CS 598:
AI Methods for Market Design

Lecture 7: Advertising Markets

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Two Forms of Online Ads
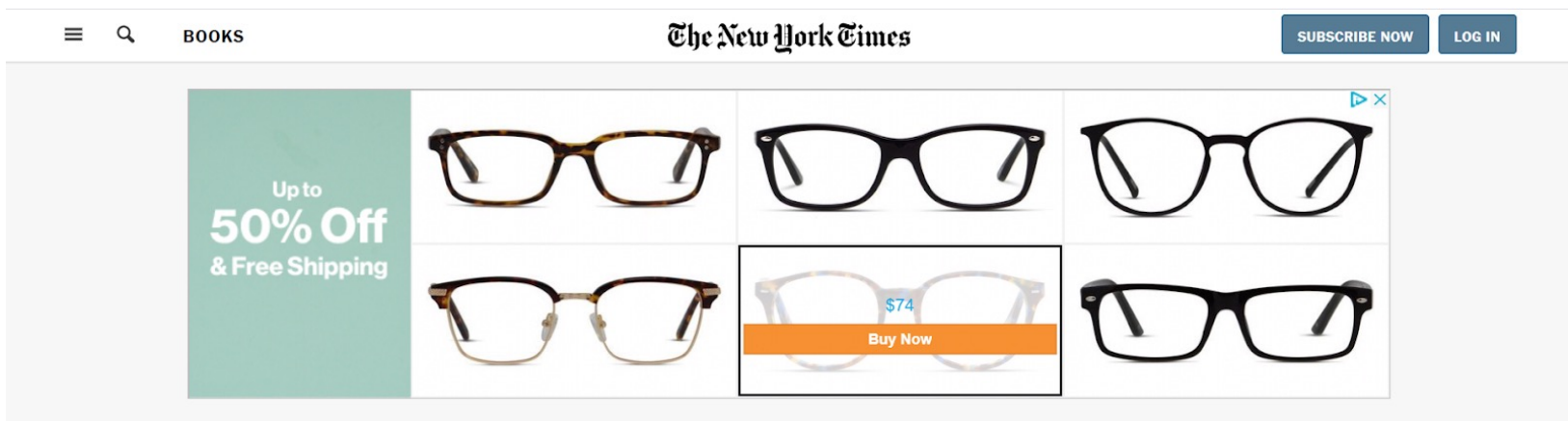
- Search advertising: sponsored search auction that sells ad space adjacent to search results

Two Forms of Online Ads

- Contextual advertising: targeting based on the content and user information

Position Auction

- The position auction assigns ads to positions and determines payments
  - M positions for N bidders / advertisers

- An advertiser i's value is associated with a user click
  - value-per-click (w_i) & bid-per-click (b_i)

- The auction models / predicts the click-through rate, i.e., the probability of clicking an ad when displayed in a particular position

Early Sponsored Search

- Rank ads by bid-per-click and use first price auction

- Can you see the problem of such design?

Modeling Click-Through Rates

- CTR_{ij}: the predicted CTR for the ad from bidder i in position j
- The separable CTR with a position effect and a quality effect

$$CTR_{ij} = \text{pos}_j \cdot Q_i$$

- The value to bidder i showing an ad in position j is

$$v_{ij} = CTR_{ij} \cdot w_i = \text{pos}_j \cdot Q_i \cdot w_i$$

- The effective bid from bidder i for showing an ad in position j

$$b_{ij} = CTR_{ij} \cdot b_i = \text{pos}_j \cdot Q_i \cdot b_i$$

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- Quick fix: rank ads by quality-adjusted bid, i.e., $Q_i \cdot b_i$

VCG Position Auction

Given bids-per-click $b = (b_1, \ldots, b_n)$ and ad quality $Q_i \in [0, 1]$ for each bidder

- Allocation rule: rank bidders in decreasing order of $Q_i \cdot b_i$ and assign positions in this order (denote z^*)

- Payment rule that charges bidder i $(i < m)$

$$t_{\text{vcg},i}(b) = \sum_{j \neq i} \hat{v}_j(z^{-i}) - \sum_{j \neq i} \hat{v}_j(z^*) = \sum_{k=[i]+1}^{m+1} (pos_{k-1} - pos_k)Q_{(k)} \cdot b_{(k)}$$

- [i]: position assigned to bidder i
- (k): the bidder assigned to position k

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VCG Position Auction

Theorem. The VCG position auction is strategy-proof and allocatively-efficient.

