Measuring Fairness in Ranked Results: An Analytical and Empirical Comparison

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People and Information Research Team

NSF

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2022

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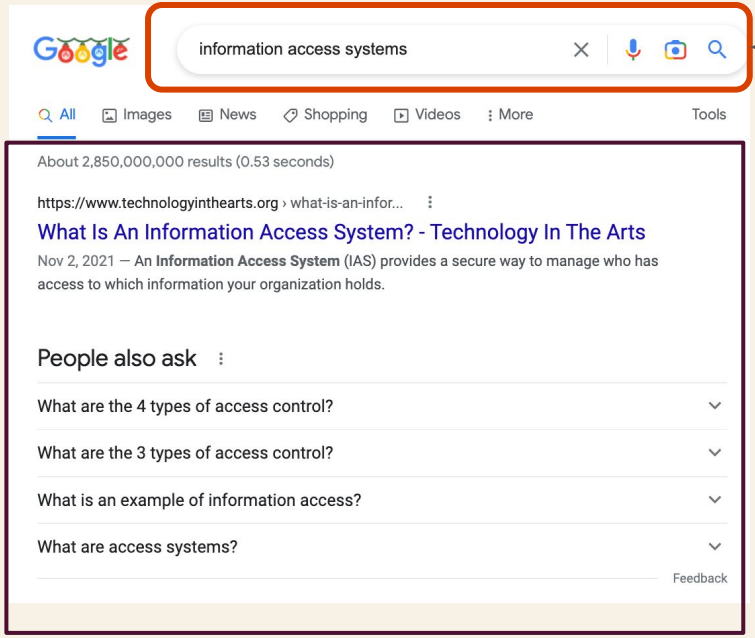
DOI 10.1145/3477495.3532018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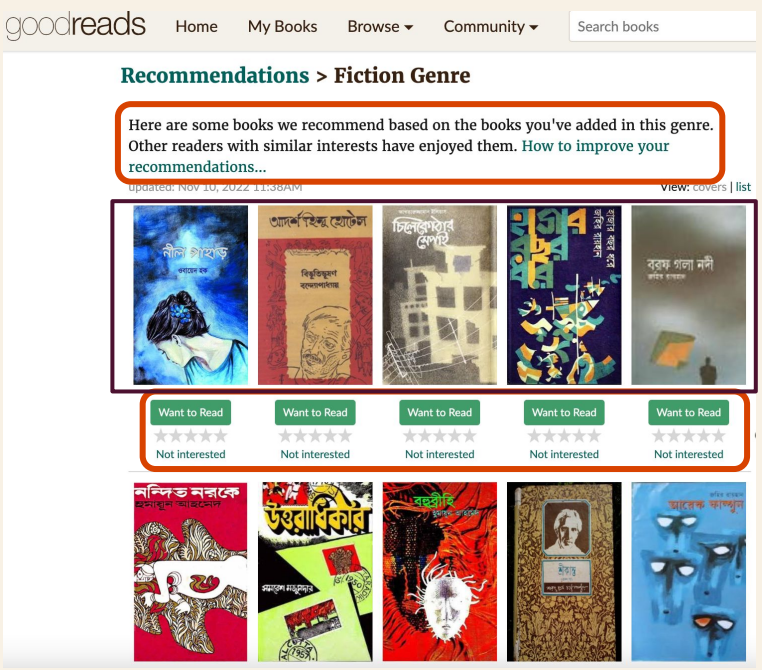
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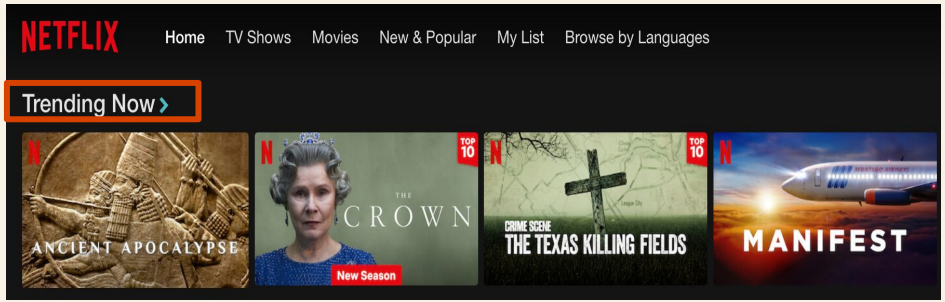
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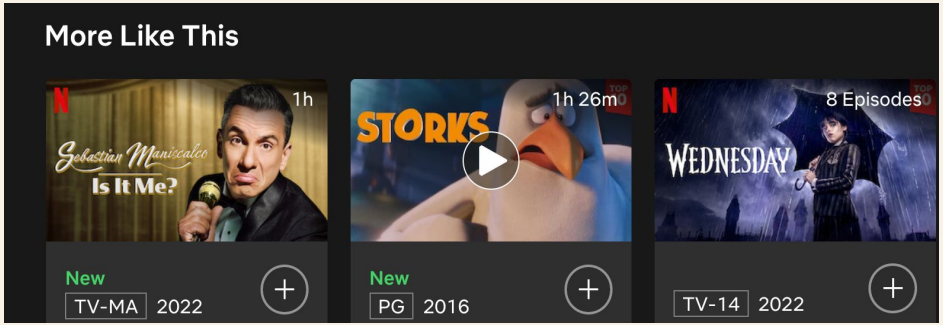
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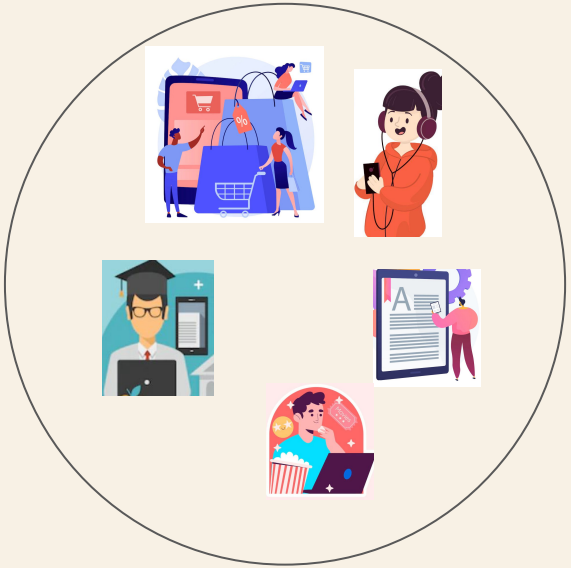

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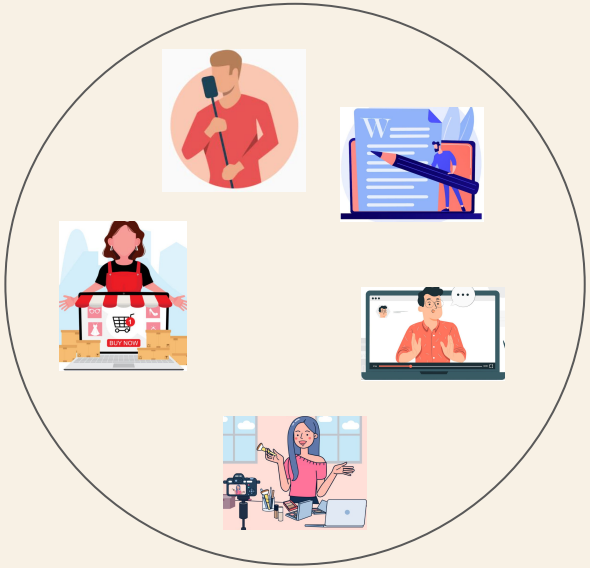

