

Fairness in Ranking in Information Access Systems

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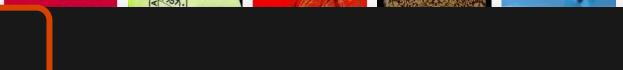
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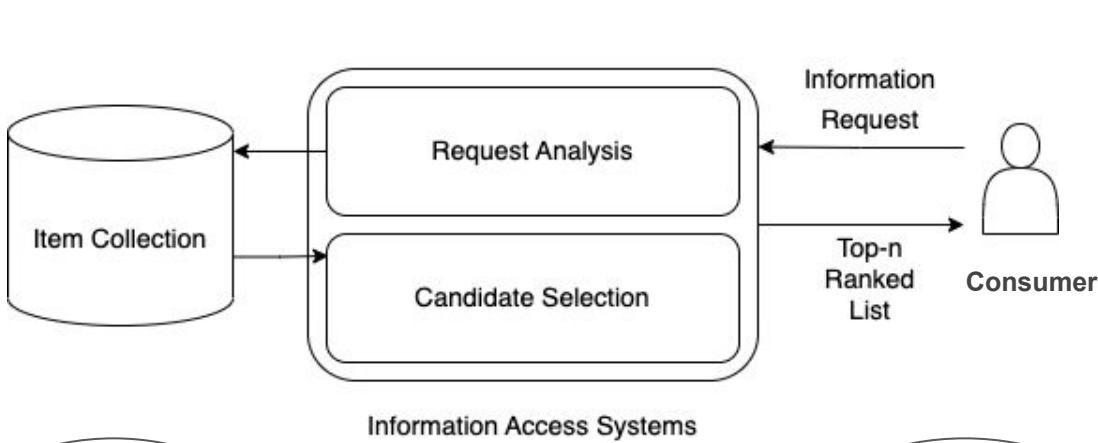
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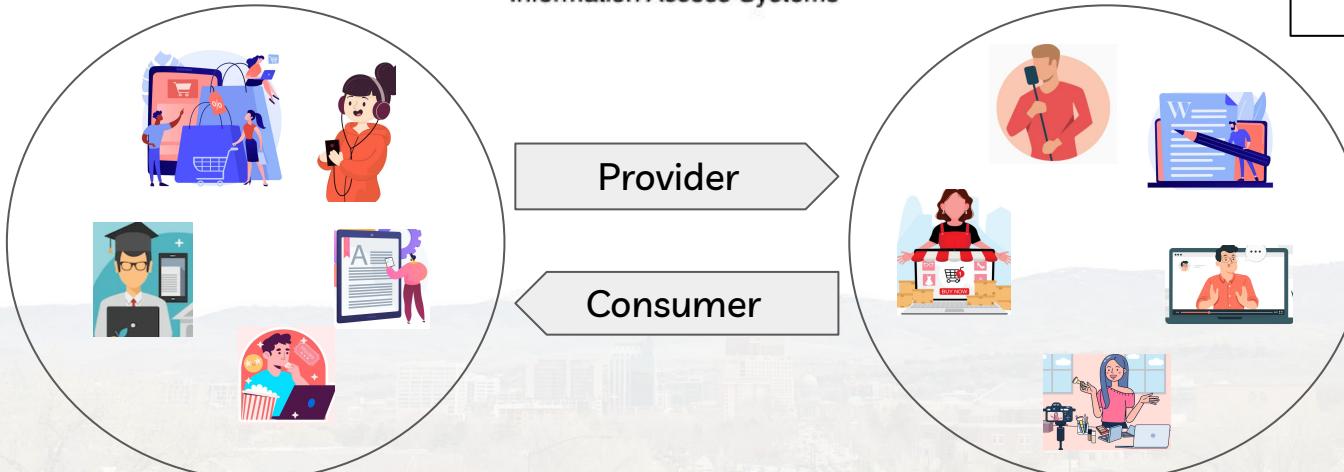
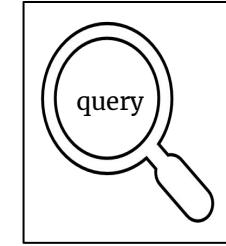
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Information Access Systems (IAS) Framework



	Green Book	Yellow Book
Person 1	✓	✗
Person 2	✗	✓
Person 3	✓	✓





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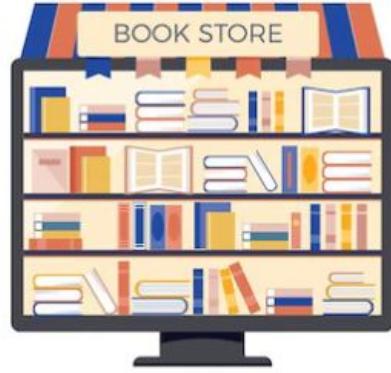
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IDEAS • TECH BIAS

Google Has a Striking History of Bias Against Black Girls

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.

MIT Technology Review

ARTIFICIAL INTELLIGENCE

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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[A. Lipani](#) - ... on Research and Development in Information Retrieval, 2016 - Springer ... The offline evaluation of Information Retrieval (IR) systems is ... This metric is called pool bias, which is the ... Thereby, this bias affects the evaluation of a

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[HTML] Bias-variance analysis in estimating true query model retrieval

[P. Zhang, D. Song, J. Wang, Y. Hou](#) - Information processing & management, 2017 - Springer ... bias-variance tradeoff, which is a fundamental theory in statistics. We formalize the bias-variance regarding retrieval ... the bias-variance tradeoff will occur,

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Impact of query sample selection bias on information retrieval system ranking

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... We report that the ranking ... bias, while the ranking of the average systems is much more affected. We also report that the measure of bias depends on the retrieval measure used to rank ...

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Rank-biased precision for measurement of retrieval effectiveness

[A. Moffat, J. Zobel](#) - ACM Transactions on Information Systems (TOIS), 2008 - dl.acm.org + Paperpile

... information retrieval systems has been proposed. These are typically intended to provide a quantitative single-value summary of a document ranking ... metric, rank-biased precision, that ...

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On the robustness and discriminative power of information retrieval metrics for top-N recommendation

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cwl_eval: An evaluation tool for information retrieval

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Key Concepts

- Bias/ Unfairness
- Exposure/Attention
- Group-fairness
- Sensitive Attributes
- Optimization
- Re-ranking

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

April 9, 2015

Who's a CEO? Google image results can shift gender biases

Jennifer Langston

UW News

Getty Images last year created a new online image catalog of women in the workplace—one that countered visual stereotypes on the Internet of moms as frazzled caregivers rather than powerful CEOs.

A [new University of Washington study](#) adds to those efforts by assessing how accurately gender representations in online image search results for 45 different occupations match reality.

In a few jobs—including CEO—women were significantly underrepresented in Google image search results, the study found, and that can change searchers' worldviews. Across all the professions, women were slightly underrepresented on average.



Percentage of women in top 100 Google image search results for CEO: 11%
Percentage of U.S. CEOs who are women: 27%

The study also answers a key question: Does the gender ratio in images that pop up when we type "author," "receptionist" or "chef" influence people's perceptions about how many men or women actually hold those jobs?