That is solving

$$\max_z \sum_{i \in N} pos_{z_i} \cdot Q_i \cdot b_i$$

VCG Position Auction

Example
(same quality)

z^* $\quad$ z^{-2}

$pos_1 = 0.2$ | $10 $\quad$ $10

$pos_2 = 0.18$ | $4 $\quad$ $2

$pos_3 = 0.1$ | $2 $\quad$ $1

$1
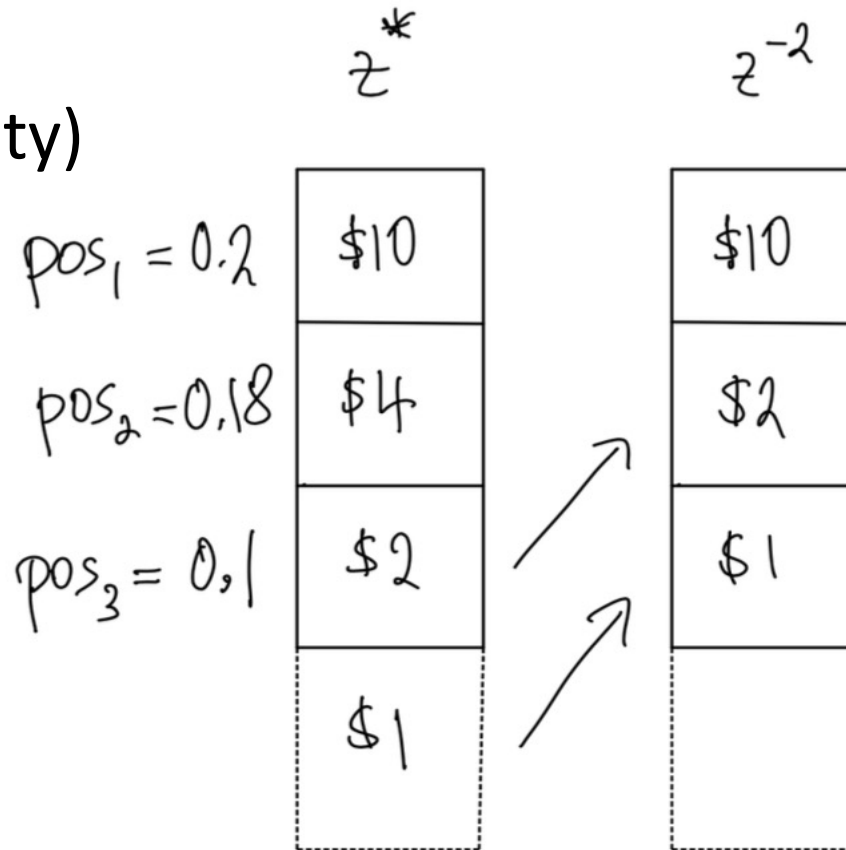
*What is the **price-per-click** for Agent 2 with $2 value-per-click?*

Generalized Second-Price Auction

Given bids-per-click $b = (b_1, \ldots, b_n)$ and ad quality $Q_i \in [0, 1]$ for each bidder

- Allocation rule: rank bidders in decreasing order of $Q_i \cdot b_i$ and assign positions in this order (denote z^*)

- Payment rule that charges bidder i $(i \leq m)$
  - All bids have same quality: $p_{\text{gsp},i}(b) = b_{([i]+1)}$
  - Bids have different quality:

  $$p_{\text{gsp},i}(b) = \frac{Q_{([i]+1)} \cdot b_{([i]+1)}}{Q_i}$$

Generalized Second-Price Auction

Example

(same quality)

$$z^*$$

$$z^{-2}$$

$pos_1 = 0.2$ | $10

$pos_2 = 0.18$ | $4 | $10

$pos_3 = 0.1$ | $2 | $2

$1 | $1
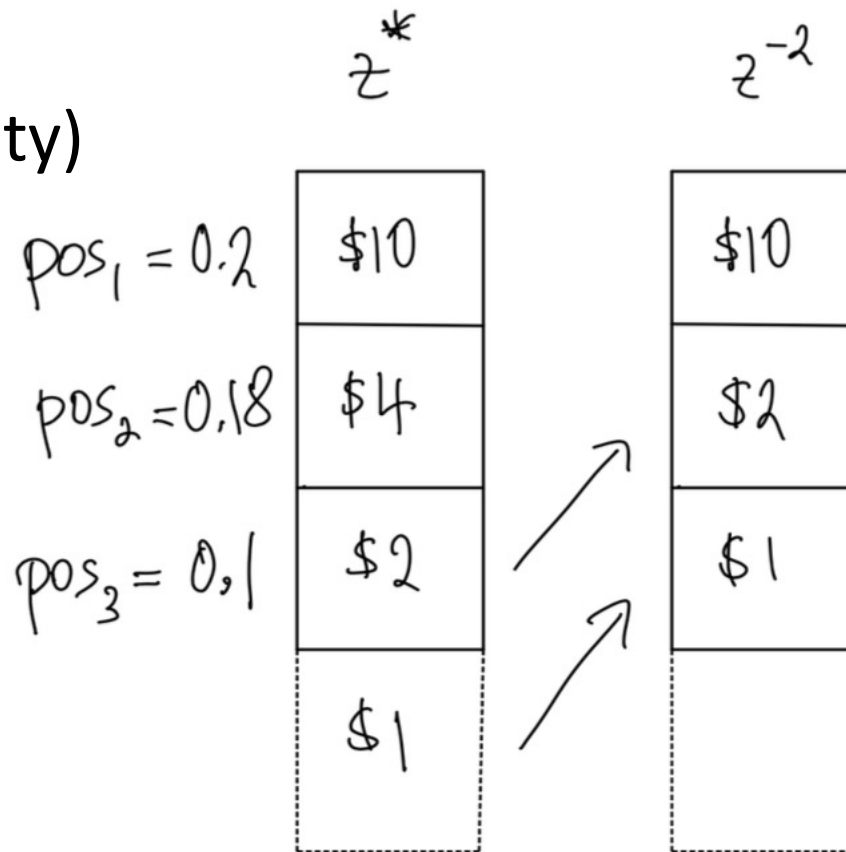
What is the price-per-click for Agent 2 with $2 value-per-click?