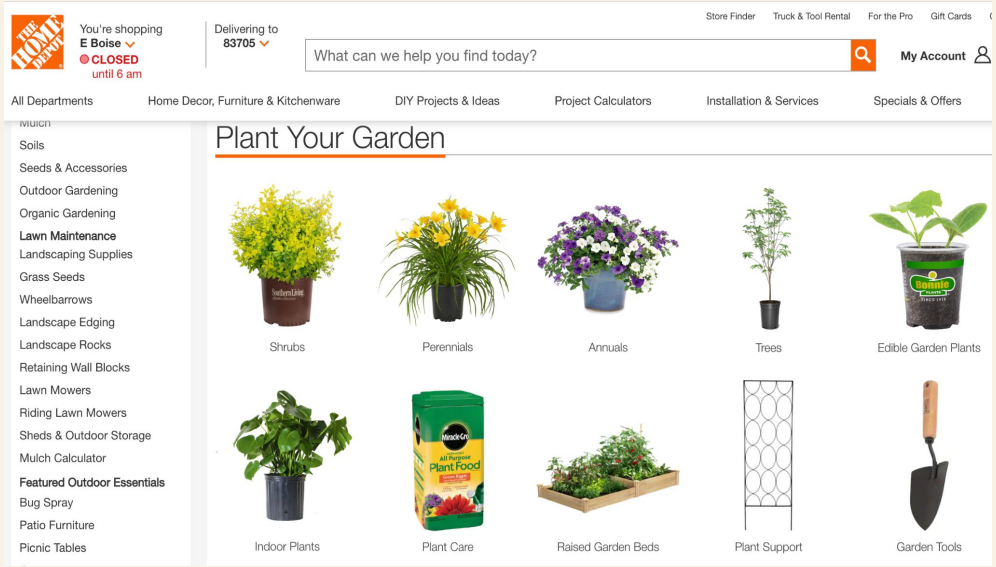
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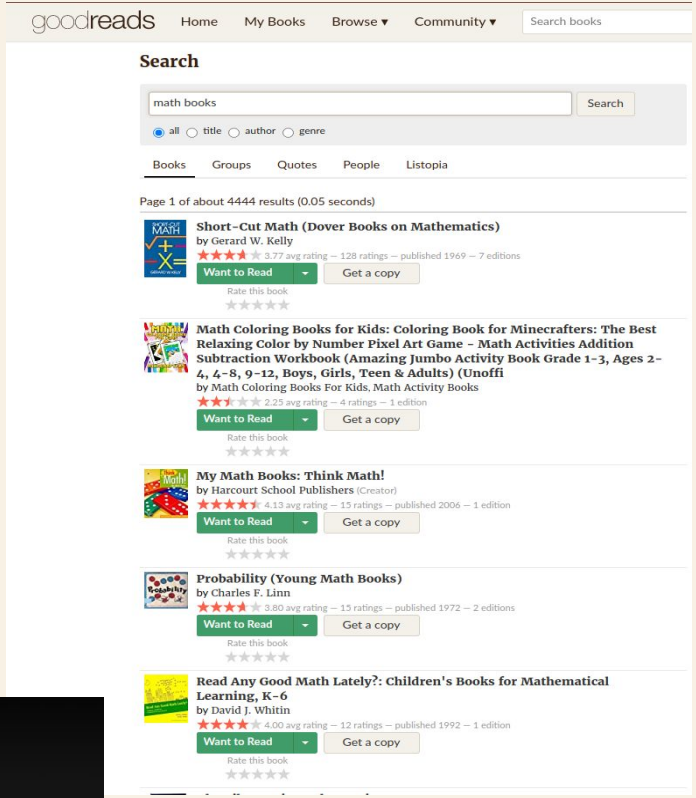
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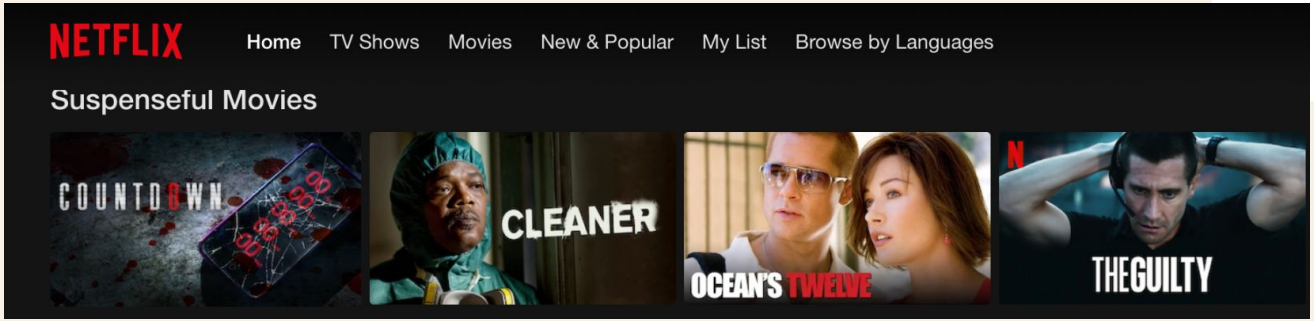
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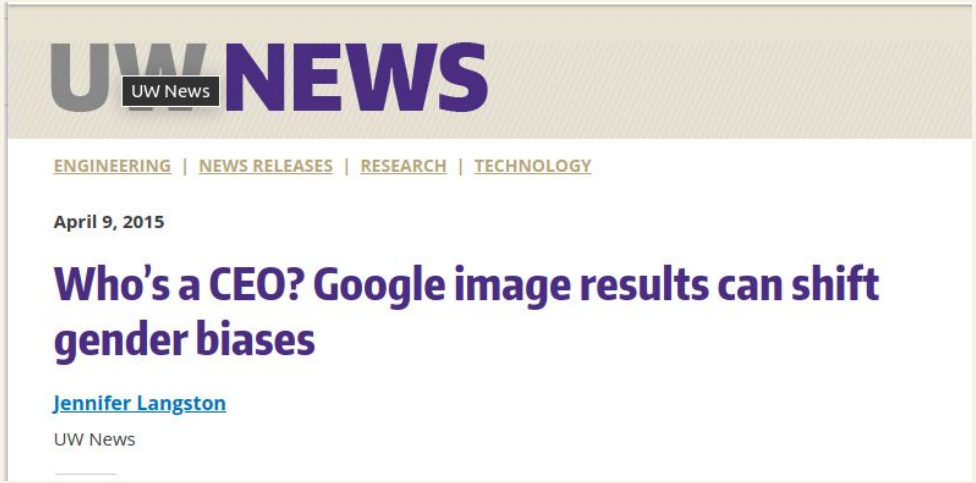
BY SAFIYA NOBLE MARCH 26, 2018 4:30 PM EDT

