Introduction to Computational Advertising

MS&E 239

Stanford University

Autumn 2011

Instructors: Dr. Andrei Broder and Dr. Vanja Josifovski

Yahoo! Research

General course info

- Course Website: http://www.stanford.edu/class/msande239/
- Instructors
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  - Office hours: Tuesdays 6:30pm-7:00pm, Huang
- Course email lists
  - Staff:msande239-aut1112-staff
  - All: msande239-aut1112-students
  - Please use the staff list to communicate with the staff
- Lectures: 10am ~ 12:30pm Fridays in HP
- Office Hours:
  - After class and by appointment
  - Andrei and Vanja will be on campus for 2 times each to meet and discuss with students. Feel free to come and chat about even issues that go beyond the class.

Course Overview (subject to change)

1. 09/30 Overview and Introduction
2. 10/07 Marketplace and Economics
3. 10/14 Textual Advertising 1: Sponsored Search
4. 10/21 Textual Advertising 2: Contextual Advertising
5. 10/28 Display Advertising 1
6. 11/04 Display Advertising 2
7. 11/11 Targeting
8. 11/18 Recommender Systems
9. 12/02 Mobile, Video and other Emerging Formats
10. 12/09 Project Presentations

Lecture 2: Marketplace & Economics

Disclaimers & acknowledgements

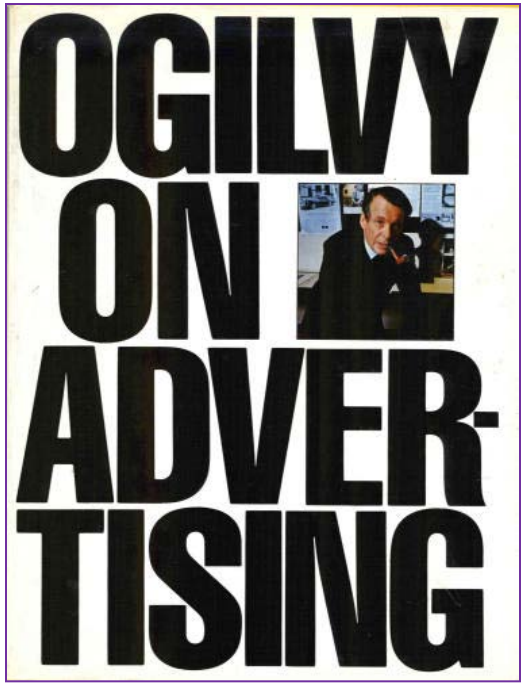
- This talk presents the opinions of the authors. It does not necessarily reflect the views of Yahoo! Inc or any other entity
- Algorithms, techniques, features, etc mentioned here might or might not be in use by Yahoo! Or any other company
- Some of the slides in this lecture are based on courseware generously donated by: Ashish Goel, Michael Schwartz, David Pennock, Prabhakar Raghavan, and others
- Second part of this lecture is based on *Edelman, Ostrovsky, and Schwarz, Internet Advertising and the Generalized Second Price Auction, 2005* **which is required reading!**

What is advertising? Why buy it?

- "Half the money I spend on advertising is wasted; the trouble is I don't know which half.“

