AdX Final Project

CSCI 1440 TAs

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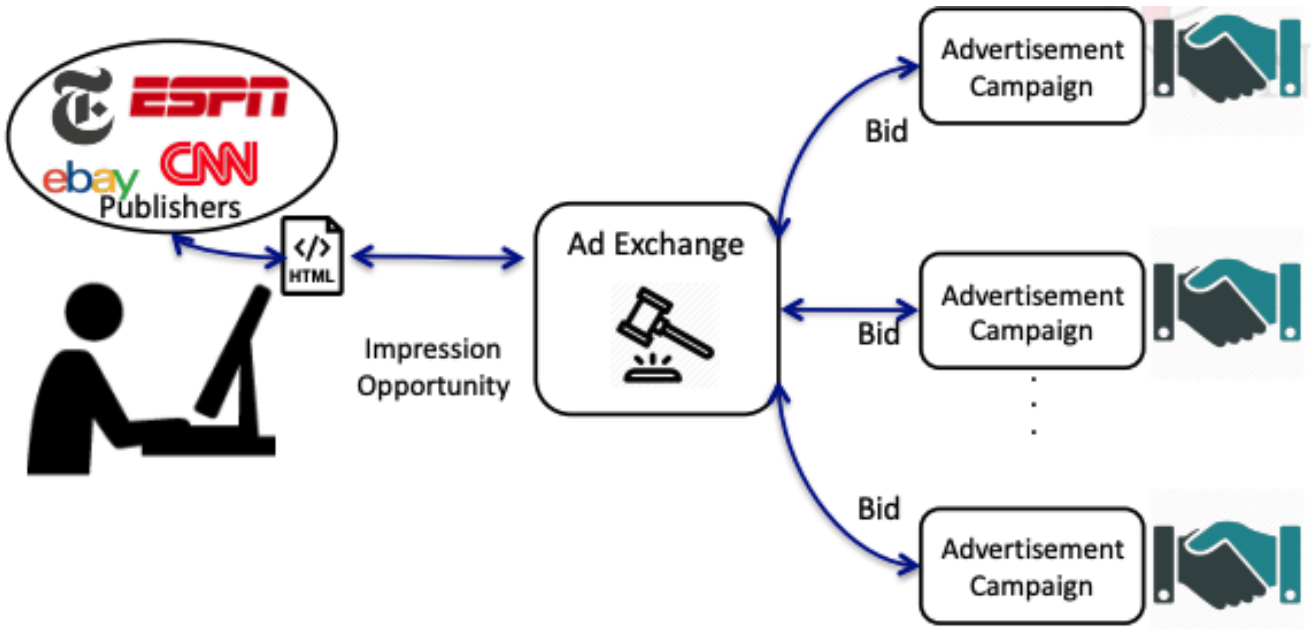
The Role of Ad Exchanges

- Online advertising connects two sides:
  - **Publishers:** websites like ESPN and CNN that sell ad space
  - **Advertisers:** companies seeking to display targeted ads to users
- Ad Exchanges automate this large-scale matching process
- They run real-time auctions to show users ad impressions



Advertising Ecosystems at a High Level

1. **Advertisers:** seek to advertise their products to users
2. **Publishers:** make ad space available on their digital content pages
3. **Supply-side Platform (SSP):** when a user visits a publisher's site, an SSP sends details about the impression (user, page content, etc.) to an ad exchange
4. **Demand-side Platform (DSP):** A DSP, representing an advertiser, evaluates the impression, estimates Pr(click), Pr(conversion), etc., and then bids on behalf of the advertiser
5. **Ad Exchange:** runs a real-time auction among DSPs, and the winning bidder's ad is shown. All within milliseconds!

6. In AdX, you will build an agent that acts as a Demand-Side Platform, bidding to fulfill advertising campaigns for advertisers you represent

The Google Ecosystem

- DoubleClick, acquired by Google in 2007 for $3.1B, evolved into AdSense. AdSense plays the role of an SSP in the Google ecosystem.
- Google Ads (AdWords) plays the role of a DSP in this ecosystem.
- Google acts as the middleman, playing the role of the ad exchange, enabling automated real-time trading of ad impressions among its publishers (Search, YouTube, etc.) and advertisers.