IDEAS

Dr. Safiya U. Noble is the author of Algorithms of Oppression: How Search Engines Reinforce Racism and is an assistant professor of communication at the University of Southern California, Annenberg School of Communication & Journalism. She is a partner in Stratelligence and co-founder of the Information Ethics & Equity Institute.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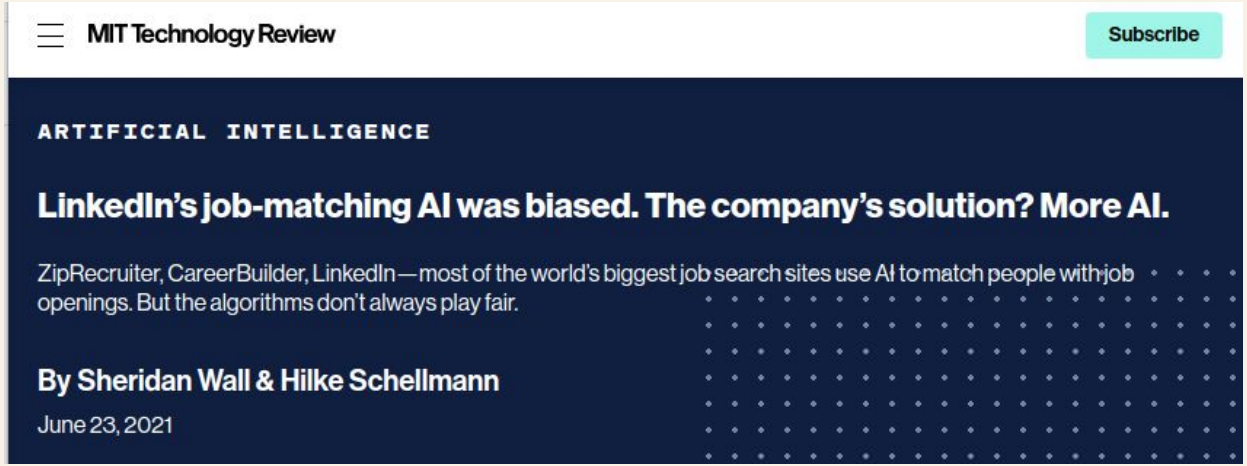
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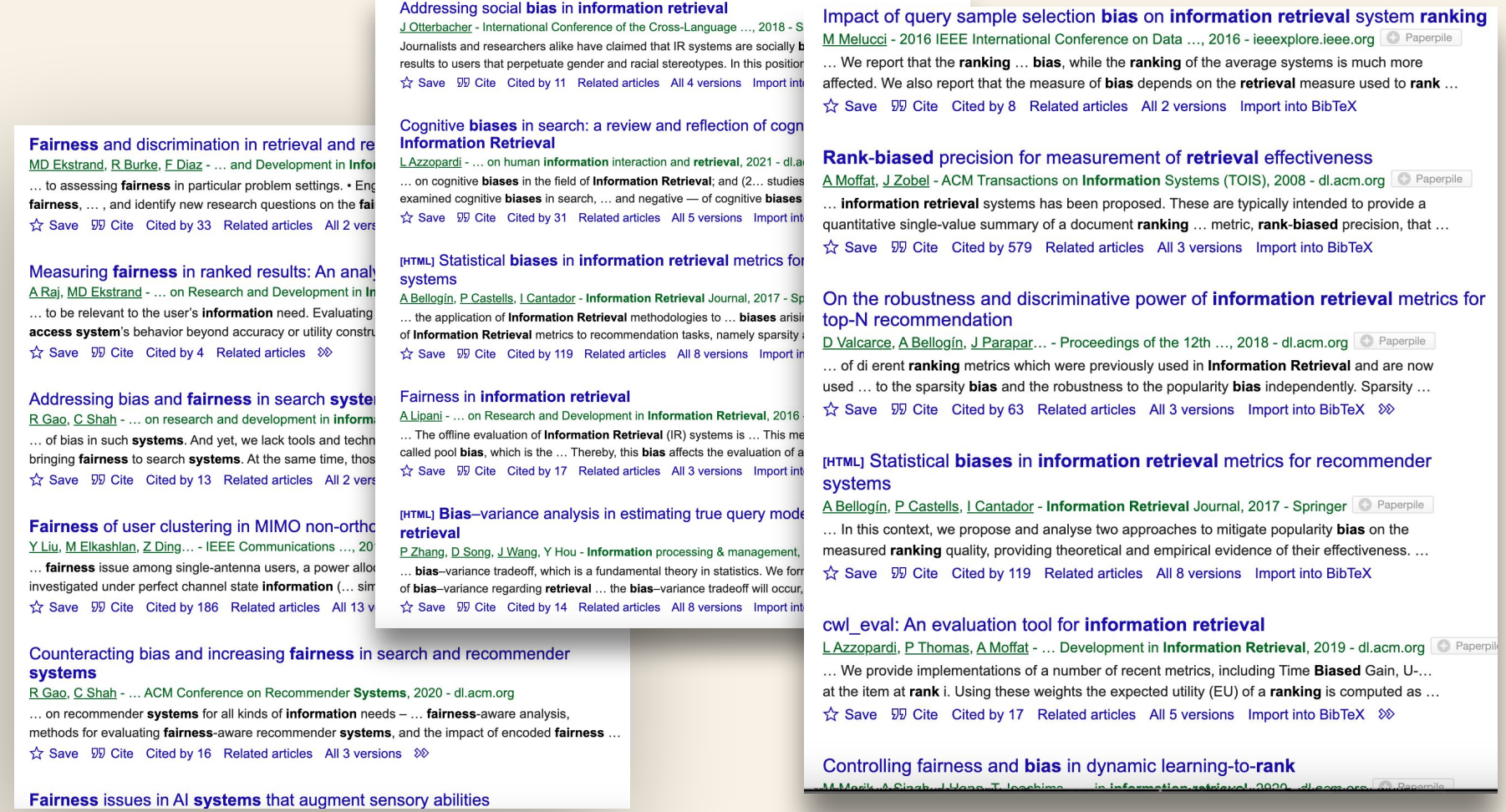
LinkedIn's job-matching AI was biased. The company's solution? More AI.

ZipRecruiter, CareerBuilder, LinkedIn—most of the world's biggest job search sites use AI to match people with job openings. But the algorithms don't always play fair.