John Wanamaker, ~ 1875

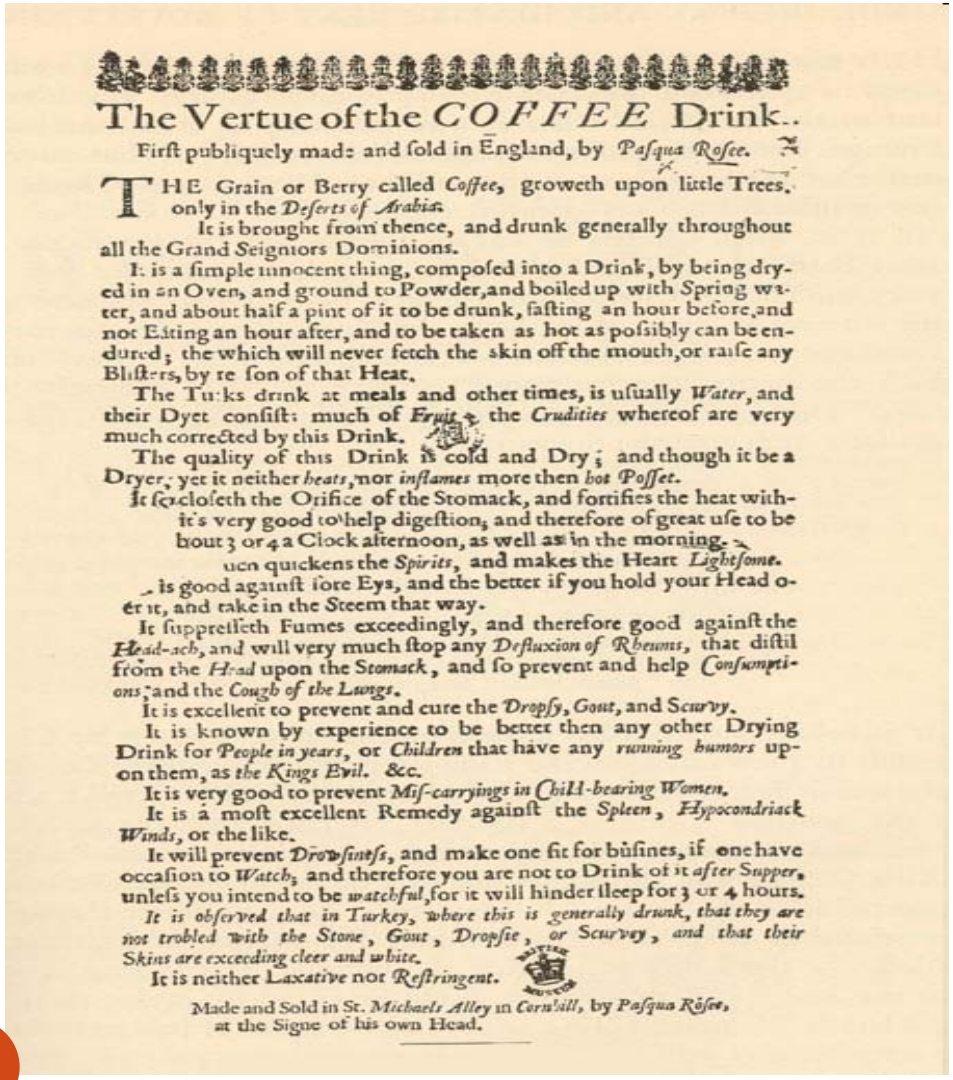
Advertising as information



- "I do not regard advertising as entertainment or an art form, but as a medium of information…." [David Ogilvy, 1985]
- "Advertising as Information" [Nelson, 1974]
- Irrelevant ads are annoying; relevant ads are interesting
  - Vogue, Skiing, etc are mostly ads and advertorials

Finding the best textual ad is an information retrieval problem with multiple, possible contradictory utility functions

Advertising as information, London 1657



The Vertue of the *COFFEE* Drink..

First publiquely made and sold in England, by *Pasqua Rosee.*

THE Grain or Berry called *Coffee*, groweth upon little Trees, only in the *Deserts of Arabia.*

It is brought from thence, and drunk generally throughout all the Grand Seignors Dominions.

It is a simple innocent thing, composed into a Drink, by being dryed in an Oven, and ground to Powder, and boiled up with Spring water, and about half a pint of it to be drunk, fasting an hour before, and not Eating an hour after, and to be taken as hot as possibly can be endured; the which will never fetch the skin off the mouth, or raise any Blisters, by reason of that Heat.

The Turks drink at meals and other times, is usually *Water*, and their Dyet consists much of *Fruit*, the *Crudities* whereof are very much corrected by this Drink.

The quality of this Drink is cold and Dry; and though it be a Dryer, yet it neither *heats*, nor *inflames* more then *hot Posset.*

It closeth the Orifice of the Stomack, and fortifies the heat with-
it's very good to help digestion, and therefore of great use to be
hout 3 or 4 a Clock afternoon, as well as in the morning.
ucn quickens the *Spirits*, and makes the Heart *Lightsome.*
is good against sore Eys, and the better if you hold your Head o-
er it, and take in the Steem that way.

It suppresseth Fumes exceedingly, and therefore good against the *Head-ach*, and will very much stop any *Defluxion of Rheums*, that distil from the *Head* upon the *Stomack*, and so prevent and help *Consumptions*, and the *Cough of the Lungs.*

It is excellent to prevent and cure the *Dropsy*, *Gout*, and *Scurvy.*

It is known by experience to be better then any other Drying Drink for *People in years*, or *Children* that have any *running humors* upon them, as *the Kings Evil.* &c.

