Some game theoretic and algorithmic issues in online advertising

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“Half the money I spend on advertising is wasted – I just don’t know which half”

John Wanamaker
Online Advertising

- Multi-billion dollar industry and growing rapidly.
- One of the primary forms:
  - **Sponsored search advertising**: Advertisers bid to have their ads shown alongside search results in response to a searcher’s query.
Appeal to Advertisers

- Highly targeted
- Only pay when ad is clicked on
- Control how much spend
- Can (or might eventually be able to) take into account demographics, geography, behavior, timing, etc. (a little bit scary)
**Sponsored Search Advertising**

Advertisers

Values

- $0.4
- $1.3
- $1.0
- $0.4
- $0.7
- $0.5
- $1.1
- $0.2
- $0.5

Bids

- $0.7
- $0.5
- $1.3
- $1.0
- $0.7
- $0.5
- $1.1
- $0.2
- $0.5
The players and their goals

- The searcher
  - Get high quality search results

- Advertiser(s)
  - Get conversions at minimum cost

- The search engine:
  - Make money: charge a lot per click \( \Rightarrow \) want high, click-through, want ads to convert.
  - Provide useful search results

- Fates of the search engine, the advertisers and the users are intertwined!
Game Theory

- **Game**: players, rules, strategies, payoff functions
- Given a set of players, each with a set of strategies, each motivated by self-interest, what constitutes rational behavior?
- Fundamental concepts are various equilibria
  - **Dominant strategies**: each player has a well-defined best strategy no matter what any of the other players do.
  - **Nash equilibria**: given strategies by all the players, no player has an incentive to deviate.
Mechanism Design

- Also called inverse game theory
- Given desired goals, such as maximizing profit or social welfare, design the game in such a clever way, that individual, rational players, motivated solely by self interest, will end up achieving the designer’s goals.

- This year’s Nobel prize in economics went to 3 people who did pioneering work in this area.

- Example: Vickrey Auction
Talk Outline

- Some answers and questions about the design of keyword auctions
- Algorithmic/game theoretic problem involved in allocation of advertisers to auctions
- Contextual targeted advertising
- Other research directions
What does mech design have to say about keyword auction design?

- To talk about it need a utility model
- Most common model:
  - Each player has an expected value for each click.
  - Player’s utility for a particular allocation/pricing = (expected value for click - price per click) Pr(click).
- From microeconomics literature:
  - VCG mechanism [Vickrey-Clarke-Groves]
    - Maximize social welfare
      - Truthful, which greatly simplifies life for bidders
The mechanism used in practice (mostly)

- **GSP** (generalized second price):
  - Rank by revenue: rank bidders by $b(i)r(i)$, where $b(i)$ is the bid of advertiser $i$ and $r(i)$ is the relevance or quality of advertiser $i$
  - $r(i) = \Pr$ (bidder $i$ will get clicked on)

- Bidder in slot $i$ gets charged $b(i+1)r(i+1)/r(i)$ per click.
- $p(i) = b(i+1)r(i+1)/r(i)$ how much bidder $i$ can lower bid and still retain slot $p(i)r(i) = b(i+1)r(i+1)$
We have a reasonable understanding of equilibria of GSP.

- Not truthful \( \Rightarrow \) bidders need to work hard
- Continuum of equilibria
- Has as one of its Nash equilibria an allocation that maximizes social welfare and prices that match those of VCG mechanism (and this equilibrium gets the lowest revenue for the search engine among all the equilibria of GSP \( \Rightarrow \) nice for bidders). [Varian][EOS]...

- Reminder: A set of bids is a Nash equilibrium if each advertiser’s bid is a best response to bids of other advertisers.
How to get there?

- It’s one thing to understand equilibria, quite another to get there.
- Continuous stream of auctions: hundreds of thousands of advertisers competing for positions alongside several million queries each day.
- Auctions are continuous and dynamic - advertisers can update bids at any time (and often use software robots to do this); new auction clears each time user issues a search query

- How should advertisers update their bids, especially if they’d like to reach that desirable equilibrium? (subject of next talk in session by Yiannis Giotis)
Some of the problems we are currently working on

- Are there better mechanisms? Alternative models? Richer bidding languages?
  - Take into account externalities
  - Charge for both impressions and clicks?
Participation

- Advertisers choose a set of keywords and submit a daily or monthly budget, and a bid for each of their keywords.
- Continuous stream of auctions. Search engines get to choose which advertisers participate in each auction.
- Their goal: get them to use up their budgets.

Example:

Type A Bidders
Budget $1000, bid $1.01 on both keywords K and K'

Type B Bidders
Budget $1000, bid $1 only on keyword K'
Participation

- Optimization problem: as searches happen, given advertisers bids and budgets, choose which advertisers should participate.
- Offline, can be solved optimally.
- Online, there is an algorithm that provably always gets 1 - 1/e of the optimal revenue, even in worst-case. [MSVV][BJN]
- [Mahdian, Nazerzadeh, Saberi] - tradeoff between worst case and best you can do using estimates.
- No understanding once incorporate game theoretic considerations

- Interesting to note that Google takes ~ 73% of its advertisers budgets.
Contextual Targeted Advertising

- Example: Google’s AdSense.
  - Web publishers allow relevant ads to appear on their web sites. Web publisher shares ad revenue.
Appeal to Advertisers

MySpace - Mozilla Firefox

Appeal to Advertisers

MySpace Specials

Strike a Pose Contest
delivered by AT&T

Think you've got the Ford Models look? Pick your best MySpace photo and enter now for a chance to win!
Find out more here. Check it out!

Sponsored Links

Who Has a Crush on You?
Calculate their exact name now. It's scary how accurate this is!
WhoHasACrushOnYou.com

Writing
Freelance writers needed now to make money writing short articles!
www.Helium.com/WritersResource

Have You Written a Book?
Get published in 30 days. Request a free author guide now!
AuthorHouse.com

Meeting Black Singles
Free to join. 1300's of pictures & video's of beautiful Black Singles!
www.BlackPeopleMeet.com

Get Started On MySpace!
Join for free, and view profiles, connect with others, blog, rank

Create Your Profile!
Tell us about yourself, upload your pictures, and start adding

Browse Through Profiles!
Read through millions of profiles on MySpace! See pix, read

Invite Your Friends!
Invite your friends, and as they invite their friends your network
Contextual Targeted Advertising

- Example: Google’s AdSense.
  - Web publishers allow relevant ads to appear on their web sites. Web publisher shares ad revenue

- Key research problem: matching up advertisements to content of web sites. Fundamental IR problem with twists
Other Directions

- Overcoming click fraud
  - In contextual advertising setting, web publisher motivated to generate bogus clicks
  - Advertisers may wish to click on rival companies ads

- [Immorlica, Jain, Mahdian, Talwar]
  If search engine estimates clickthrough rates in a smart way, then system can be shown to be provably resilient to click fraud.
Other Directions

- Advertising in social networks? Advertising on home entertainment systems? Advertising on cell phones? How should the mechanisms change? What are the new issues that arise?

- Optimization problems arising from other kinds of marketing, e.g. viral marketing, where want to take advantage of word-of-mouth effects. (subject of third talk in this session - Ning Chen).
Conclusion

- Online advertising is a fascinating, rapidly growing market.
- Raises many interesting algorithmic and economic issues.

- Thank you for your attention!