By Sheridan Wall & Hilke Schellmann

June 23, 2021



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J Otterbacher - International Conference of the Cross-Language …, 2018 - S
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A Bellogín, P Castells, I Cantador - **Information Retrieval** Journal, 2017 - Sp
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A Lipani - … on Research and Development in **Information Retrieval**, 2016
… The offline evaluation of **Information Retrieval** (IR) systems is … This me
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M Melucci - 2016 IEEE International Conference on Data …, 2016 - ieeexplore.ieee.org Paperpile
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D Valcarce, A Bellogín, J Parapar… - Proceedings of the 12th …, 2018 - dl.acm.org Paperpile
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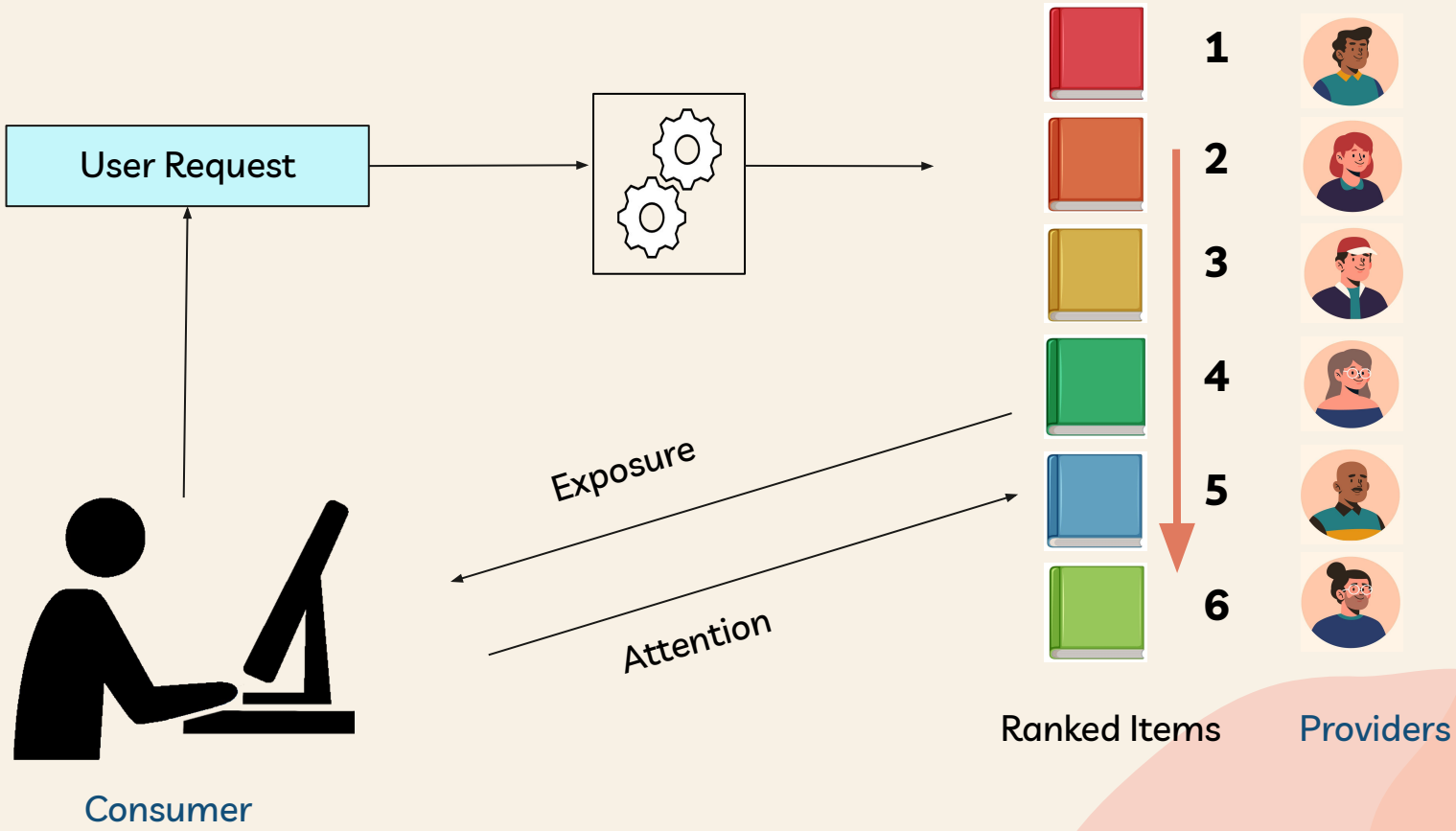
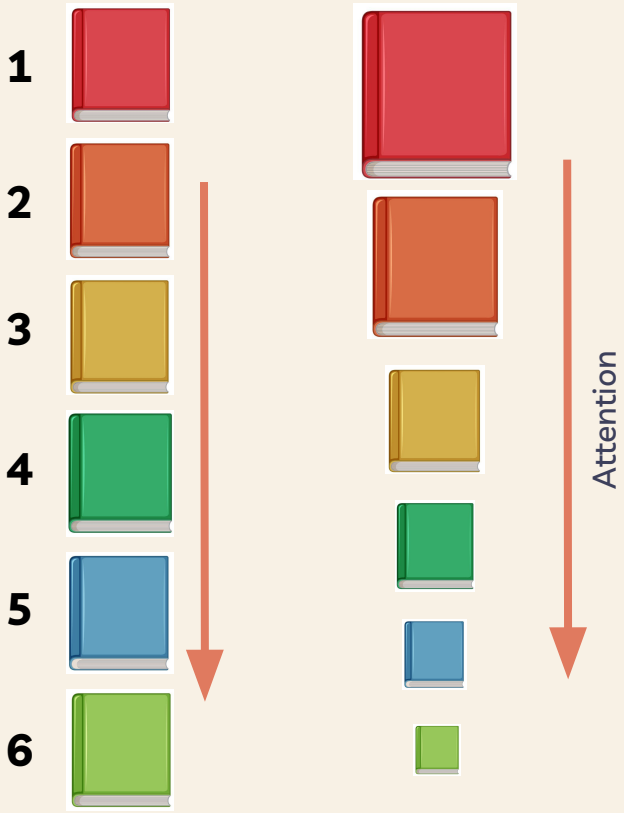
Controlling fairness and **bias** in dynamic learning-to-**rank**

Bias

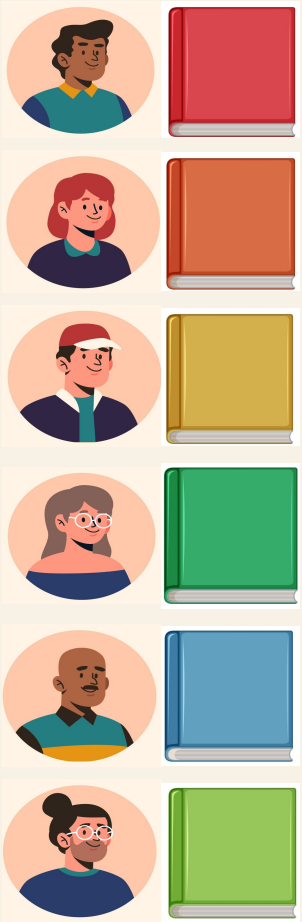
- Difficult to define
- Domain dependent
- Systematic and unfair discrimination against certain **individual** or **group** entities by denying opportunity and assigning unfair outcomes
- Group (Sensitive Attributes) and Individual Fairness