It is very good to prevent *Mis-carryings in Child-bearing Women.*

It is a most excellent Remedy against the *Spleen*, *Hypocondriack Winds*, or the like.

It will prevent *Drowsiness*, and make one fit for busines, if one have occasion to *Watch*; and therefore you are not to Drink of it *after Supper*, unless you intend to be *watchful*, for it will hinder sleep for 3 or 4 hours.

It is observed that in Turkey, where this is generally drunk, that they are not trobled with the Stone, Gout, Dropsie, or Scurvey, and that their Skins are exceeding cleer and white.

It is neither Laxative nor *Restringent.*

Made and Sold in St. *Michaels Alley* in *Cornhill*, by *Pasqua Rosee*, at the Signe of his own Head.

The ad explains "*The Vertue of the COFFEE drink*" what coffee is, how it grows, how it cures numerous maladies, including Dropsy, Gout, and Scurvy, …

What are advertisers buying?

- "...in an information-rich world, the wealth of information means a dearth of something else: a scarcity of whatever it is that information consumes. What information consumes is rather obvious: it consumes the attention of its recipients. Hence a wealth of information creates a poverty of attention and a need to allocate that attention efficiently among the overabundance of information sources that might consume it."

Herbert Simon, 1971

Advertisers are buying attention!

What kind of users are advertisers looking for?

- **Qualified**
  - Selection of users by business rules on concrete attributes
  - For example: car model sold only in USA → US residents, appropriate income
- **Receptive**
  - Interest level of the user in the advertiser's message and the user's willingness to absorb it
  - For example: people interested in skiing ads are often interested in biking ads
- **Responsive**
  - Propensity of the user to respond in a desired way to the advertiser's message, within a relatively short period of time
  - Responsiveness is the goal of performance advertisers, but short term responsiveness is less important for brand advertisers.
  - For example: likelihood of clicks, conversions, or brick and mortar purchases

Advertising as a market for attention

- A good theory of attention is missing
- Attention is not like other goods – it is like finding a mate – the match is important on both sides!
  - Usual goods:
    - Car sellers do not care who buys the cars!
  - Attention "goods"
    - Advertisers want the attention of **certain people**
    - People are only open to **certain** ads (whether or not in the market for the advertised good)

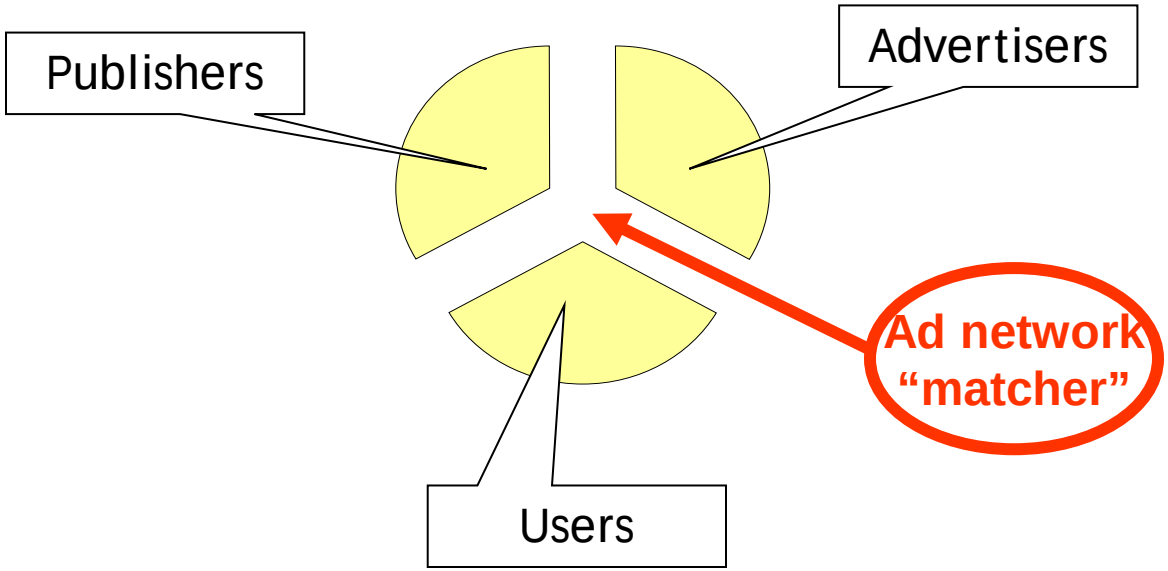
Sponsored search advertising (a.k.a. Paid Search)

Computational advertising – the central challenge

Find the "best match" between a given user in a given context and a suitable advertisement.

