Individual Fairness in Advertising Auctions through Inverse Proportionality

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ITCS 2022

Full paper at `https://arxiv.org/abs/2003.13966`

Skewed delivery in online advertising

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MACHINE BIAS

Facebook Ads Can Still Discriminate Against Women and Older Workers, Despite a Civil Rights Settlement

New research and Facebook's own ad archive show that the company's new system to ensure diverse audiences for housing and employment ads has many of the same problems as its predecessor.

by Ava Kofman and Ariana Tobin, Dec. 13, 2019, 5 a.m. EST

Overview of ad auctions

The ad auction pipeline (simplified):

1. When a user arrives on the platform, bids are collected (either directly from the advertisers or through automated bidding).
2. The platform then runs an auction to determine which advertisement(s) to show the user.

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Common ad auction formats:

- *First price auction:* Allocate to the highest bidding advertiser and charge them their bid.
- *Second price auction:* Allocate to the highest bidding advertiser and charge them the second highest bid.

Sources of unfairness

Source 1: Advertiser targeting is unfair. (This can be audited.)

Source 2: The platform's allocation algorithm can create unfairness, even when bids are fair.

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- *Housing:* Skewed delivery in ads even when advertiser targeting parameters are inclusive. (Ali et al., 2019)

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Unfairness can arise solely from the allocation algorithm!

Our contribution: A fairness framework that eliminates unfairness introduced by the platform (building on Chawla, Ilvento, **J** '20).

Example: Skewed delivery within a category

Users: Alice and Bob
Tech advertisers: Big Tech Company and Startup

Advertiser bids are as follows:

	Big Tech Company	Startup
Alice	**1.01**	1
Bob	1	**1.01**

$\Longrightarrow$ Alice sees big tech company ad; Bob sees startup ad.

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Highest-bid-wins auction exaggerates small fluctuations in bids.

We also show that these fluctuations occur on the Yahoo ads dataset.

The model

We study advertisement auctions in the online setting.

- Universe U of users that arrive sequentially
- k advertisers that each have valuations on every user in U
  Each user has a value vector $\mathbf{v} = [v_1, v_2, \ldots, v_k]$.
- The auction allocates a single slot per user.
  Each user is assigned an allocation $[p_1, p_2, \ldots, p_k]$ s.t. $\sum_{i=1}^{k} p_i \leq 1$.

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Our contribution

We design ad auctions that do not introduce unfairness.

Our ad auctions achieve:

1. *constant fraction of social welfare compared to the unfair optimal*
2. *near-optimal tradeoffs between fairness and social welfare.*

The fairness constraint

We consider a fairness constraint expressed as a **stability condition**.

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Definition

An allocation is **value-stable** with function $f : [1, \infty] \to [0, 1]$ if the following condition is satisfied for every pair of value vectors $\mathbf{v}$ and $\mathbf{v}'$:

If $v_i \in [1/\alpha, \alpha] v_i'$ for all $i \in [k]$, then $|p_i - p_i'| \leq f(\alpha)$ for all $i \in [k]$.

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(The auction itself does not introduce any further unfairness than what may be present already in advertisers' values.)

Designing value-stable allocation algorithms

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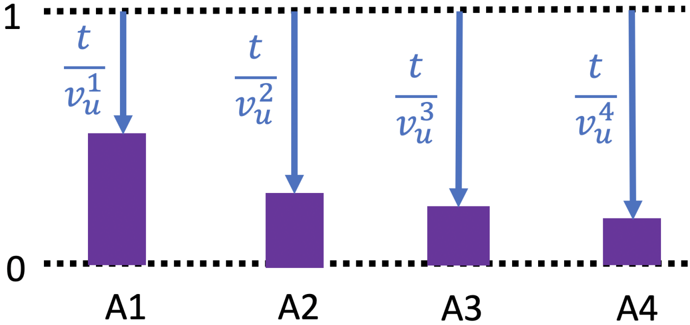
Our family of allocation algorithms is *value-stable* and achieves a *constant fraction of the social welfare* regardless of k.

Our solution: Inverse proportional allocation (IPA)

Core idea: *deduct* proportionally to the inverse of the values



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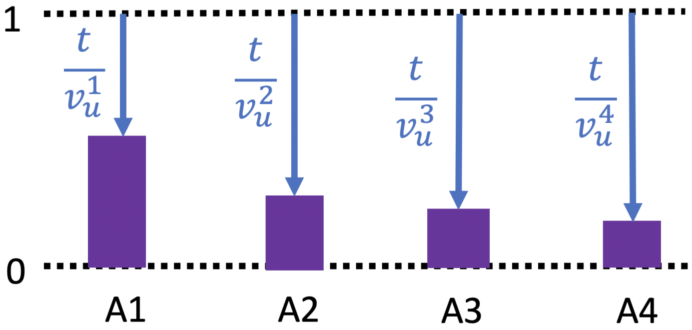

Set t so that $\sum_{i=1}^{k} \max(0, 1 - t/v_u^i) = 1$. (Can be computed efficiently.)

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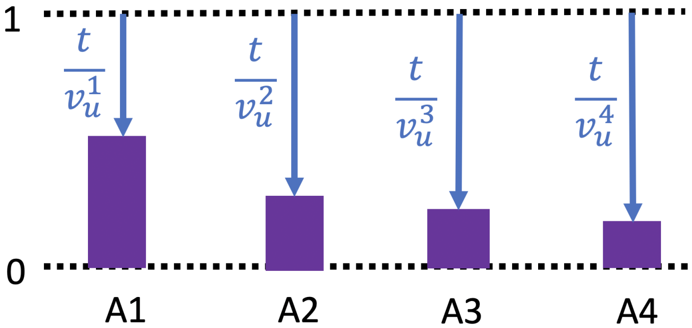

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We generalize to deducting proportionally to *functions* of the values.

Performance of inverse proportional allocation (IPA)

Achieves value-stability and high social welfare (even as $k \to \infty$):

Theorem

IPA with parameter ℓ is value-stable with $f(\lambda) = 1 - \lambda^{-2\ell}$, and achieves approximation ratio $1 - \frac{1}{\ell+1}\left(\frac{\ell}{\ell+1}\right)^{\ell}$.

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Achieves *near-optimal* tradeoffs between value-stability and social welfare:

Theorem

For any f satisfying a mild condition, there exists an IPA algorithm that is value-stable and achieves a near-optimal approximation ratio for the constraint f.

Conclusion

We considered fairness in ad auctions: designing ad auctions that don't create unfairness in the allocation.

With each category, we proposed the fairness notion of *value-stability* where if the bids are similar, then the allocations are similar.

We designed *inverse proportional allocation* algorithms that achieve:

1. a *constant fraction* of the social welfare compared to unfair optimal
2. *near-optimal tradeoffs* between fairness and social welfare.

Our results extend to *subset fairness* and *multi-category fairness*.