User Request
Exposure
Attention
1
2
3
4
5
6
Consumer
Ranked Items
Providers

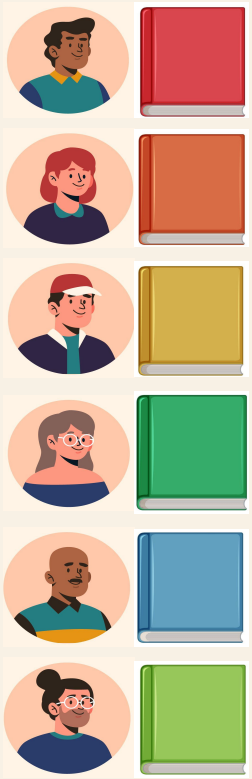
Disparate Exposure



Ranked List



Fairness Positioning



Provider Fairness

Geography

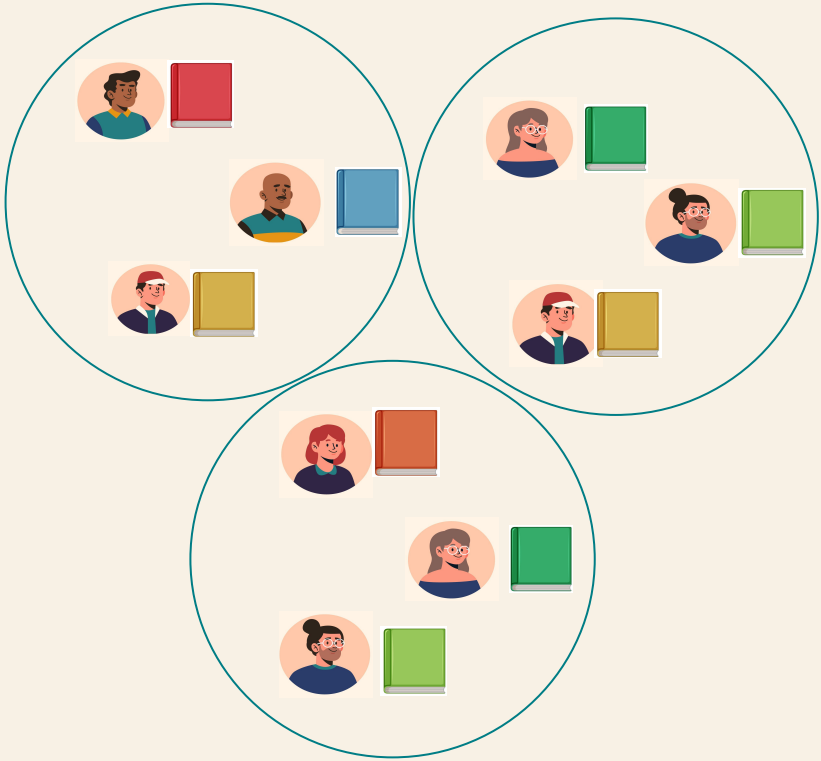
Age

Race

Gender

Economic status

Sensitive Attributes



Group Fairness

Fair Ranking Metrics

PreFΔ
(Yang et. al.; SSDBM ‘17):

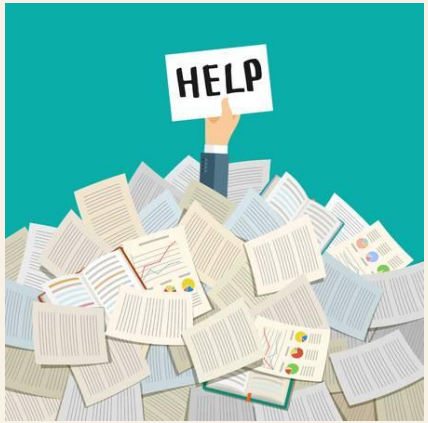
AWRF
(Sapienzynski et. al.; WWW’19)

EEL, EED, EER
Diaz et.al.; CIKM’20)

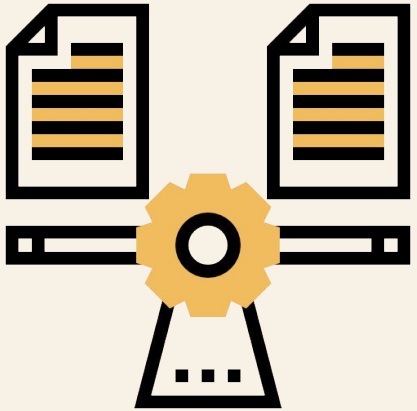
FAIR
(Zehlike et.al.; CIKM’17)

IAA
(Biega et. al.; SIGIR’18)

DP, EUR, RUR
(Singh et.al.; KDD’18)



Several Fair Ranking Metrics



No Comparative and Comprehensive Analysis

Why is the Problem a Problem?

Finding suitable Metrics

Differences among the Metrics

Implementation in Real-world IAS dataset

Research Questions

RQ1. What are the conceptual differences among the fair ranking metrics?

RQ2. What is needed to apply these metrics to real IAS?

RQ3. What are the design decisions and parameters involved, and how sensitive are the resulting metrics to those decisions?

RQ4. What are the empirical differences in how these metrics assess the relative fairness of different recommendation algorithms or retrieval runs?

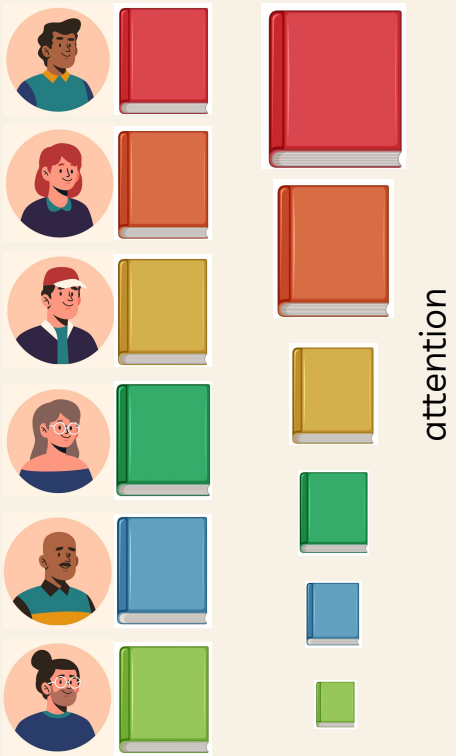
Research Tasks

Conceptual Analysis of Fair Ranking Metrics

Implementing Fair Ranking Metrics in Real-World IAS Datasets

Sensitivity Analysis

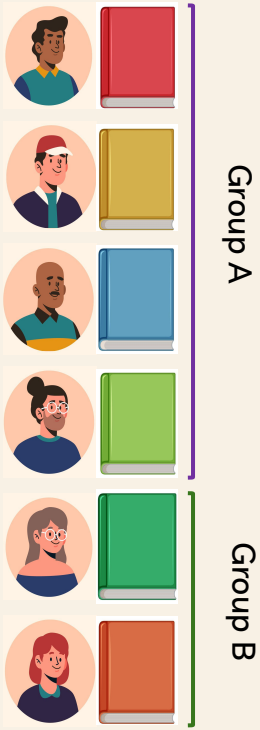
Metrics Design Decomposition



Fairness Goal

What does it mean to be fair?