Biased Representation

ARTIFICIAL INTELLIGENCE

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

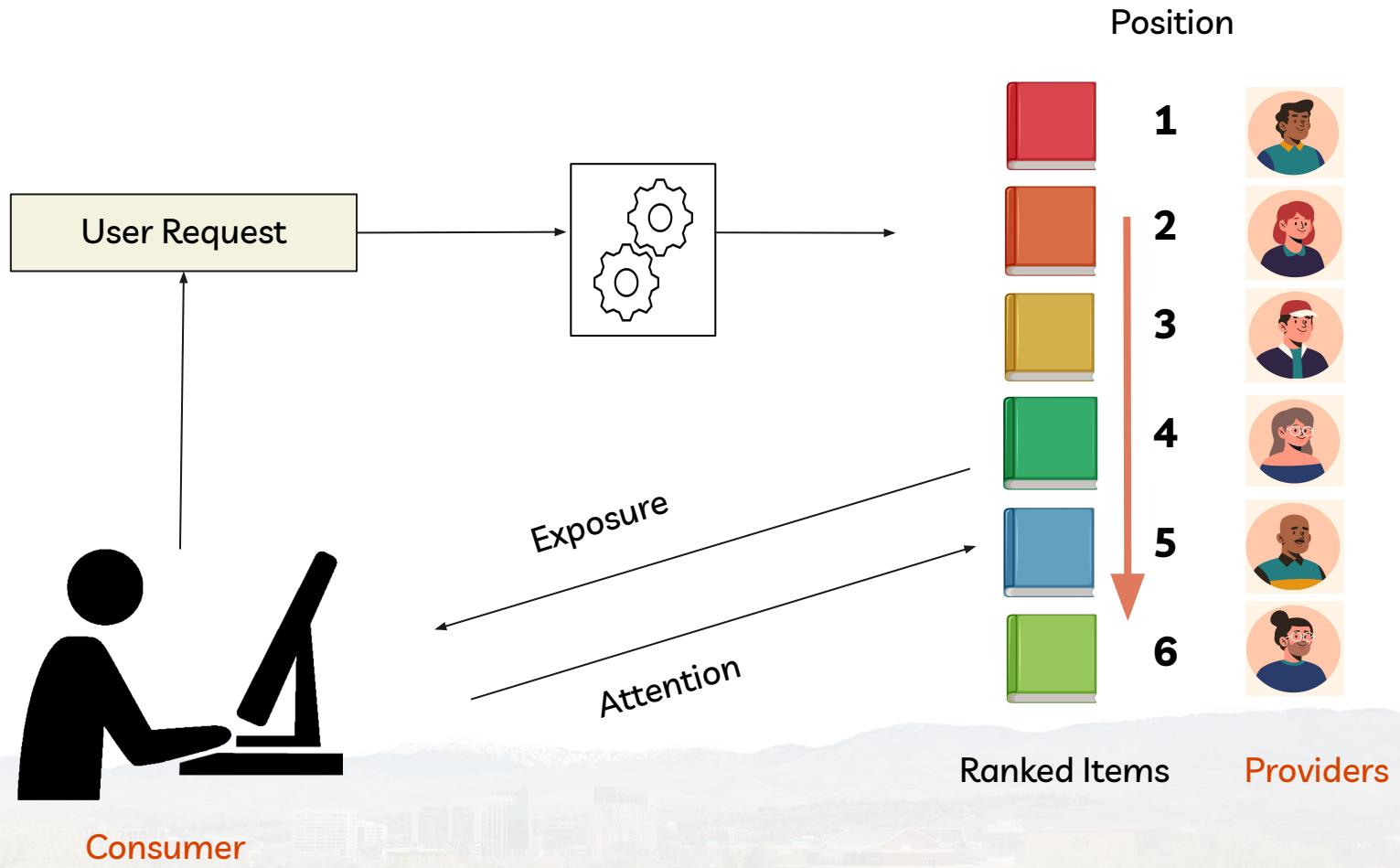


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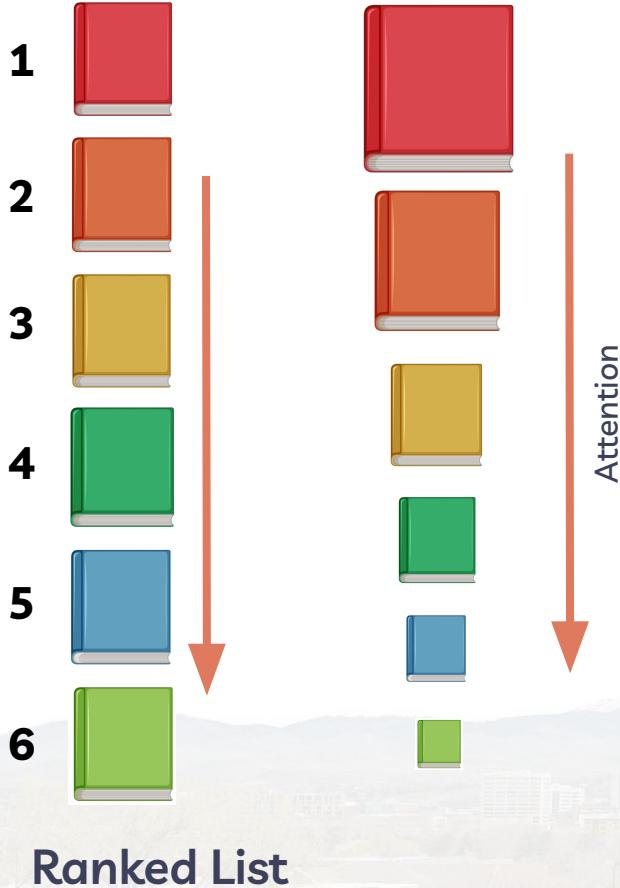
Years ago, LinkedIn discovered that the recommendation algorithms it uses to match job candidates with opportunities were producing biased results. The algorithms were ranking candidates partly on the basis of how likely they were to apply for a position or respond to a recruiter. The system wound up referring more men than women for open roles simply because men are often more aggressive at seeking out new opportunities.

LinkedIn discovered the problem and built another AI program to counteract the bias in the results of the first. Meanwhile, some of the world's largest job search sites—including CareerBuilder, ZipRecruiter, and Monster—are taking very different approaches to addressing bias on their own platforms, as we report in the newest episode of MIT Technology Review's podcast *"In Machines We Trust."* Since these platforms don't disclose exactly how their systems work, though, it's hard for job seekers to know how effective any of these measures are at actually preventing discrimination.

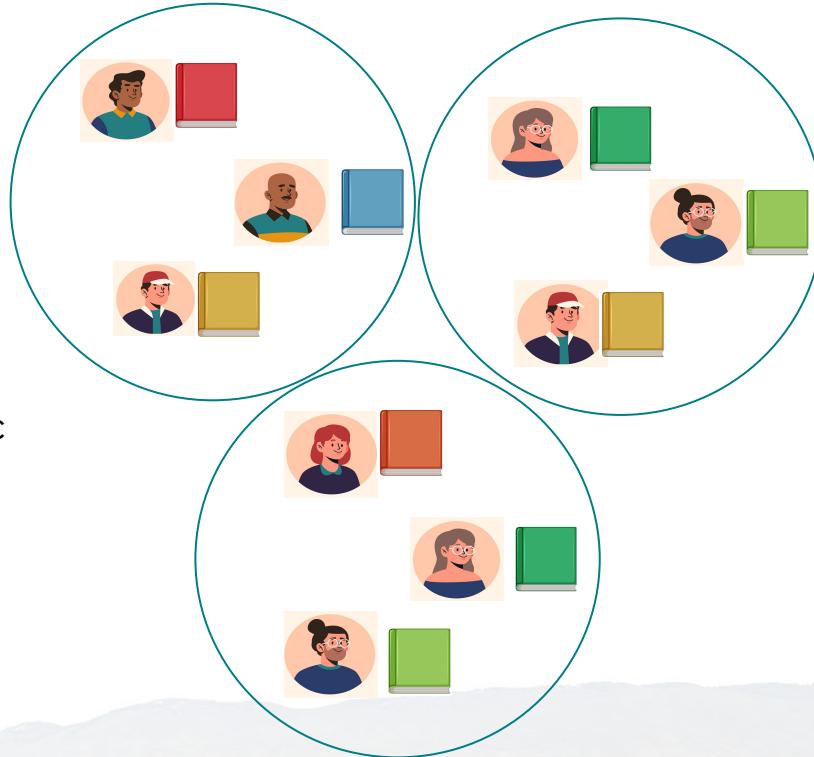
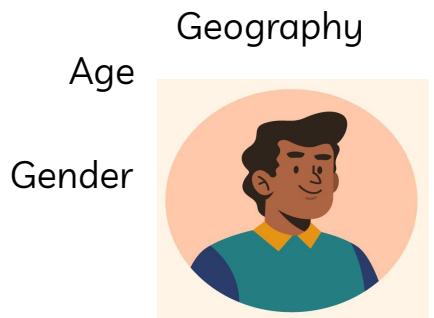
Biased Allocation/Distribution



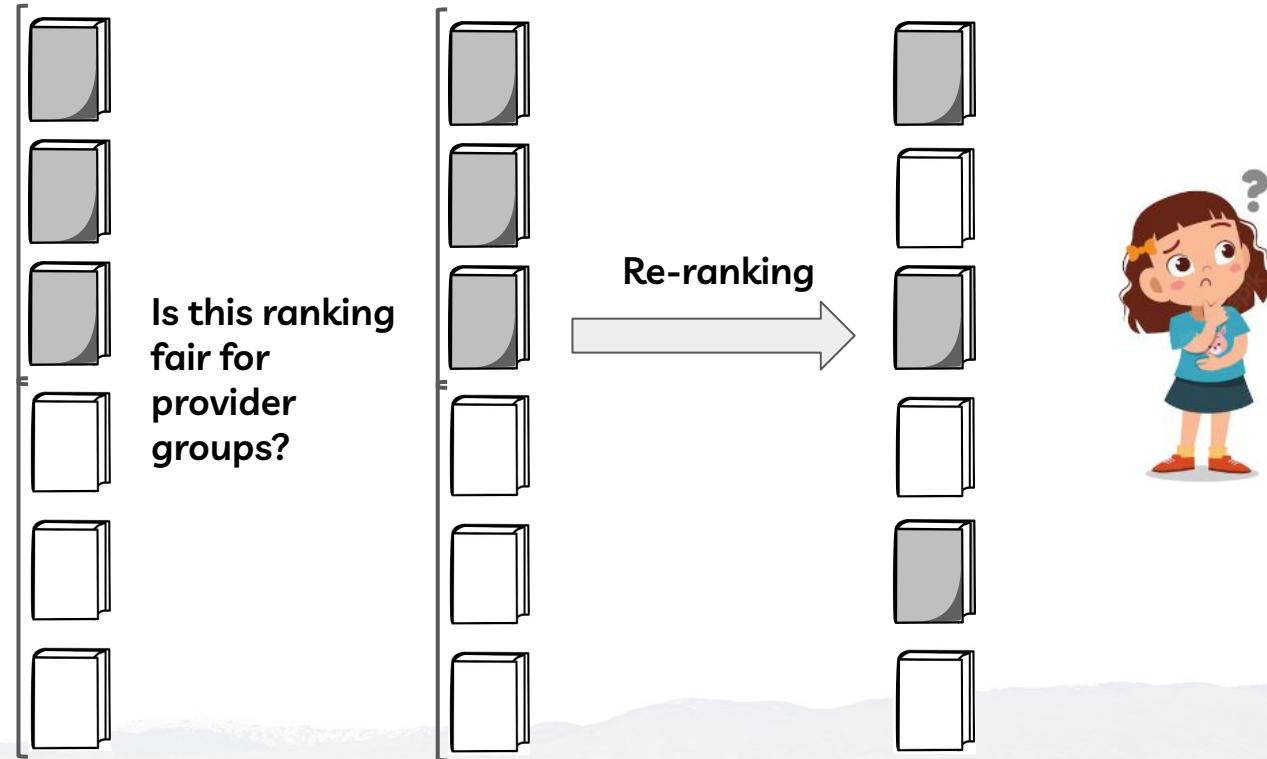
Disparate Exposure



Fairness Positioning



Fairness Concern



Measure Fairness

Fairness Optimization

Fairness Concern

Measurement and optimization of provider-side group fairness in ranking of information access systems (IAS)