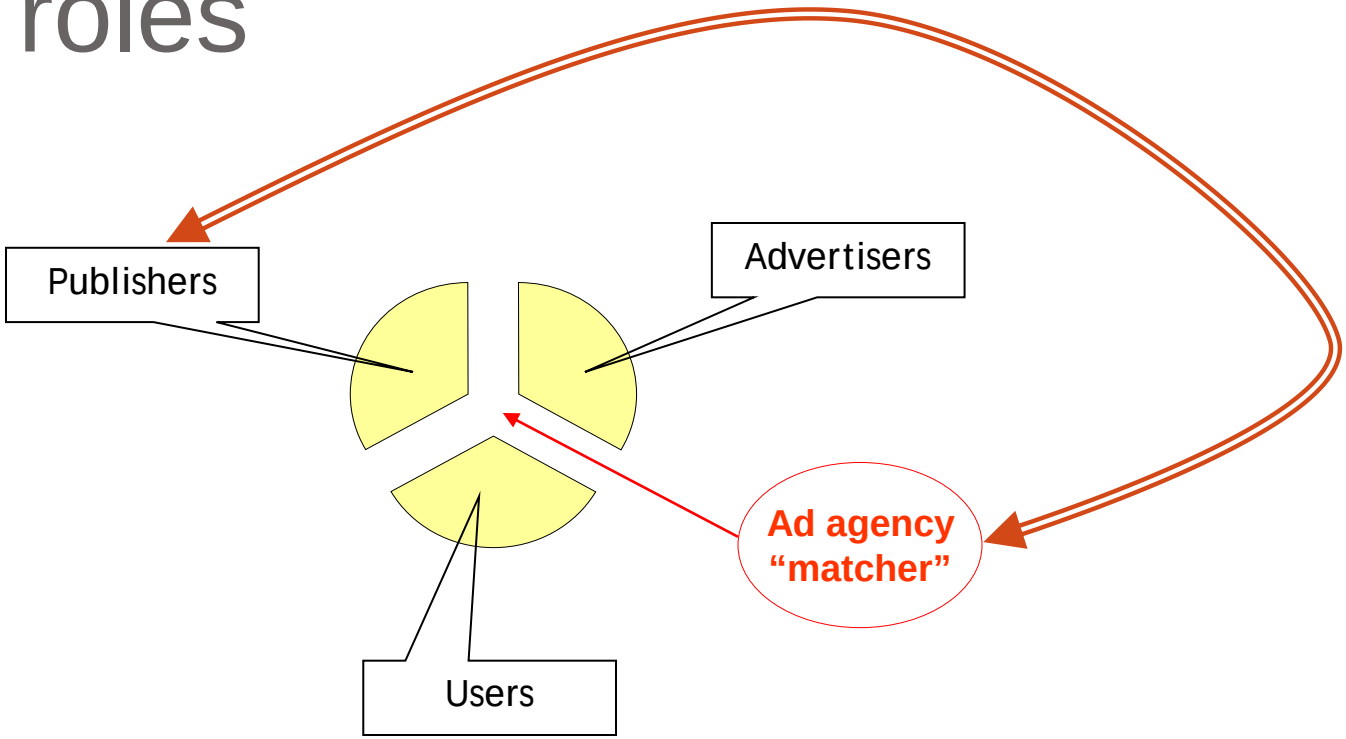
- Examples
  - Context = Web search results → Sponsored search
  - Context = Publisher page → Content match, banners
  - Other contexts: mobile, video, newspapers, etc

The actors: Publishers, Advertisers, Users, & “Ad network”



- Each actor has a separate utility function
  - User utility (relevance of the ad)
  - Advertiser utility (ROI)
  - Publisher utility (Revenue)