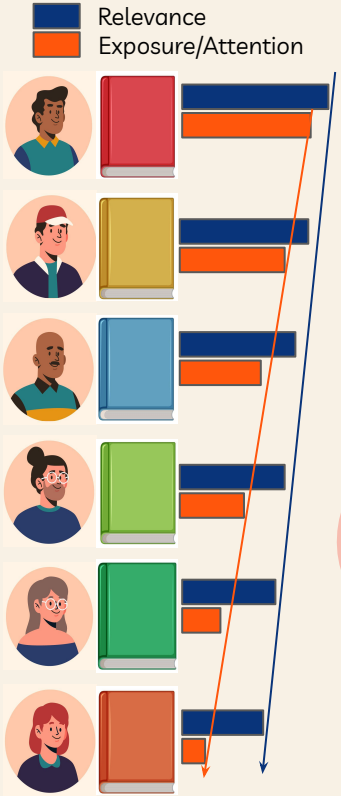
Fairness Goal



PreFΔ, FAIR, AWRF, DP, EED

Item position should not be affected by membership

Statistical Parity

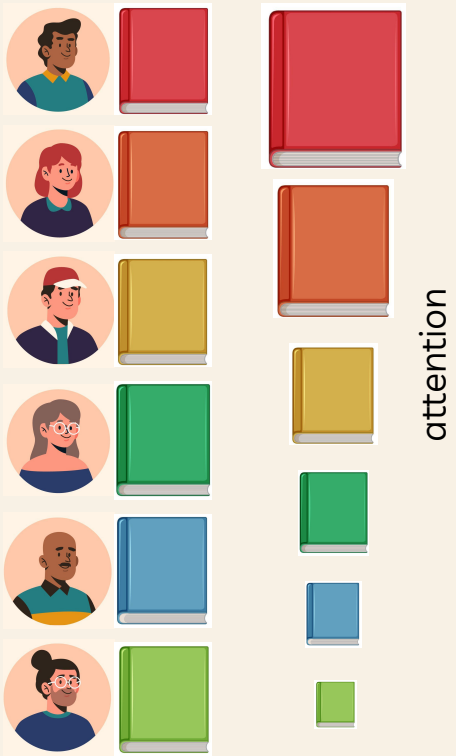


IAA, EUR, RUR, EEL, EER

Exposure/attention should be proportional to relevance

Equal Opportunity

Metrics Design Decomposition



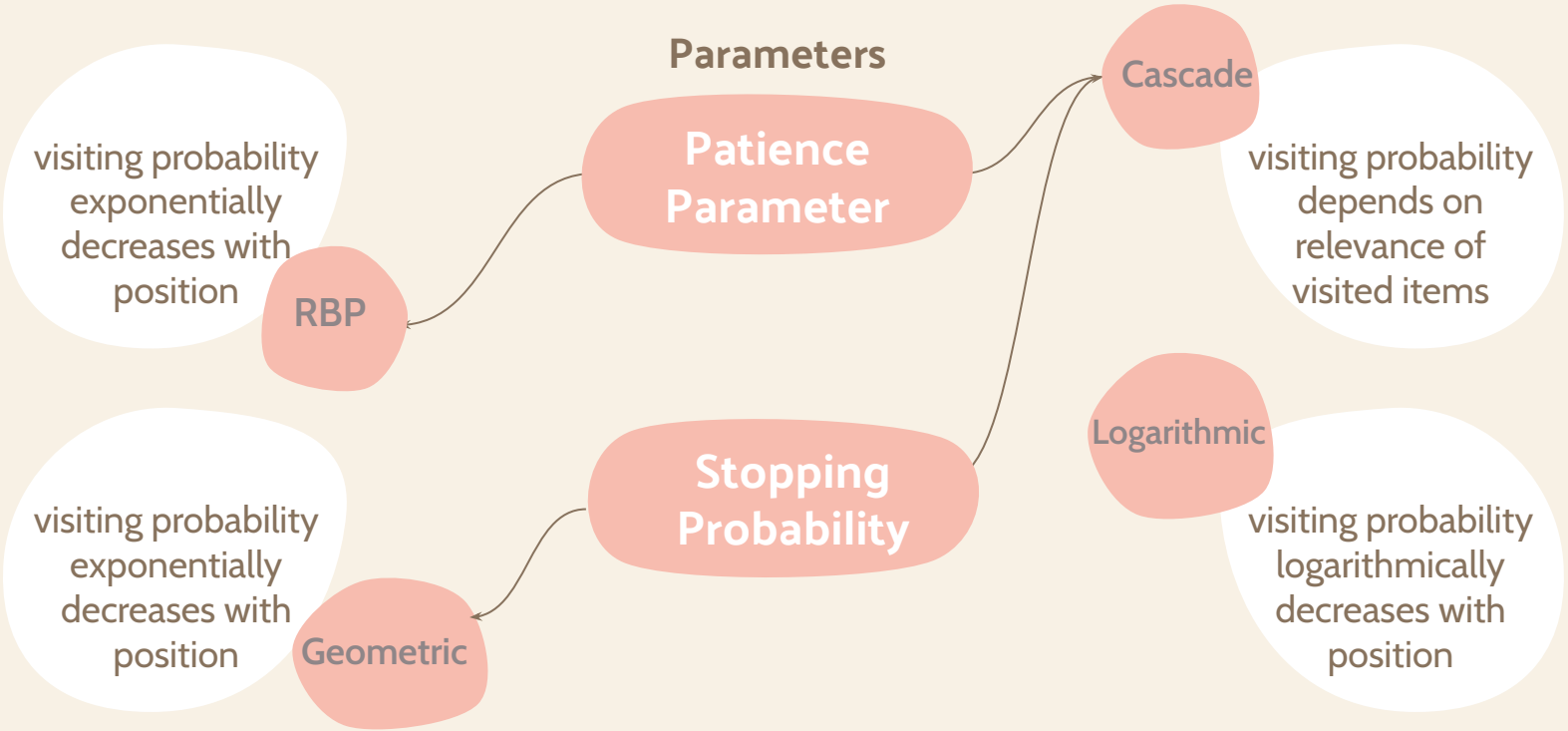
Fairness Goal

What does it mean to be fair?

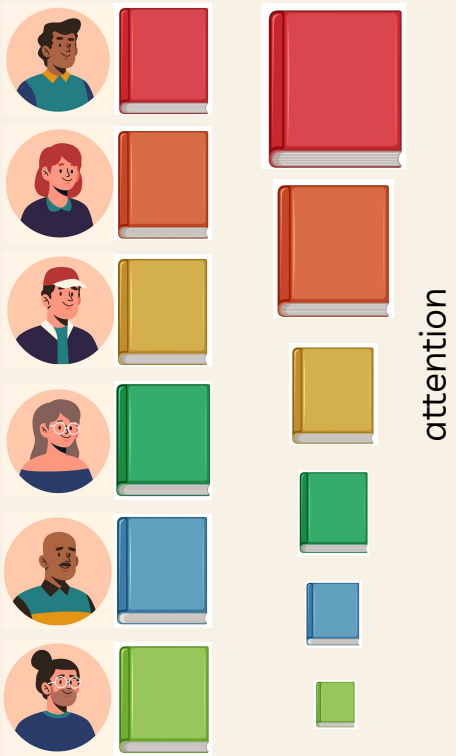
Browsing Model

How to measure position weight?

Browsing Models



Metrics Design Decomposition



Fairness Goal

What does it mean to be fair?

Browsing Model

How to measure position weight?

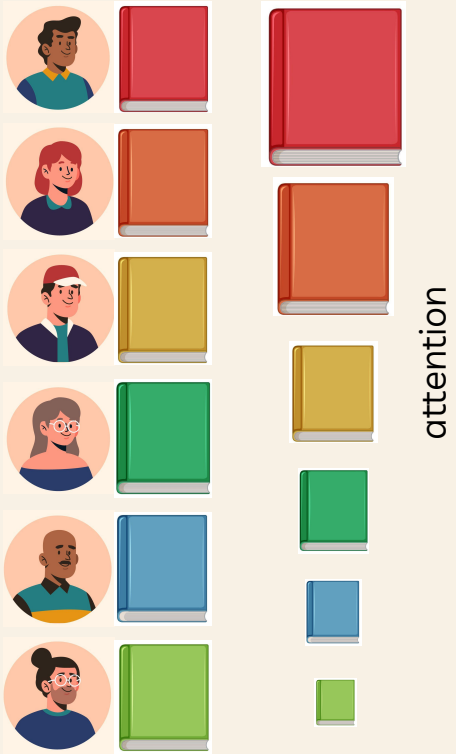
Target Exposure

Compare system exposure with what?