Research Objectives

01

Analyzing Fair Ranking Metrics

Provide comprehensive and comparative analysis of fair ranking metrics research

02

Beyond Linear Layout Fairness

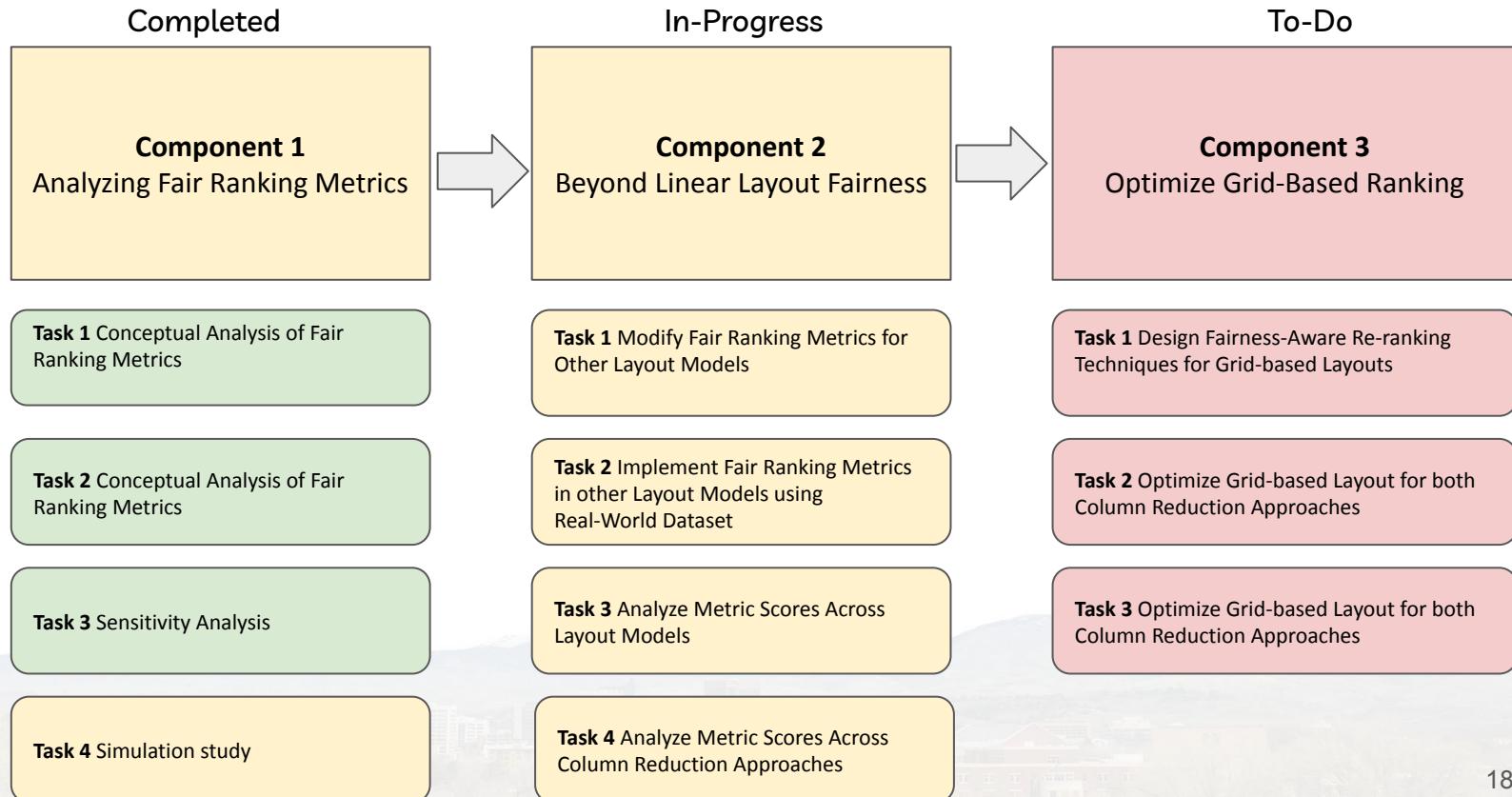
Contribute to the advancement of fair ranking metrics

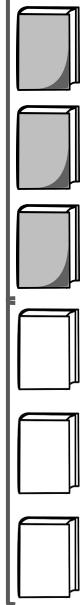
03

Optimize Grid-Based Layout

Contribute to the improvement of provider-side group fairness in IAS ranking

Research Components





Is this
ranking
fair for
provider
groups?

Component 1

Analyzing Fair Ranking Metrics

Analyzing Fair Ranking Metrics

PreF Δ

(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)

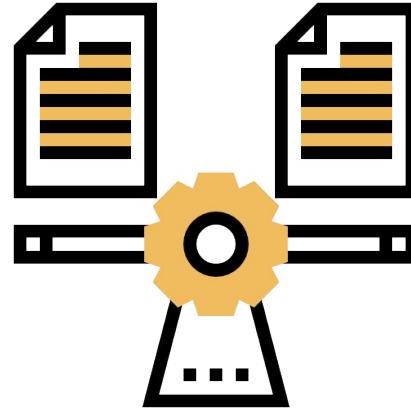
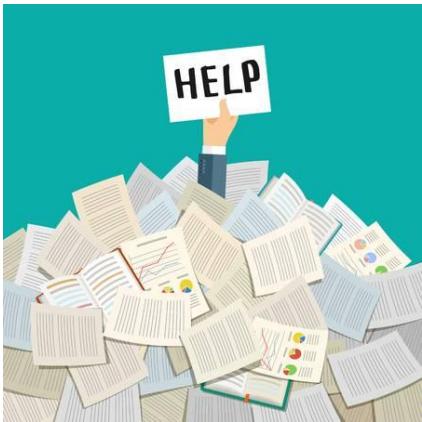
IAA

(Biega et. al.; SIGIR'18)

DP, EUR, RUR

(Singh et.al.; KDD'18)

Motivation



Several Fair Ranking Metrics

No Comparative and Comprehensive Analysis

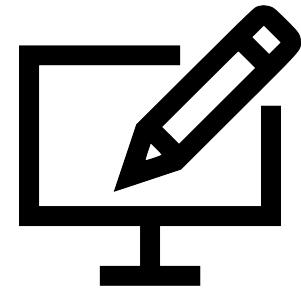
Why is the Problem a Problem?