The Google Ecosystem (cont'd)

- A user visits a blog that uses AdSense
- AdSense requests an ad for this impression
- Google Ads (and others) compete in a real-time auction
- The highest bidder's ad wins the impression
- The advertiser pays Google
- Google pays the publisher, after taking a cut

- In 2024, Google's revenue was about $350 billion.
  - about $199 billion was generated by Google Ads (and other sources)
  - about $30 billion was generated by AdSense

  Source: The Visual Capitalist

AdX Game

- Each agent functions as an ad network, competing to
  - Win advertising campaigns
  - Fulfill those campaigns by winning user impressions
- Two linked auction formats
  - **Campaign Auction (Second-Price Reverse Auction)**
    Compete for advertising contracts
    At the start of each "day"
  - **Ad Auction (Second-Price Auction)**
    Bid for user impressions that match campaign targets
    All throughout the rest of each "day"
- Goal: maximize total profit over the 10-day simulation

Advertising Campaigns and Users

- An agent's primary task: bid for and fulfill advertising campaigns
- Each day, a random number of Internet users appear, drawn from 26 market segments, which are combinations of

$$\{\text{Male, Female}\} \times \{\text{HighIncome, LowIncome}\} \times \{\text{Old, Young}\}$$

- Each advertising campaign is defined by:
  - **Market segment:** The targeted demographic(s)
  - **Reach:** Number of impressions to deliver
  - **Budget:** Payout if the campaign is fulfilled
  - **Start and end day:** Active period (inclusive)
- Example: [Market Segment = `Female_Old`, Reach = 500, Budget = \$40, Start = 4, End = 6]
- The campaign auctions your agent wins determine the user impressions it should pursue

Ad Auctions: Impression Opportunities

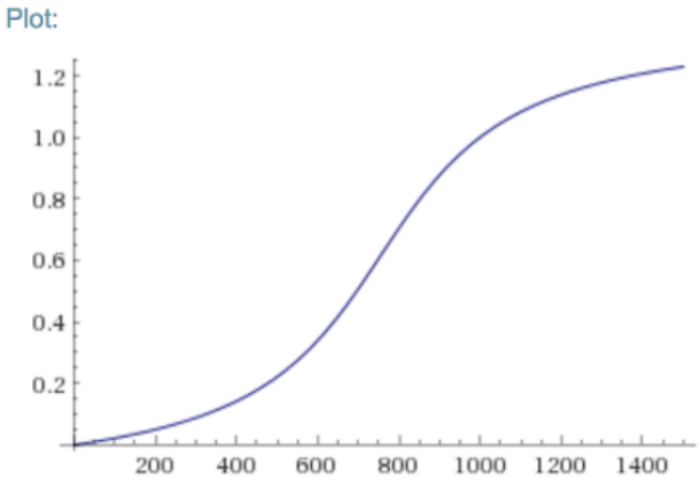
- Each user visit triggers a second-price sealed-bid auction for an impression
- The highest bidder wins the impression, and pays the second-highest price
- Impressions only count toward campaigns if the user matches that campaign's target segment
- Agents bid once per "day," in the "morning," i.e., setting their strategy *before* user arrivals

Bids and Spending Limits

- Agents must decide
  - How much to bid for each market segment
  - Spending limits per market segment
  - Spending limits per campaign
- Spending limits cap how much can be spent
  - On a specific market segment, and/or
  - Across all segments in a campaign
- Example: An agent with a `Female` campaign can set different bids and spending limits for `Female_Old` and `Female_Young`, and for the `Female` campaign overall

Effective Reach and Profit

Effective reach function ($R = 1000$). Middle impressions contribute most.



- Effective reach $\rho(R)$ measures how near to completion a campaign is
- $\rho(0) = 0$, $\rho(R) = 1$, $\lim_{x \to \infty} \rho(C) = 1.38442$
- **Profit:** $\Pi = \rho(C) \cdot$ Budget $-$ Cost
- Key Observation: Nearly completing campaigns yields much higher marginal returns than barely completing them

Quality Score

- The quality score reflects the agent's past performance
- Updated daily, using the average effective reach $\bar{\rho}$ of all campaigns that end on that day: $Q_{\text{after}} = (1 - \alpha)Q_{\text{before}} + \alpha\bar{\rho}$, with $\alpha = 0.5$
- Higher average effective reach $\rightarrow$ higher Q $\rightarrow$ better reputation

- Q is used to determine an **effective bid** in campaign auctions:

$$\text{Effective Bid} = \frac{\text{Raw Bid}}{Q}$$

- A higher Q makes the same bid appear lower, increasing the chances of winning campaigns (since campaigns are sold in reverse auctions)

Campaign Auctions: Reverse Auction Structure

- Each day, multiple campaigns are listed for auction.
  Market segment, reach, and start & end days are given.
  Budget is determined endogenously.
- Auctions are second-price reverse auctions
  - The lowest effective bid wins
  - The winner's payment is set to the second-lowest effective bid
  - The campaign's budget is the second-lowest effective bid times the winner's quality score
- Bids must lie within $[0.1R, R]$, where R is the campaign's reach

AdX Game Summary

- The AdX game runs for 10 simulated days
- Each day:
  1. New campaigns are auctioned
  2. Agents bid for campaigns and users
  3. Impressions are allocated and costs are calculated
  4. Profits and quality scores are updated
- The agent with the highest total profit wins