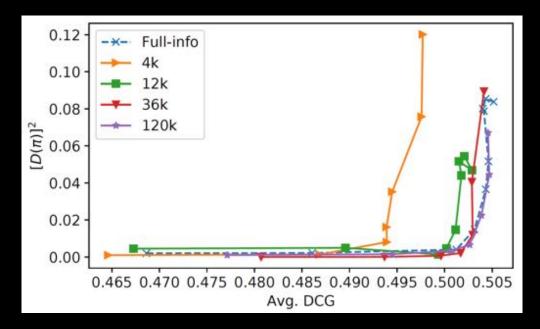
– Microsoft LTR Corpus

Fairness

- Amortized proportional exposure
- Group fairness

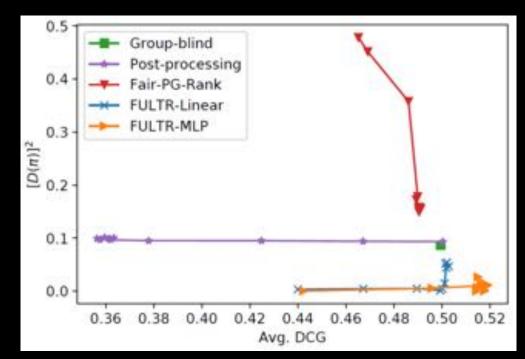
Ranking policy

- Plackett-Luce
- Linear scorer



Comparison

- Group blind
 - Fairness through unawareness
- Post processing
 - IPS regression
 - Biega et al. fairness
- Fair-PG-Rank
 - Method from before



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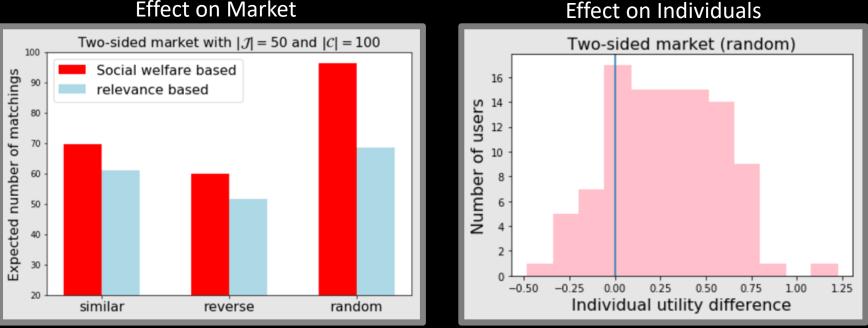
Matching Markets

Employer	Preference		Applicant	Preference
Z	A > D >	\leftarrow	А	X > Z >
Υ	C > A >		В	W > V >
Х	E > C >	Job	С	Y > X >
W	A > B >	Recommender	D	Y > Z >
V	A > D >		E	V > Z >
	•••			•••

→ Multi-sided Preferences, Fairness, and Social Welfare.

[Tu et al., 2014] [Hopcroft et al., 2011]

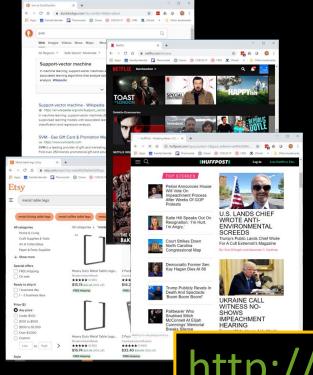
Simulation Experiment



Effect on Market

[Su et al., 2021]

Research Agenda for Ranking



- Fairness to items
- Fairness to user groups
- Market-level objectives
- Long-term dynamics
- Transparency
- Privacy

http://www.joachims.org