Finding Suitable Metrics



Differences among the Metrics



Implementation in Real-world IAS dataset

Research Questions

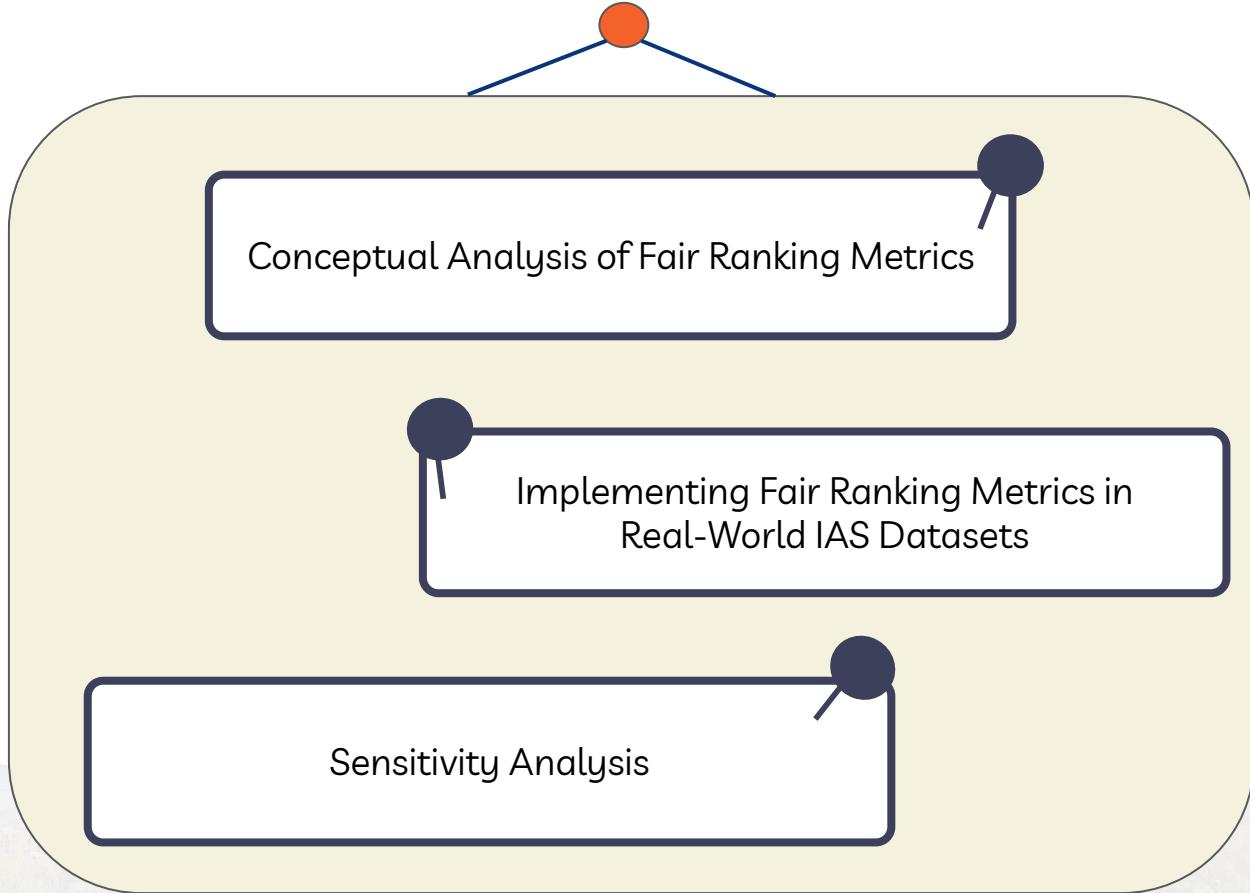
RQ1. What are the conceptual differences among the fair ranking metrics?

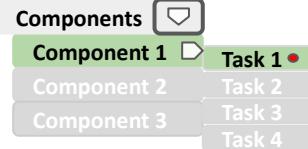
RQ2. What is needed to apply these metrics to real IAS?

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

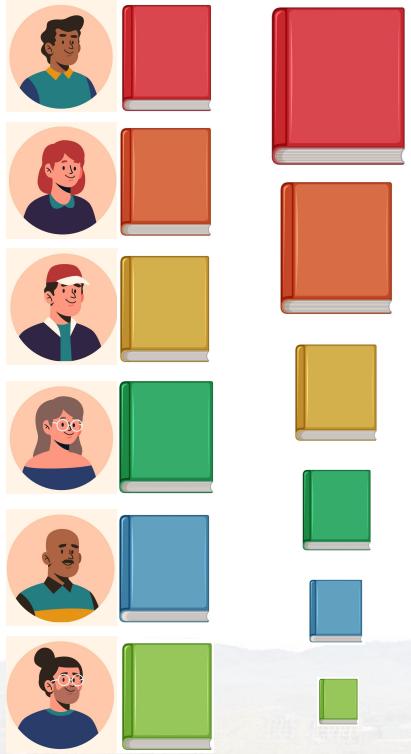




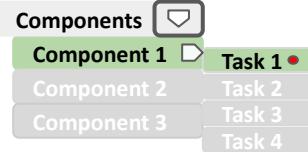
Metrics Design Decomposition

Fairness Goal

What does it mean to be fair?



Fairness Goal

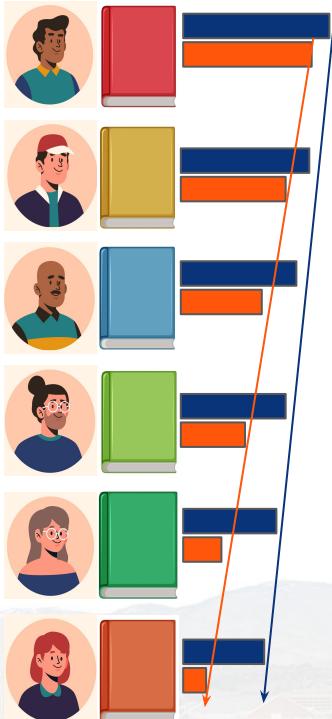


PreF Δ , FAIR, AWRF, DP, EED

Item position should not be affected by membership

Statistical Parity

Relevance
Exposure/Attention

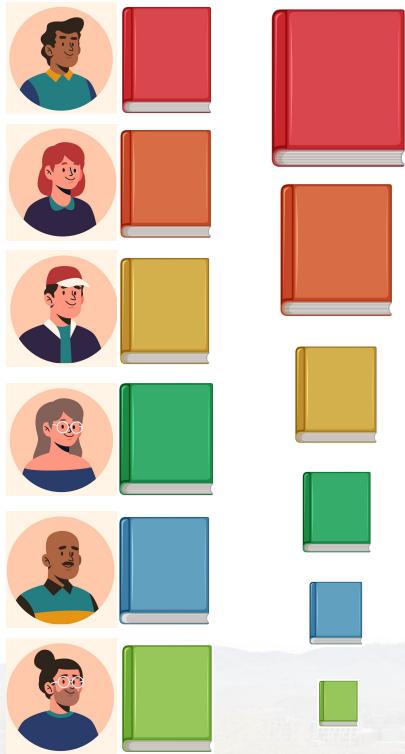
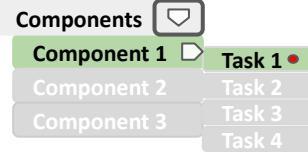


IAA, EUR, RUR, EEL, EER

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?

attention

Components	
Component 1	Task 1 •
Component 2	Task 2
Component 3	Task 3
	Task 4

Browsing Models

patience parameter

visiting probability exponentially decreases with position
RBP

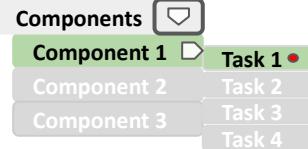
stopping probability

visiting probability exponentially decreases with position
Geometric

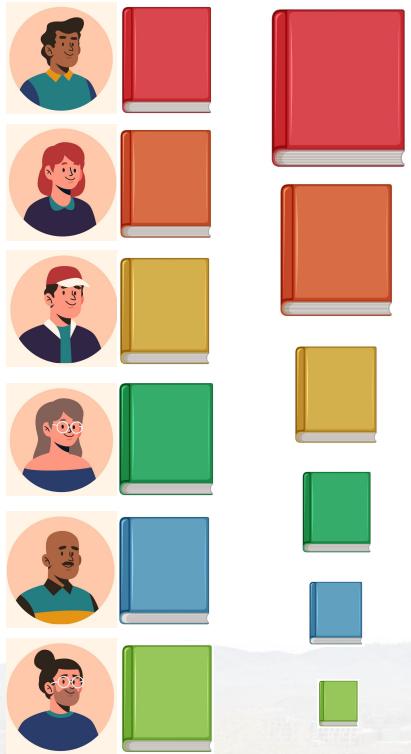
patience parameter
stopping probability

visiting probability depends on relevance of visited items
Cascade

visiting probability logarithmically decreases with position
Logarithmic



Metrics Design Decomposition



Fairness Goal

What does it mean to be fair?

Browsing Model

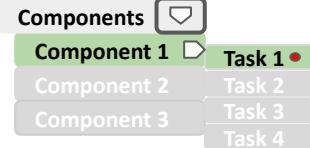
How to measure position weight?

Target Exposure

Compare system exposure
with what?

Target Exposure

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



Metrics Design Decomposition



attention

Fairness Goal

What does it mean to be fair?

Browsing Model

How to measure position weight?

Target Exposure

Compare system exposure
with what?

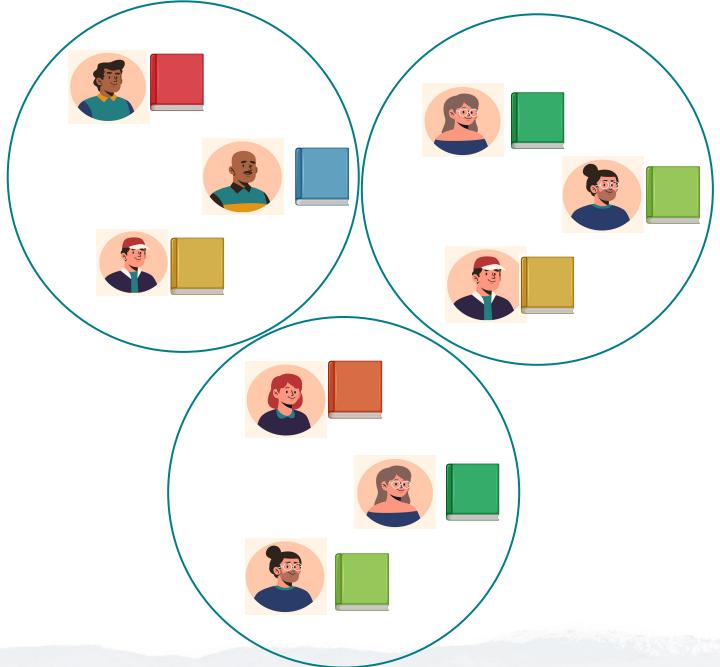
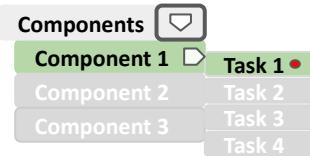
Relevance

How to incorporate relevance?