Comparing VCG & GSP

position	position effect	value-per-click	bid-per-click	VCG price	GSP price
1	0.2	10	10	17/10	4
2	0.18	4	4	13/9	2
3	0.1	2	2	1	1
–	0	1	1	0	0

- GSP charges more than VCG

- VCG: a bid has the effect of moving every lower-ranked bid down by one position

- GSP: a bid prevents the next highest bid from getting any click, but has no effect on other bids

Generalized Second-Price Auction

Theorem: The GSP auction is not strategy-proof

$$z^*$$

$pos_1 = 0.2$ — $\$10$

$pos_2 = 0.18$ — $\$4$

$pos_3 = 0.1$ — $\$2$

$\$1$
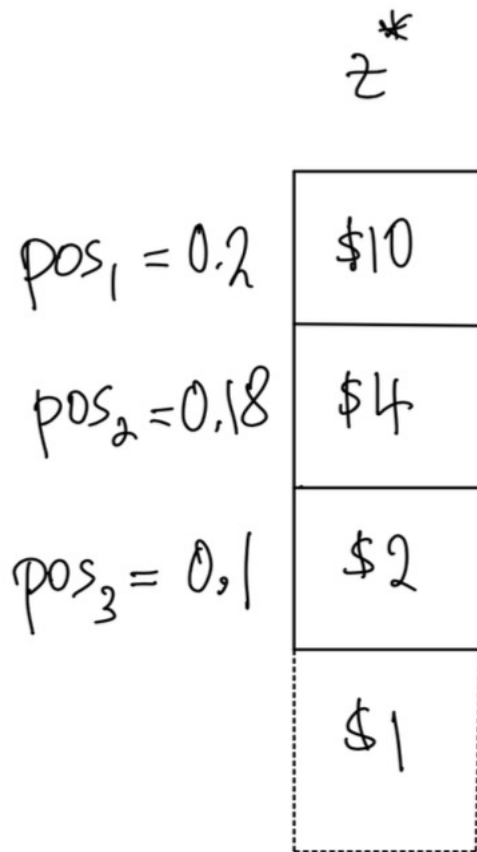
What would be a beneficial deviation for Agent 1?

- Truthful utility by bidding $10:
  $$0.2*(10-4) = 1.2$$

- Utility by bidding $3:
  $$0.18*(10-2) = 1.44$$

Auction Designs for Online Ads (2022)

	Non real-time	**Real-time (programmatic)**

Sponsored search	○ Google search and Microsoft Bing
	    GSP (was first price)
	○ Yandex
	    VCG (was GSP)
		n/a

Contextual	*Own inventory*
	○ Twitter and Facebook feeds
	    VCG
	
	3rd-party inventory (ad networks)
	○ Google AdSense
	    FPSB (was VCG, earlier GSP)
	○ FB Audience Network
	    FPSB
		3rd-party inventory (ad exchanges)
		○ Microsoft Xandr,
		    Twitter,
		    AppLovin, and
		    Google Marketing Platform
		    FPSB (some were SPSB)

Privacy and Fairness Considerations

- An ad may reveal something private

- Ads may be unfairly targeted

- An advertiser or the platform may learn sensitive info from a click on targeted ads

Regulatory Actions

Fair Information Practice Principles (FIPPs) in the U.S. in 1973

- Notice: no secret collection of data

- Choice: prevent information that is gathered for one use being used for another

- Access: inspect, review, and amend data about themselves

- Security: data is stored securely

- Redress: firms are responsible for damages when information is misused

Regulatory Actions

General Data Protection Regulation (GDPR) by EU in 2018

- Delete: request that personal data be erased when no longer needed

- Data portability: receive personal data in machine-readable format and send it to another company

- Algorithmic accountability: request that significant decisions based on personal data are not made solely by computers

Announcements

- Three paper presentations today! None next week
    - Get ready with peer evaluation form

- HW1 is due next Monday! If work in pairs, both students should submit their (same) writeup

- Discuss final project guidelines. Feel free to discuss your idea with me during office hour

- Class survey instead of pre-class CQ for next week