Dual roles



- Sponsored search:
  - Publisher = the owner of the search results page (SERP)
  - Usually the publisher (the owner of the SERP) and the "matcher" are the same (Google, Bing) but can be different (MS provides both algo search and paid search results to Yahoo)
  - WLOG, we'll assume the former for this lecture

Interactions in Sponsored Search

- **Advertisers**:
  - Submit ads associated to certain bid phrases
  - Bid for position
  - Pay CPC

  This lecture
- **Users**
  - Make queries to search engine, expressing some intent
- **Search engine**
  - Executes query against web corpus + other data sources
  - Executes query against the ad corpus
  - Displays a Search Results Page (SERP) = integration of web results, other data, and ads

Back to the ad discussed in Lecture 1

Visible and invisible parts

Bid phrase: sigir 2010
Bid: $1

Title — Tutorial at **SIGIR 2010**

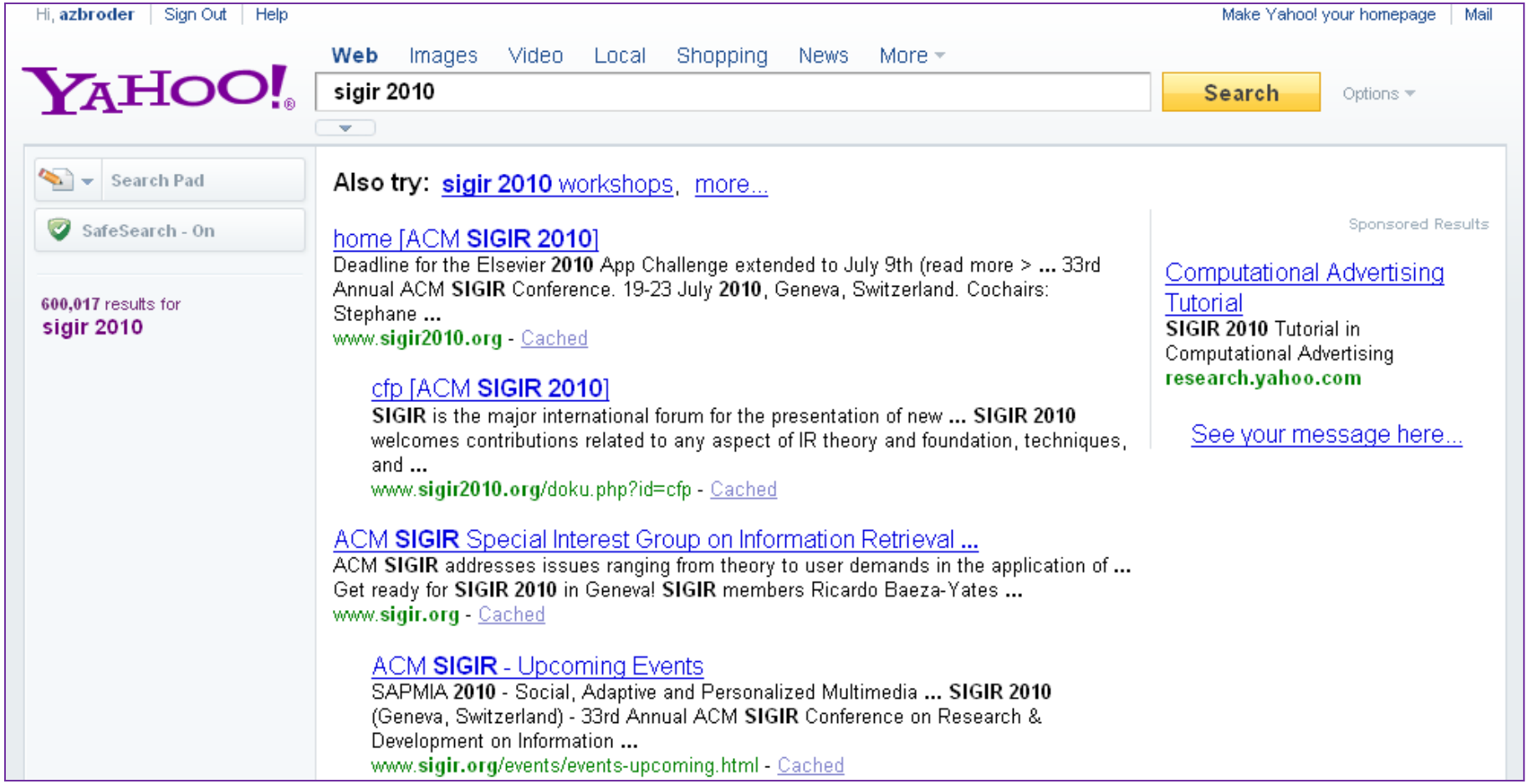
Creative — Information Retrieval Challenges in Computational Advertising