Group Membership

Does it allow multinomial
and soft group association?

Group Membership

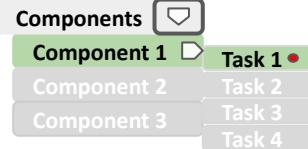


Multinomial Protected Attributes

Non-Binary Groups, such as gender

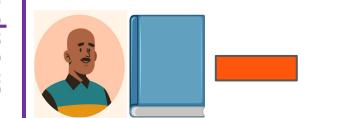
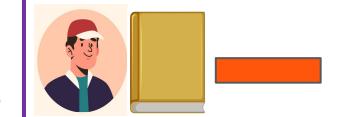
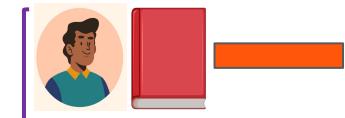
Soft Group Association

Partial or mixed group membership such as race



Statistical Parity

Exposure/Attention



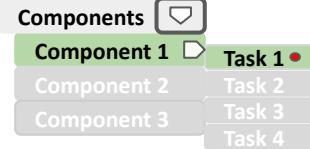
AWRF (Sapienzynski et. al, WWW'19)

Expected cumulative exposure(Group B x position weight) $\geq p$

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

PreF Δ (Yang et. al, SSDBM'17) and FAIR (Zehlike et. al, CIKM'17) do not use position weight and do not allow multinomial group membership.



Sequences of Ranking

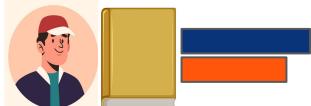
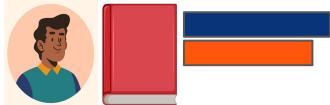


Statistical Parity (Multiple Rankings)

- DP, EED
- Equal Opportunity
- All the metrics

Equal Opportunity

 Relevance
 Exposure/Attention



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

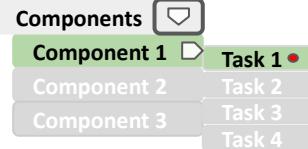
EEL(Expected Exposure Loss):
 $\| \text{target-system} \|_2$

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



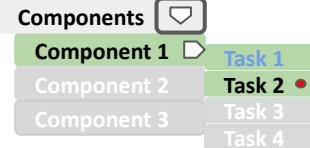
Findings

Task 1: Conceptual Analysis Fair Ranking Metrics

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



Metric Implementation



Dataset

Sensitive Attributes

Algorithms

Recommendations

GoodReads bookdata

Gender of author

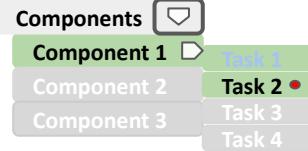
CF (implicit feedback)

Search (retrieval and re-ranking)

FairTREC 2020

Economic development of the author's country of scholarly articles

Participants provided



Challenges in Implementation



Missing Relevance Information



Missing Group Label



Extreme Imbalance

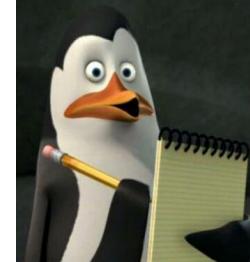
IAA, EE*, DP, EUR, RUR

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

All the metrics

PreFΔ, FAIR, IAA, DP, EUR, RUR

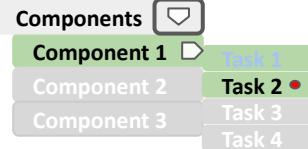
- **PreFΔ** and **RUR**: suffer from missing data (sparsity) problem
- Reformulated ratio-based metric to smoothed log ratio



Parameter Setting



Soft Group Association
Non-binary groups



Findings

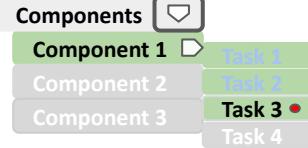
Task 1: Conceptual Analysis of Fair Ranking Metrics

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

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

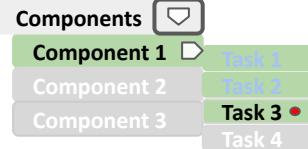
- Default parameters
- EEL and logRUR showed high sensitivity

Stopping Probability

- Almost all metrics showed sensitivity
- logRUR is extremely sensitive

Patience Parameter

- logRUR showed high sensitivity



Sensitivity Analysis

Task 1: Conceptual Analysis of Fair Ranking Metrics

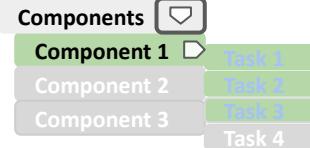
- Metrics are conceptually similar with common components like relevance, browsing model, aggregation, target exposure
- Metrics differ in their design choices and fairness assumption
- Metrics with same goal can have different design choices

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

Task 3: Sensitivity Analysis

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



Metric Recommendations



Single-list metrics
FAIR, AWRF

Demographic Parity in Sequence
DP, EED

Equal Opportunity in Sequence
EUR, RUR, IAA, EER, EEL

Allow multinomial protected attributes

AWRF

EED

EER, EEL

Allow soft group association

AWRF

EED

EER, EEL

Sensitivity towards design choices

AWRF

EED

EER, EEL, IAA



Contribution



01

Describe and compare rank-fairness metrics in unified framework

02

Identify gaps between their original presentation and the practicalities of applying them to IAS

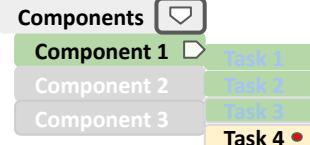


03

Direct comparison of their outcomes with same data and experimental setting

04

Sensitivity analysis to assess the impact of design choices and external factors on these metrics



Current Stage

2020

Raj, A., Wood, C., Montoly, A., & Ekstrand, M. D. (2020). Comparing fair ranking metrics. 3rd FAccTRec Workshop at RecSys 2020
arXiv:2009.01311

2022

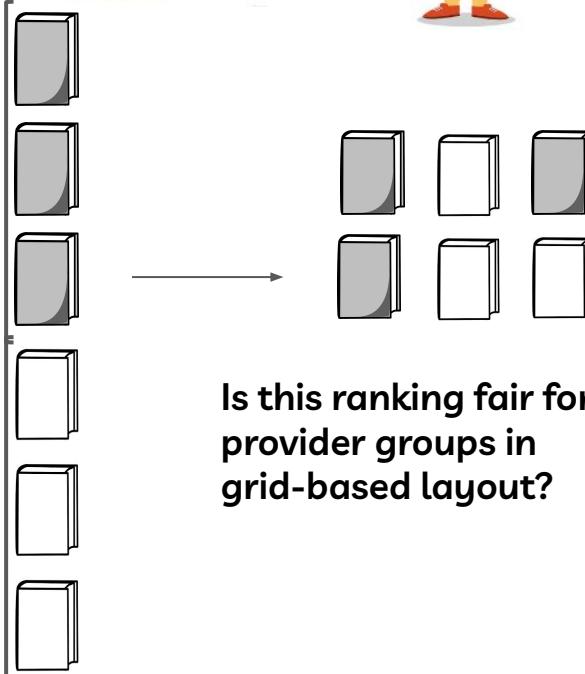
Raj, A., & Ekstrand, M. D. (2022, July). Measuring Fairness in Ranked Results: An Analytical and Empirical Comparison. In *Proceedings of the 45th International ACM SIGIR Conference on*
DOI 10.1145/3477495.3532018

Simulation Study

Better understand the impact of design factors like

- relevance-set size
- group distribution, and
- missing relevance information

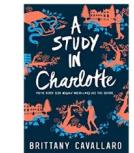
on metric implementation and outputs



Component 2

Beyond Linear Layout Fairness

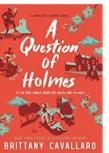
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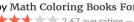
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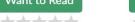


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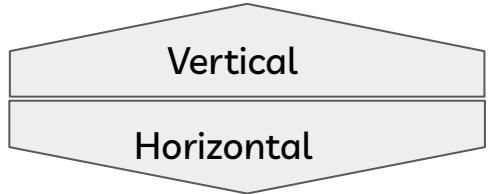
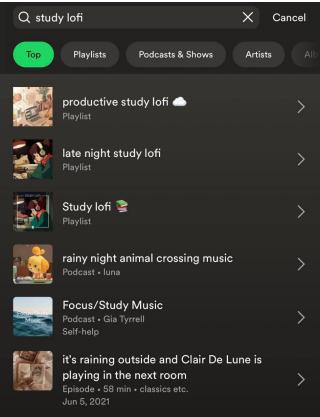
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Layout Models

