

CS 598:  
AI Methods for Market Design  
Lecture 7: Advertising Markets

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# Two Forms of Online Ads

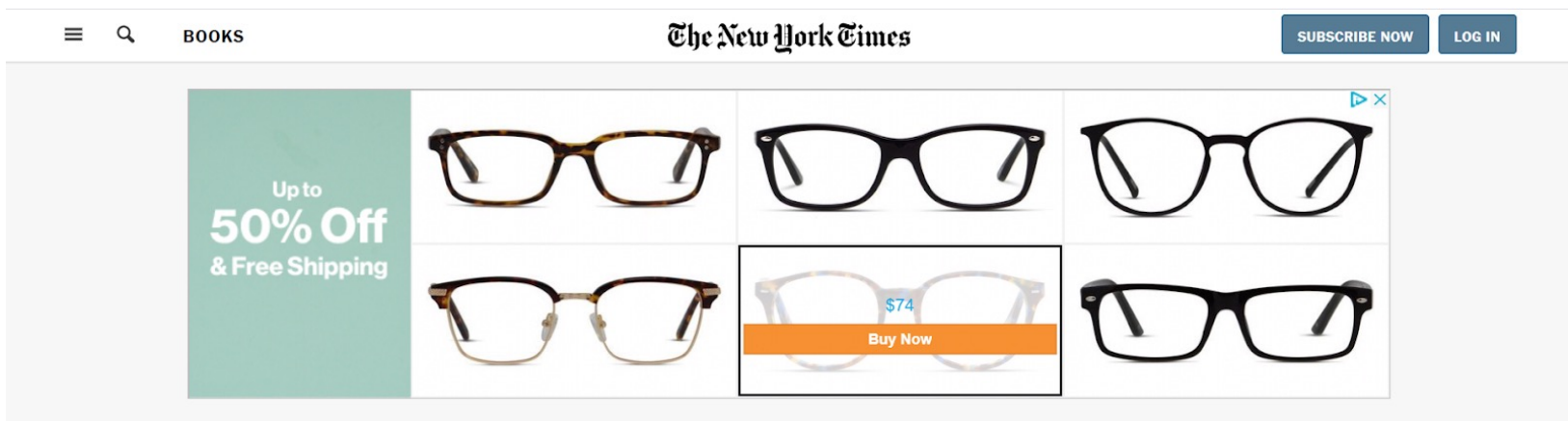
- Search advertising: **sponsored search auction** that sells ad space adjacent to search results

The screenshot shows a Google search for "flowers" with the following elements:

- Search Bar:** "flowers" with a search icon and a microphone icon.
- Filters:** Images, Shopping, Perspectives, Videos, Drawing, Photos, Types, Near me, 1800.
- Results:** About 6,440,000,000 results (0.54 seconds).
- Location:** Results for Piscataway, NJ. Use precise location.
- Sponsored Section:**
  - 1-800-Flowers:** <https://www.1800flowers.com>. Rating: 4.2 - 69 reviews.
  - Same Day Flower Delivery:** 1800FLOWERS® Official Site – 1800FLOWERS® Celebration Passport. Great Gifts, Exclusive Perks And Free Standard Shipping. Free Shipping With The Celebration Passport From 1800FLOWERS®. Gift More, Gift Better.
  - New Arrivals:** The Latest Bouquets & Styles. Shop 1800Flowers!
  - Football Gifts & Flowers:** Shop Unique Presents & Bouquets For All the Fans in Your Life!
  - Join Passport Today:** Free Shipping & No Service Fees in Our Family of Brands. Join Today!
- Sponsored Search Results (Grid):**
  - Flower Delivery -...:** \$19.99. FromYouFlo...
  - Two Dozen Red Roses...:** \$44.99. 1800Flower...
  - Flowers - Same Day...:** \$19.99. FromYouFlo...
  - Elegant Blush Bouquet Extr...:** \$67.99. 1800Flower...
  - One of a Kind Bouquet |...:** \$39.99. 1800Flower...
  - Send Pink & White Roses...:** \$35.99. FromYouFlo...