Display URL — research.yahoo.com/tutorials/**sigir**

Landing URL:
http://research.yahoo.com/tutorials/sigir10_compadv/

Destination: the landing page

Search Yahoo for sigir 2010



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Google AdWords

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All online campaigns >

Campaign: Campaign #1

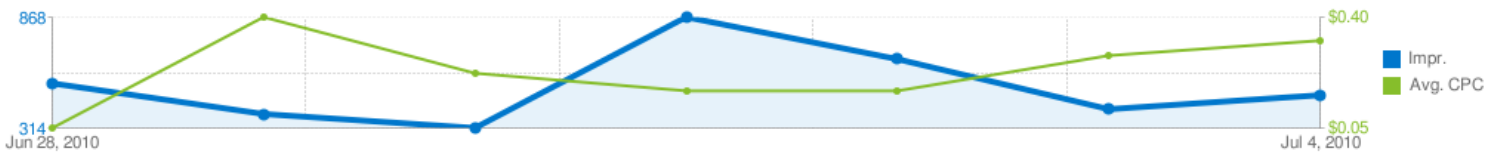
Last 7 days
Jun 28, 2010 - Jul 4, 2010

Enabled Budget: $7.00/day Edit Targeting: Search Edit All devices Edit All languages Edit All countries and territories Edit

Ad groups | Settings | Ads | Keywords | Networks

All but deleted Keywords | Segment | Filter | Columns | Search

View Change History



+ Add keywords | Edit | Change status... | See search terms... | More actions...

Keyword	Ad group	Status	Max. CPC	Clicks	Impr.	CTR	Avg. CPC	Cost	Avg. Pos.
sigir	Computational Advertising	Below first page bid First page bid estimate: $1.00	$0.40	20	2,449	0.82%	$0.16	$3.19	1.2
sigir 2010	Computational Advertising	Eligible	$0.40	3	647	0.46%	$0.40	$1.20	1
sigir2010	Computational Advertising	Eligible	$0.40	1	25	4.00%	$0.16	$0.16	1
text retrieval conference	Computational Advertising	Rarely shown due to low quality score	$1.00	0	108	0.00%	$0.00	$0.00	1.1
andrei z broder	Computational Advertising	Eligible	$0.40	0	6	0.00%	$0.00	$0.00	1
sigir geneva	Computational Advertising	Eligible	$1.00	0	3	0.00%	$0.00	$0.00	1
sigir forum	Computational Advertising	Rarely shown due to low quality score	$1.00	0	4	0.00%	$0.00	$0.00	1
evgeniy gabrilovich	Computational Advertising	Eligible	$0.40	0	12	0.00%	$0.00	$0.00	1