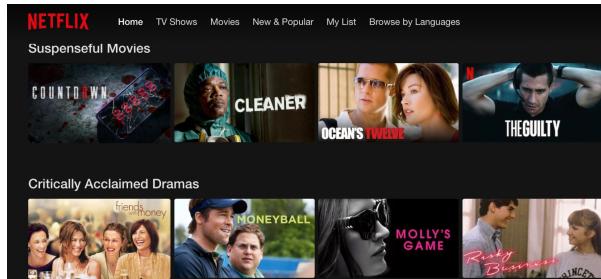
Linear Layout Model



Digital magazines you may like

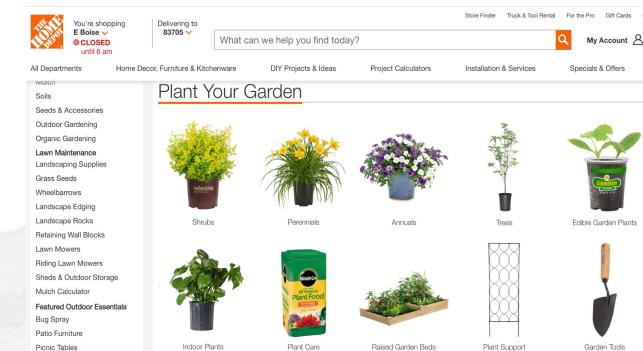


Grid Layout Model



Multi-List

Wrapped



Motivation



Metrics Only Suitable for Linear Layout

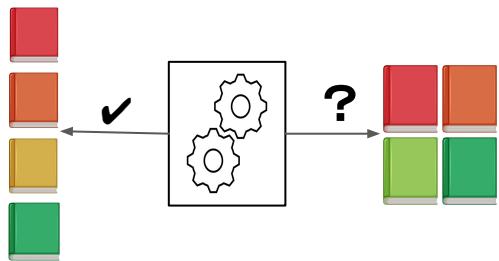
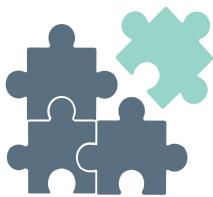


Common Use of Various Layout Models



Lack of Previous Research

Why is the Problem a Problem?



Metric Applicability?

Fairness Score Consistency
Across Layout Models?

Fairness Score Consistency
Within Layout Model?

popular 2022 movies

2022 action movies

The Lost City, PREY, THE ADAM PROJECT, MASSIVE TALENT, BULLET TRAIN

News Images Videos + Kids + Ne

2022 action movies

The Lost City, PREY, THE ADAM PROJECT

2022, 2022, 2022

Research Questions

RQ1. Does the fair ranking metric score remain consistent across layout models?

RQ2. Does a group fairness-aware ranked list remain fair across layout model?

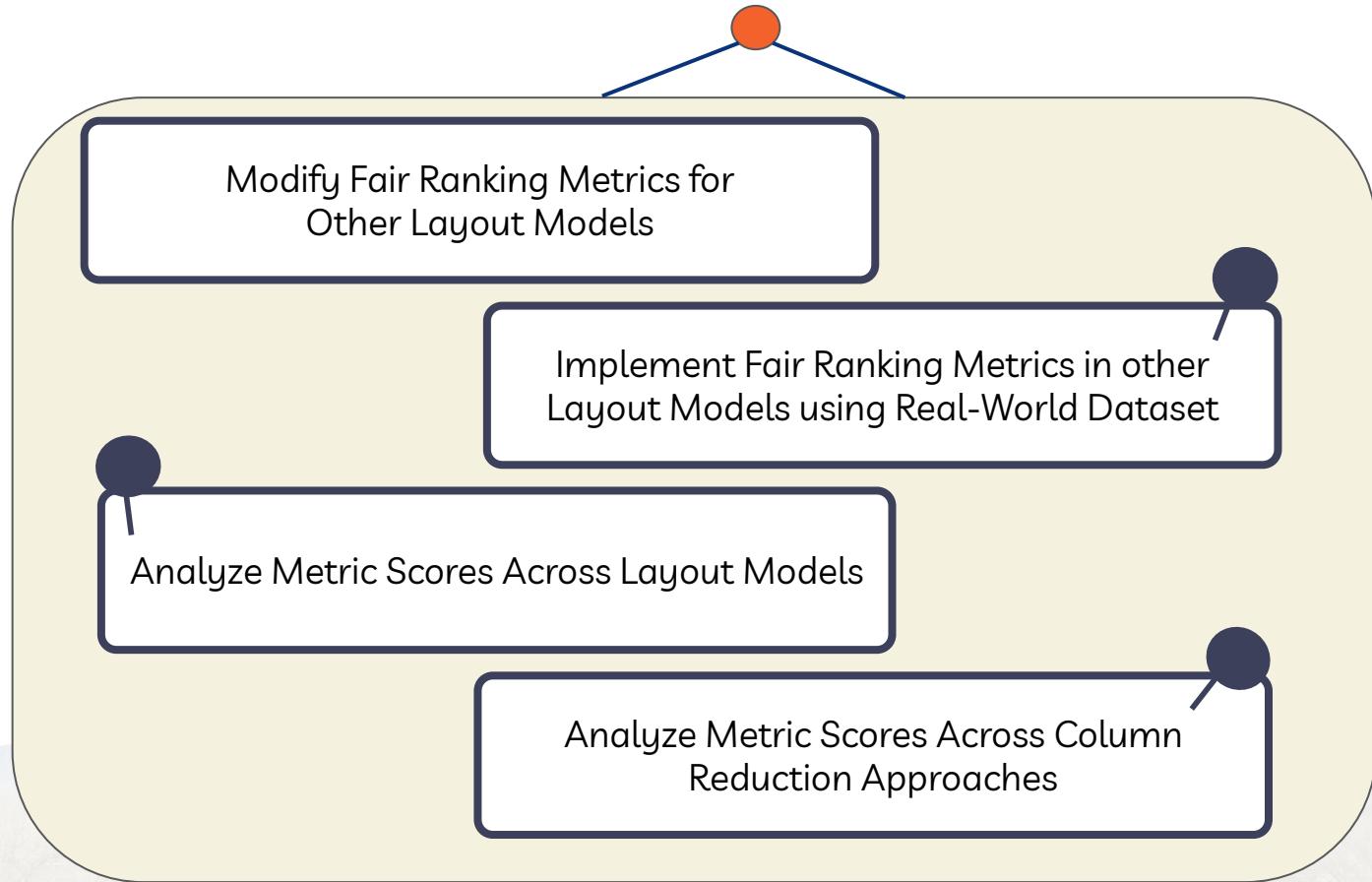
RQ3. Does the group fairness score for providers change with the reduction of ranking size within a grid-based ranking?

RQ3.a. Does the fair ranking metric score change when the grid-based list is truncated?

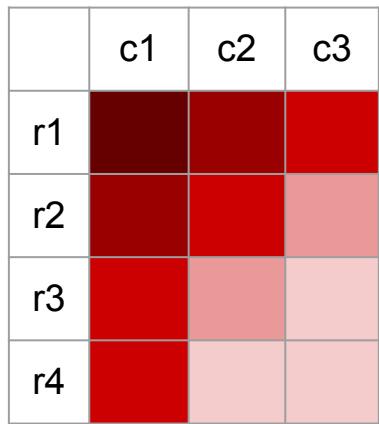
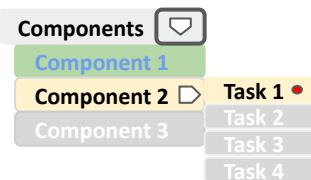
RQ3.b. Does the fair ranking metric score change when the grid-based list is re-wrapped?

RQ3.c. Does the change in group-fairness score with column size reduction remain consistent across truncation and re-wrap approach?

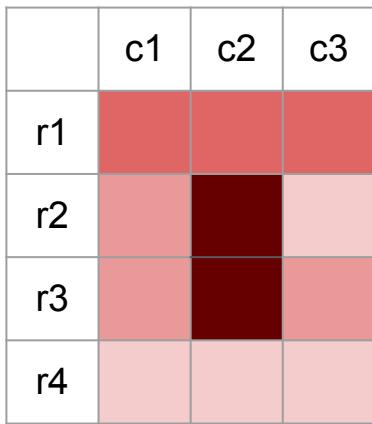
Research Tasks



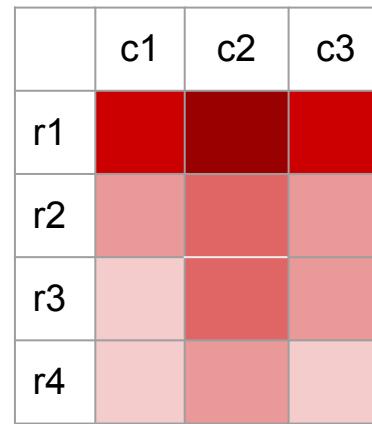
User Attention



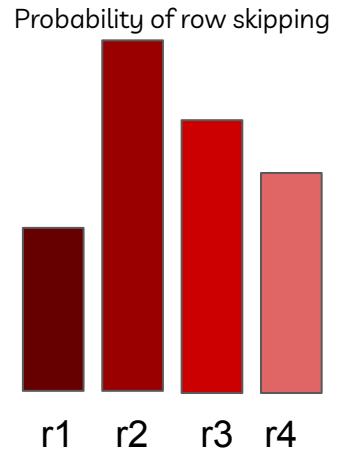
F-shaped



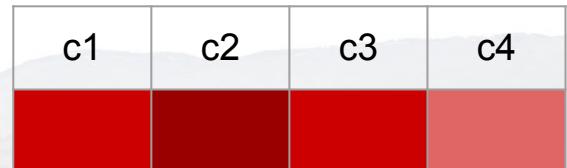
Central-Fixation



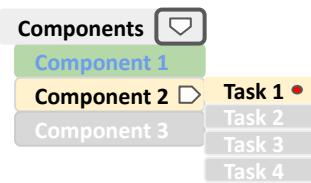
Middle-Bias



Row-Skipping



Slower-Decay

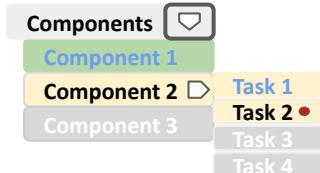


Expected Findings

Task 1: Modify Fair Ranking Metrics for Various Layout Models

- Find layout-suitable user browsing models
- Find how to modify user-browsing models for layout suitable user attention behavior