# Two Forms of Online Ads

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

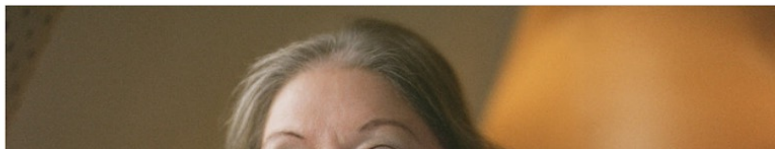


The screenshot shows the top navigation bar of The New York Times website. On the left, there is a menu icon, a search icon, and the word "BOOKS". In the center, the "The New York Times" logo is displayed. On the right, there are two buttons: "SUBSCRIBE NOW" and "LOG IN". Below the navigation bar is a large advertisement for glasses. The ad features a green sidebar on the left with the text "Up to 50% Off & Free Shipping". The main area of the ad is a grid of six pairs of glasses. The bottom-middle pair of glasses is highlighted with a white border and an orange "Buy Now" button. A price tag of "\$74" is visible above this pair. A small "x" icon is in the top right corner of the ad.

## ARTS

# Books

BOOK REVIEW | BEST SELLERS | BY THE BOOK | CRIME | CHILDREN'S BOOKS | BOOK REVIEW PODCAST | NOW READ THIS | GLOBETROTTING



BOOKS OF THE TIMES

A Survivor Recalls the Charlie Hebdo Massacre and a Long Road to Recovery

# 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  $j$

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

# Modeling Click-Through Rates

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

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

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

# VCG Position Auction

Given bids-per-click  $b = (b_1, \dots, b_n)$  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  $i$  ( $i < m$ )

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

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



# VCG Position Auction

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

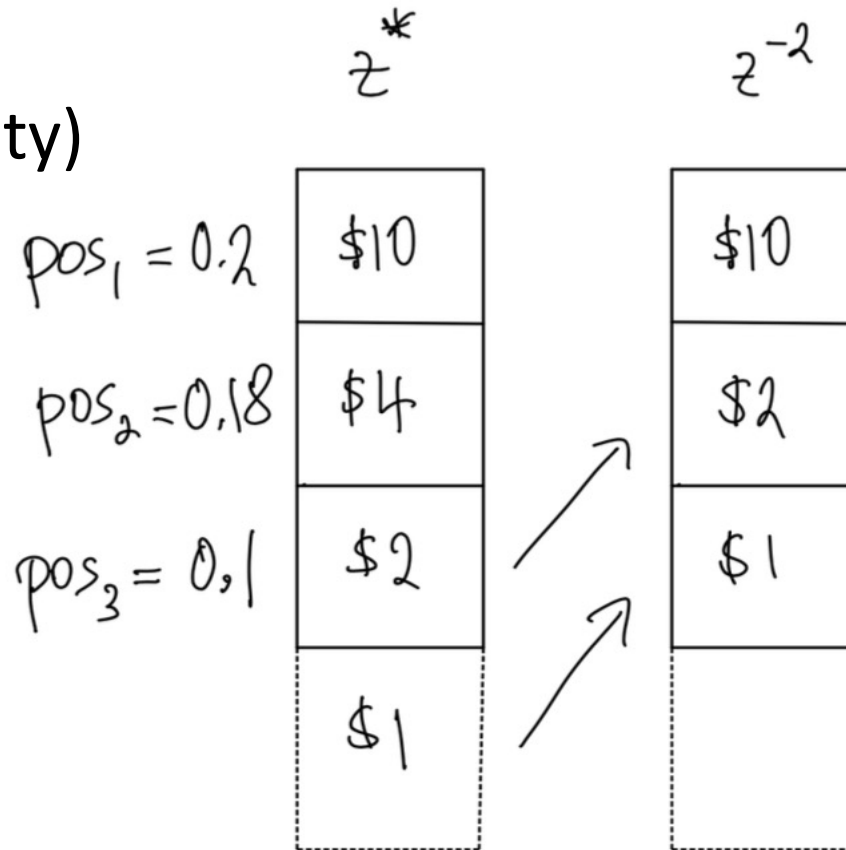
That is solving

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

# VCG Position Auction

Example

(same quality)