Target Exposure

- Population estimator
  - From full ranking
  - Configured
- Ideal exposure based on relevance
- Estimated utility (Predicted relevance)

Metrics Design Decomposition



Fairness Goal

What does it mean to be fair?

Browsing Model

How to measure position weight?

Target Exposure

Compare system exposure with what?

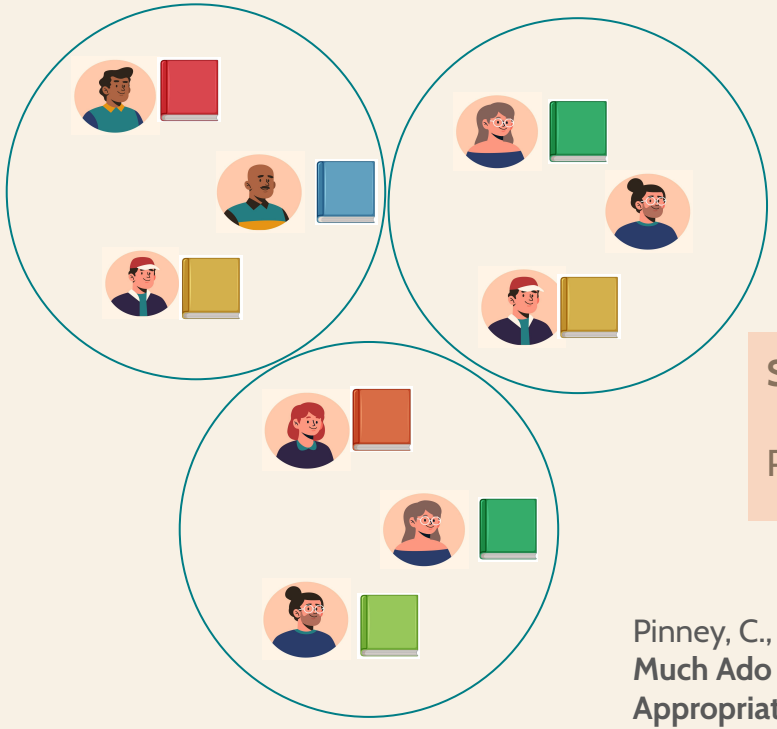
Relevance

How to incorporate relevance?

Group Membership

Does it allow multinomial and soft group association?

Group Membership



Multinomial Protected Attributes

Non-Binary Groups, such as gender

Soft Group Association

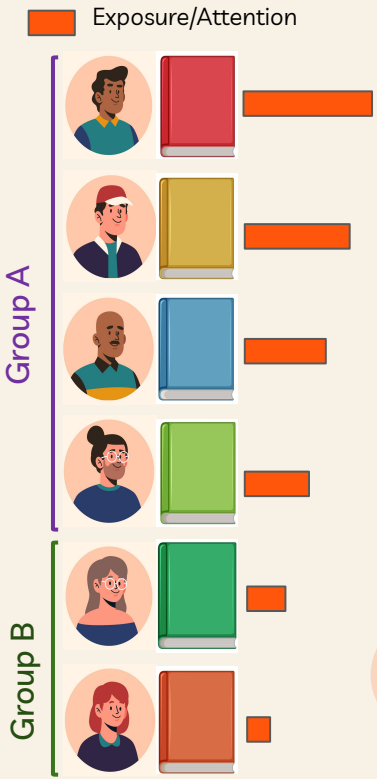
Partial or mixed group membership such as race

Pinney, C., Raj, A., Hanna, A., & Ekstrand, M. D. (2023)
Much Ado About Gender: Current Practices and Future Recommendations for Appropriate Gender-Aware Information Access.
To appear in CHIIR 2023 proceedings.
https://arxiv.org/abs/2301.04780

Summary of Fair Ranking Metrics

Metric(s)	Goal	Weighting	Relevance	Binomial?
PreFd	Each prefix representative of whole ranking	✗	✗	Dep on d
FAIR	Each prefix matches target distribution	✗	✗	✓
AWRF	Weighted representation matches population	Geometric	✗	✗
DP	Exposure equal across groups	Logarithmic	✗	✓
EUR	Exposure proportional to relevance	Logarithmic	✓	✓
RUR	Discounted gain proportional to relevance	Logarithmic	✓	✓
IAA	Exposure proportional to predicted relevance	Geometric	Predicted	✗
EEL, EER	Exposure matches ideal (from relevance)	Cascade, Geom	✓	✗
EED	Exposure well-distributed	Cascade, Geom	✗	✗

Statistical Parity



AWRF

(Sapienzynski et. al, WWW'19)

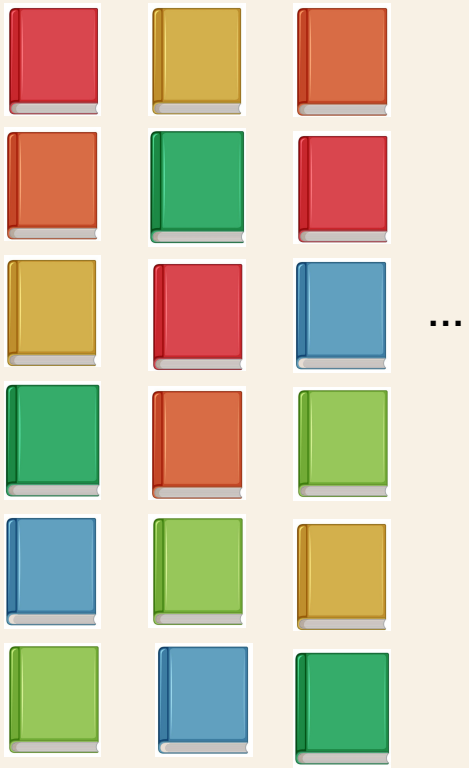
Expected cumulative exposure(Group B x position weight) >=p

Target distribution is the group distribution in entire ranked list (true demographics)

- no relevance information
- geometric attention decay
- non-binary group membership
- uses a target distribution to compare

PreFΔ (Yang et. al, SSDBM'17) and FAIR (Zehlike et. al, CIKM'17) differ in measuring position weight and allowing multinomial groups.

Sequences of Ranking



...