Metric Implementation



Dataset

Recommendations: GoodReads bookdata

Search: Fair Ranking Track (TREC)

Metrics

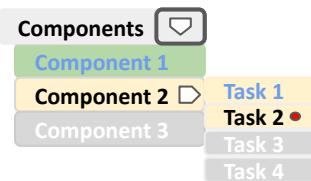
Demographic Parity: AWRF

Equal-Opportunity: Expected-Exposure Family Metrics

**Browsing
Models**

Linear: Cascade, Geometric, Logarithmic

Grid: Modified for slower-decay, row-skipping, and middle-bias



Expected Findings

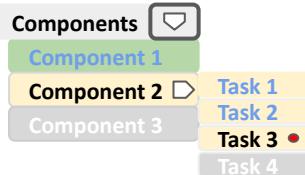
Task 1: Modify Fair Ranking Metrics for Various Layout Models

- Find suitable layout-suitable user browsing models
- Find how to modify user-browsing models for layout suitable user attention behavior

Task 2: Implementing Fair Ranking Metrics in

- Find the requirements to implement metrics in various layout models

Analyzing Metric Scores across Layout Models

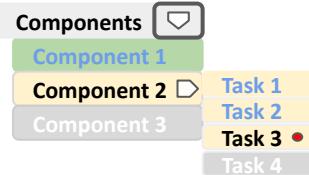


Fairness Score Consistency

1. Given a set of ranked items
2. Measure fairness of the ranking in linear list
3. Measure fairness of the ranking in grid-view
4. Compare the fairness scores

Is it Still Fair?

1. Given a set of ranked items
2. Optimize the linear ranking for fairness
3. Measure fairness of the optimized ranking in grid-view
4. Compare the fairness scores



Expected Findings

Task 1: Modify Fair Ranking Metrics for Various Layout Models

- Find suitable layout-suitable user browsing models
- Find how to modify user-browsing models for layout suitable user attention behavior

Task 2: Implementing Fair Ranking Metrics in

- Find the requirements to implement metrics in various layout models

Task 3: Analyze Metric Scores Across Layout Models

- Find the persistence of fairness score across layout models
- Find how user attention and group distribution changes across layout models
- Find if the ranking remains fair with the change of layout models

Analyzing Metric Scores within Grid-View

Components

Component 1

Component 2

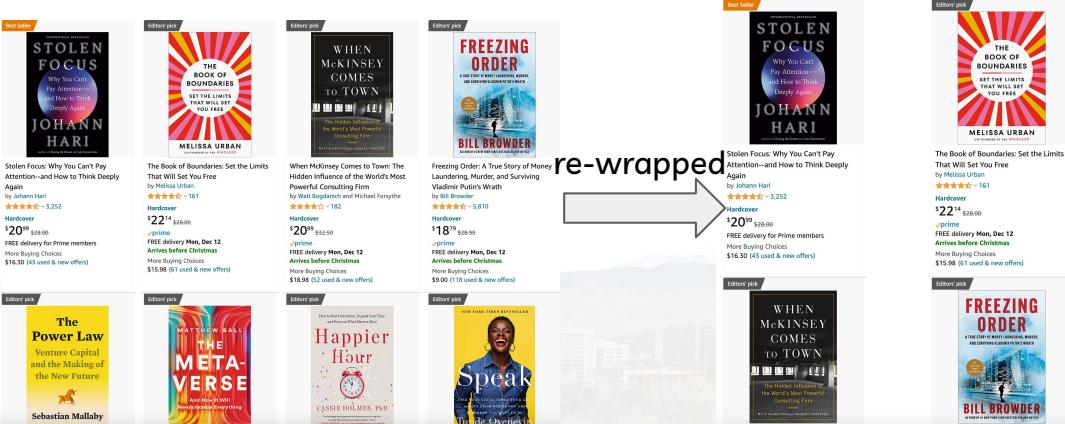
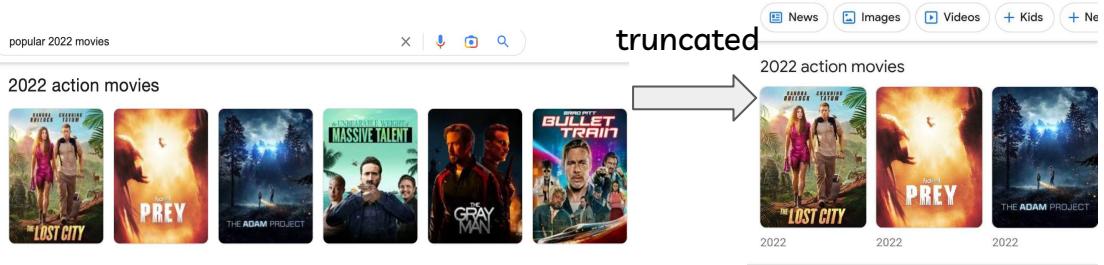
Component 3

Task 1

Task 2

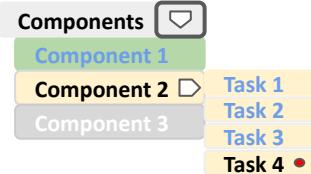
Task 3

Task 4



Fairness Score Consistency

- Given a set of ranked items
- Measure fairness of the ranking changing column size using both truncate and re-wrapped approach
- Measure fairness
- Compare the fairness scores across column reduction approaches



Expected Findings

Task 1: Modify Fair Ranking Metrics for Various Layout Models

- Find suitable layout-suitable user browsing models
- Find how to modify user-browsing models for layout suitable user attention behavior

Task 2: Implementing Fair Ranking Metrics in

- Find the requirements to implement metrics in various layout models

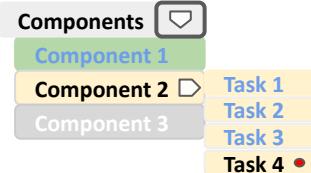
Task 3: Analyze Metric Scores Across Layout Models

- Find the persistence of fairness score across layout models
- Find how user attention and group distribution changes across layout models
- Find if the ranking remains fair with the change of layout models

Task 4: Analyze Metric Scores Across Column-Reduction Approaches

- Find the impact of column size on metrics scores
- Find how group distribution changes with reduction approaches
- Find the impact of reduction approaches on provider-side group fairness scores

Contribution



01

Provide types of ranking layout models that are often used to display search results and recommended items.

02

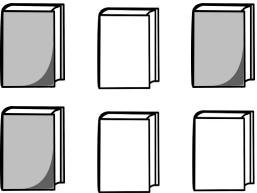
Provide modified fair ranking metrics which incorporate suitable browsing models to measure fairness in a given layout model.

03

Provide insights on fairness score consistency and applicability across layout models.

04

Provide insights on the impact of column reduction approaches on fairness score within a grid-based ranking.



How to optimize this ranking for group-fairness?

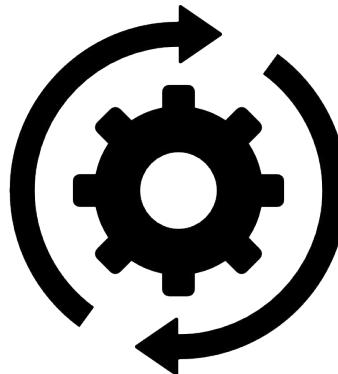
Component 3

Optimize Grid-Based Layout

Motivation



Common Use of Various Layout Models



Re-ranking Techniques Only Suitable for Linear Layout



Lack of Previous Research

Why is the Problem a Problem?



Fairness can vary across devices
(column size)



Fairness can vary
column-reduction approaches

Research Questions

RQ1. How can we design fairness aware re-ranking techniques for grid-based layouts?