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

# Generalized Second-Price Auction

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

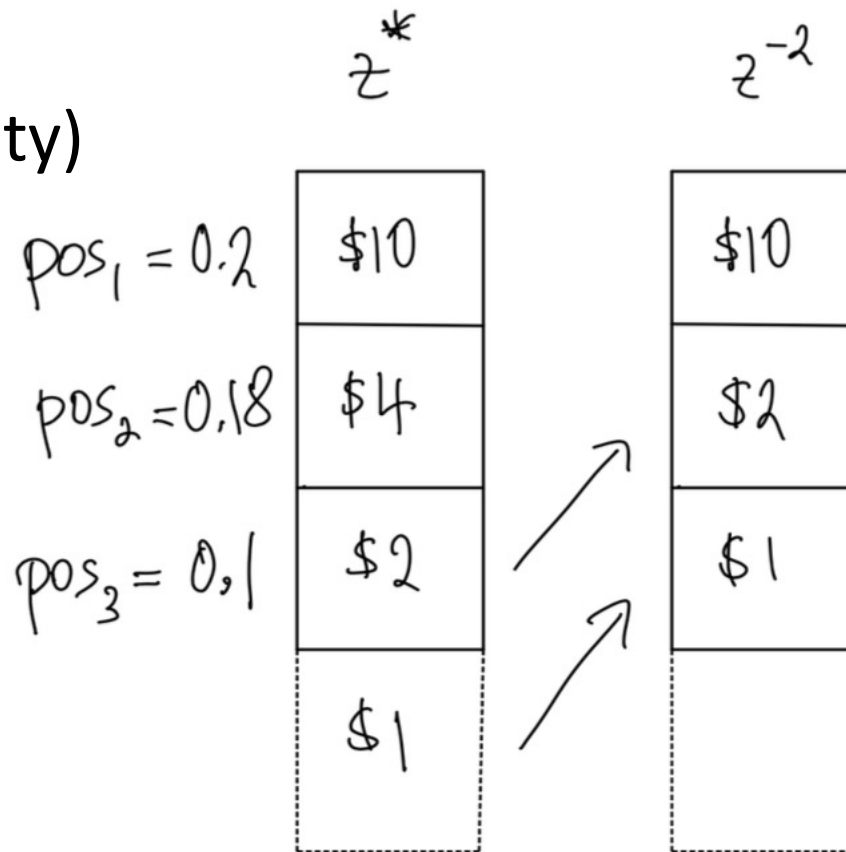
- Allocation rule: rank bidders in decreasing order of  $Q_i \cdot b_i$  and assign positions in this order (denote  $z^*$ )
- Payment rule that charges bidder  $i$  ( $i \leq m$ )
  - All bids have same quality:  $p_{\text{gsp},i}(b) = b_{([i]+1)}$
  - Bids have different quality:

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

# Generalized Second-Price Auction

Example

(same quality)



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

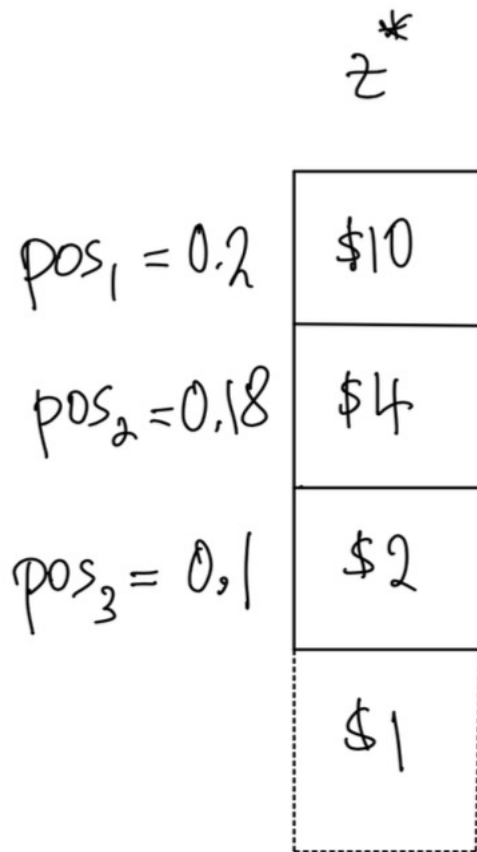
# Comparing VCG & GSP

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



*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)
<b>Sponsored search</b>	<ul style="list-style-type: none"> <li>○ Google search and Microsoft Bing <b>GSP</b> (was first price)</li> <li>○ Yandex <b>VCG</b> (was GSP)</li> </ul>	n/a
<b>Contextual</b>	<p><i>Own inventory</i></p> <ul style="list-style-type: none"> <li>○ Twitter and Facebook feeds <b>VCG</b></li> </ul> <p><i>3rd-party inventory (ad networks)</i></p> <ul style="list-style-type: none"> <li>○ Google AdSense <b>FPSB</b> (was VCG, earlier GSP)</li> <li>○ FB Audience Network <b>FPSB</b></li> </ul>	<p><i>3rd-party inventory (ad exchanges)</i></p> <ul style="list-style-type: none"> <li>○ Microsoft Xandr, Twitter, AppLovin, and Google Marketing Platform <b>FPSB</b> (some were SPSB)</li> </ul>

# 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