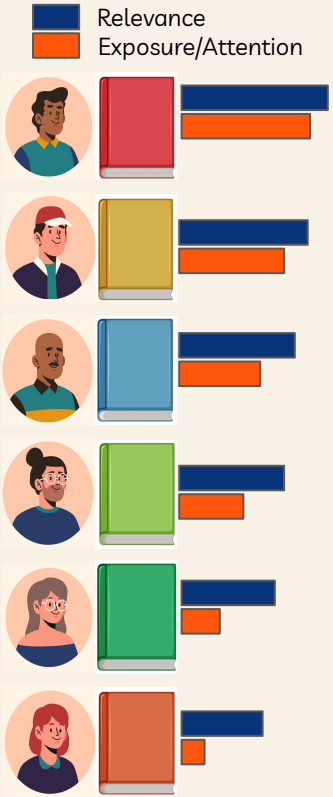
Statistical Priority

DP, EED

Equal Opportunity

IAA, EUR, RUR, EER, EEL

Equal Opportunity



EE*
(Diaz et. al, CIKM'20)

EEL(Expected Exposure Loss): ||target-system||2

EER (Expected Exposure Relevance): Exposure-relevance distribution

- stochastic ranking
- rbp & cascade attention decay
- non-binary group membership

IAA (Biega et. al, SIGIR'18) differs in weighting strategy, group membership, and relevance

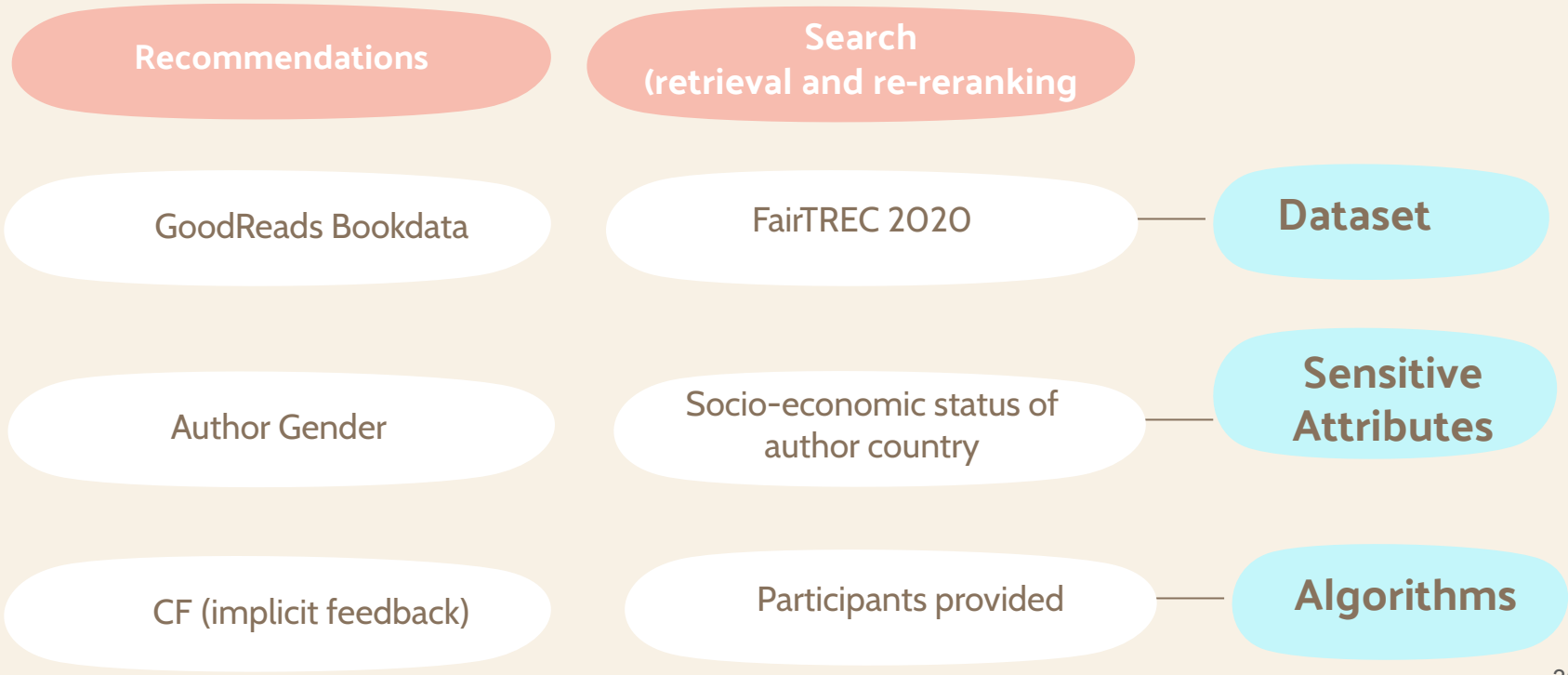
EUR, RUR (Singh et. al, SIGKDD'18) differs in weighting strategy and group membership

Task 1 Findings

Task 1: Conceptual Analysis Fair Ranking Metrics

- Metrics are conceptually similar with common components like relevance, browsing model, aggregation, target exposure
- Metrics differs in their design choices and fairness assumption
- Metrics with same goal can have different design choices

Implementing the Metrics



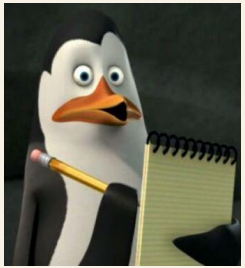
https://fair-trec.github.io/

Challenges in Implementation

Missing Relevance Information

IAA, EE*, DP, EUR, RUR

AWRF, IAA, DP, EUR, RUR, EE*



Parameter Setting

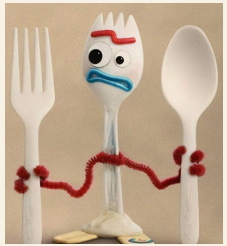
Missing Group Label

All the metrics

Extreme Imbalance

- **PreFΔ** and **RUR:** suffer from missing data (sparsity) problem
- Reformulated ratio-based metric to smoothed log ratio

PreFΔ, FAIR, IAA, DP, EUR, RUR



Soft Group Association
Non-binary groups

Task 2 Findings

Task 2: Implementing Fair Ranking Metrics in Real-World Datasets

- Missing data, missing relevance information, ranked list size are crucial/delicate factors in implementing metrics.
- Metrics with similar fairness goals differ in their ease of implementations

Sensitivity Analysis

Ranked-list size

- No effect on metrics for FairTREC
- Ratio-based metrics and FAIR showed sensitivity

Weighting Strategy

- Default parameters
- EEL and logRUR showed high sensitivity

Parameter Settings

- Almost all metrics showed sensitivity
- logRUR is extremely sensitive

Task 3 Findings

Task 3: Sensitivity Analysis

- Metrics differ in their sensitivity towards external factors.
- High sensitivity towards design choices add complexity in the usability of metrics

Key Findings

Defining metrics in unified framework

- Metrics are surprisingly similar

Implement the metrics in same experimental setup

- Missing data, missing relevance information, ranked list size are crucial/delicate factors in implementing metrics.

Sensitivity Analysis

- Metrics differ in their sensitivity towards external factors.

Recommendations

	Allow multinomial protected attributes	Allow soft group association	Sensitivity towards design choices
Single-list metrics FAIR, AWRF	AWRF	AWRF	AWRF
Demographic Parity in Sequence DP, EED	EED	EED	EED
Equal Opportunity in Sequence EUR, RUR, IAA, EER, EEL	EER, EEL	EER, EEL	EER, EEL, IAA

Research Directions

- Simulation study to understand the impact of crucial factors in metric implementation.
- Incorporating various browsing models
- Missing label
- Missing or sparse relevance
- Ambiguous or multiple group association
- Robust, explainable, and efficient metric design

THANK You!

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