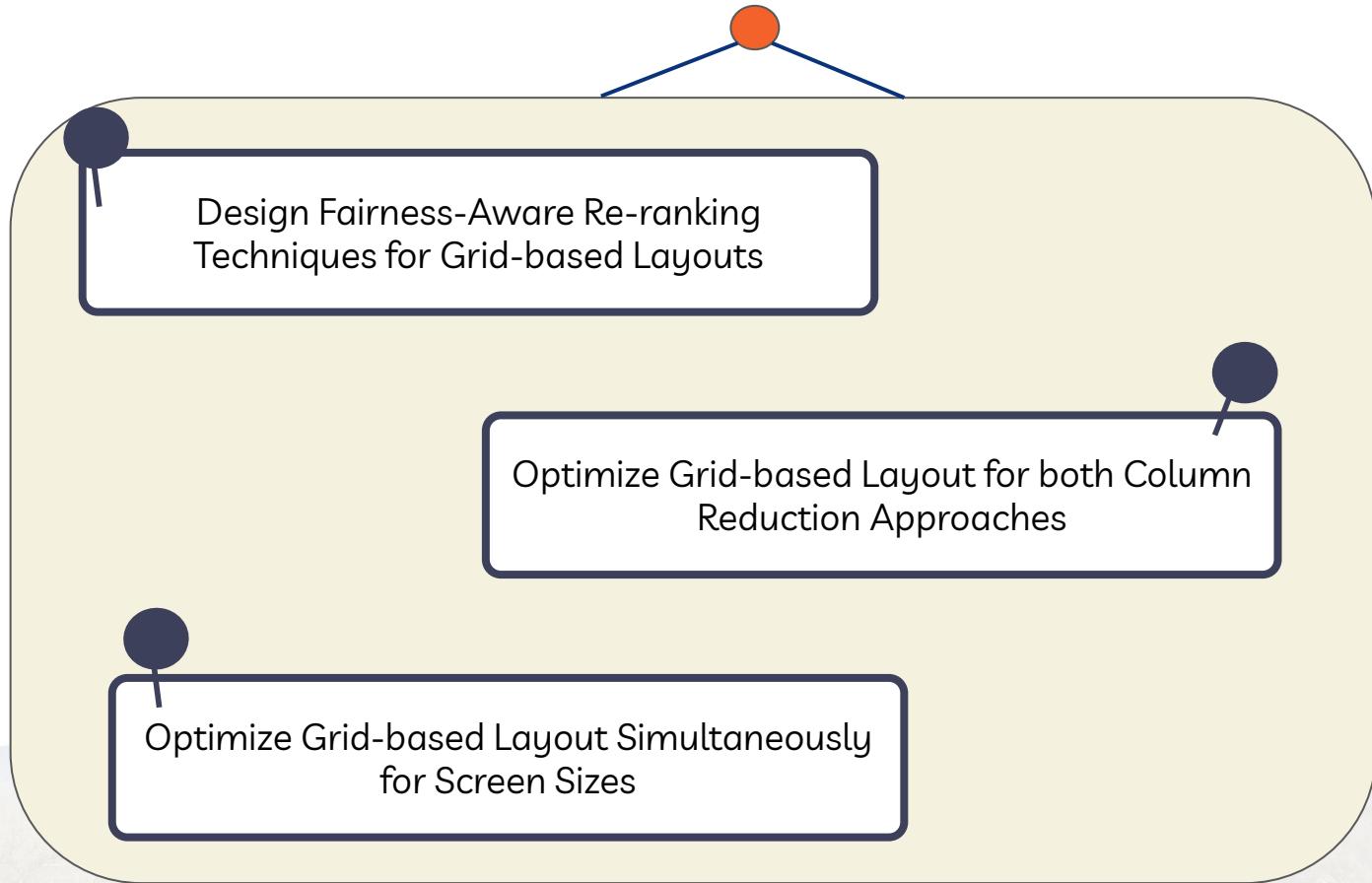
RQ2. How can we optimize grid-based ranking layout for group fairness in IAS when the size of column is being reduced?

RQ2.a. How can we optimize truncated grid-based layout for group fairness ?

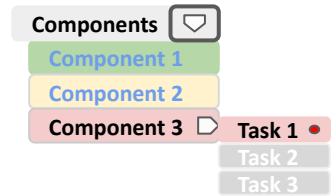
RQ2.b. How can we optimize re-wrapped grid-based layout for group fairness?

RQ2.c. How can we optimize grid-based layout simultaneously for various screen sizes?

Research Tasks



Fairness-Aware Re-ranking Techniques for Grid-based Layouts



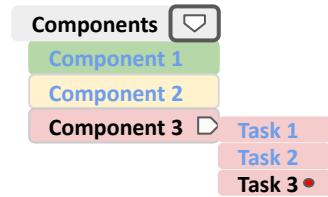
1. Component 2 will provide an insight on group exposure distribution in grid-based ranking
2. Design a simple and preliminary re-ranking technique to optimize grid-based ranking for provider-side group fairness
3. Design the technique as reusable for more suitable user attention models

Optimize Grid-based Layout for both Column Reduction Approaches



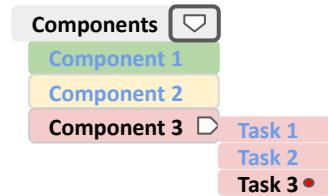
1. Component 2 will show how group fairness score changes across column-reduction approaches.
2. Design group fairness-aware re-ranking technique for truncated grid-based ranking
3. Design group fairness-aware re-ranking technique for re-wrapped grid-based ranking

Optimize Grid-based Layout Simultaneously for Screen Sizes



1. Component 2 will show how group fairness score changes across column size.
2. Design group fairness-aware re-ranking technique that will optimize grid-based ranking when device is uncertain

Expected Contribution



01

Provide preliminary and reusable re-ranking techniques for grid-based ranking

02

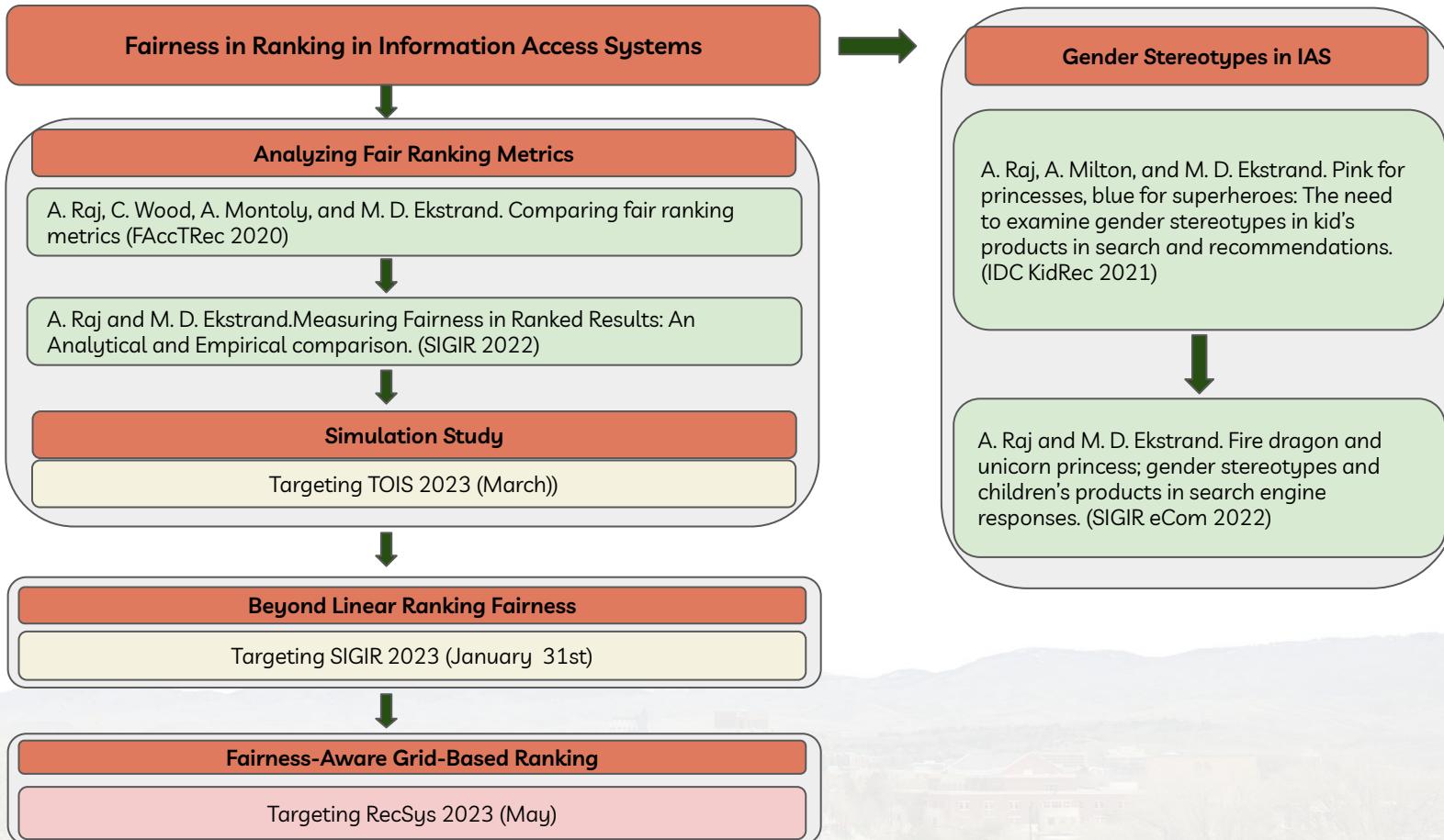
Provide insights on fairness optimization when device is uncertain

03

Provide insights on fairness optimization suitable for column reduction approaches



Publications and Target



	2018	2019			2020			2021			2022			2023	
	Fall	Spr.	Sum.												
Coursework															
Component 1															
Comprehensive Exam															
Research Publication															
Internship (Microsoft)															
Proposal Defense															
Component 2															
Component 3															
Final Defense															

Thank you



High-Level Research Question

How to improve fairness in ranking of information access systems (IAS)?