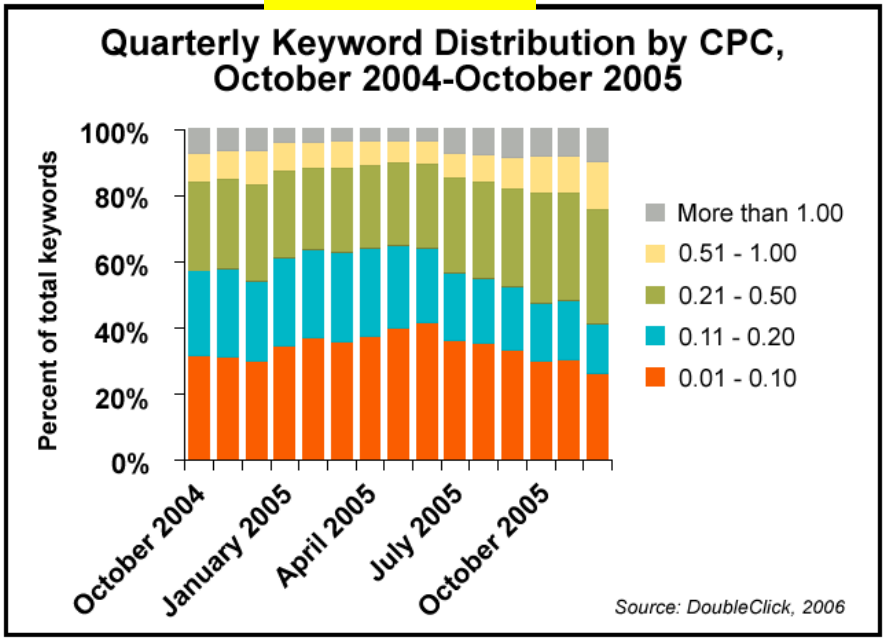
Details

re actions...

Status	Max. CPC	Clicks	Impr.	CTR	Avg. CPC	Cost	Avg. Pos.
Below first page bid First page bid estimate: $1.00	$0.40	20	2,449	0.82%	$0.16	$3.19	1.2
Eligible	$0.40	3	647	0.46%	$0.40	$1.20	1
Eligible	$0.40	1	25	4.00%	$0.16	$0.16	1
Rarely shown due to low quality score	$1.00	0	108	0.00%	$0.00	$0.00	1.1
Eligible	$0.40	0	6	0.00%	$0.00	$0.00	1
Eligible	$1.00	0	3	0.00%	$0.00	$0.00	1
Rarely shown due to low quality score	$1.00	0	4	0.00%	$0.00	$0.00	1
Eligible	$0.40	0	12	0.00%	$0.00	$0.00	1

CPC costs historical

2005



2009

U.S. Average Search CPC by Category, September and October

Category	CPC Sep ($)	CPC Oct ($)	Change (%)
Automotive	0.47	0.50	6.3
Finance	1.80	1.63	-9.4
Retail	0.40	0.43	7.5
Travel	0.55	0.54	-1.8

Source: efficient frontier 2009 (Via ClikZ.com)

2011

Average Search Cost per Click (CPC) in the US, by Industry, March-April 2010 & March-April 2011

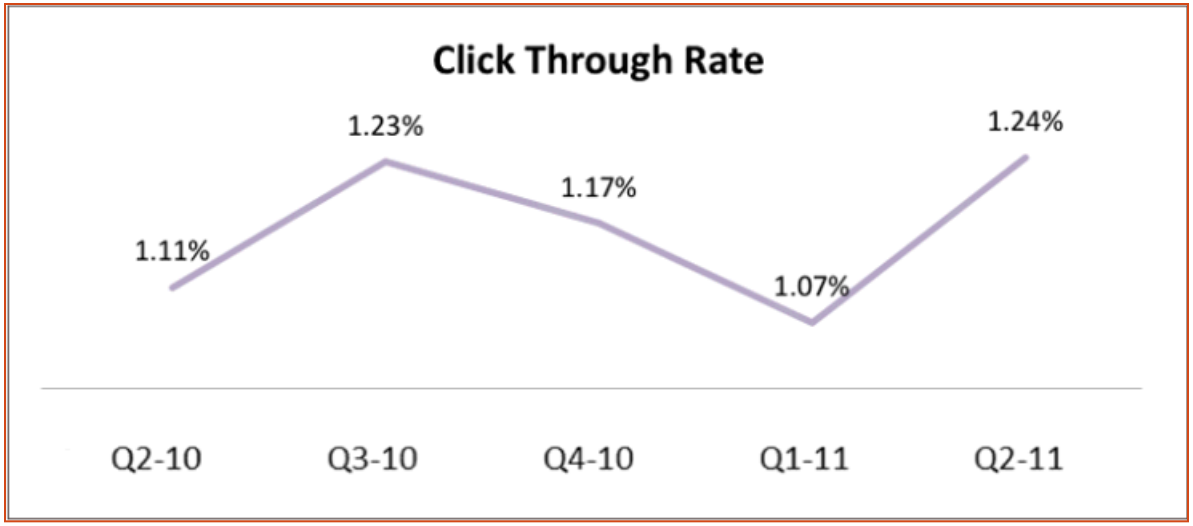
	March 2010	April 2010	March 2011	April 2011	% change (April vs. March 2011)	% change (April 2011 vs. April 2010)
Finance	$1.45	$1.61	$2.03	$2.26	11.3%	40.4%
Automotive	$0.55	$0.52	$0.53	$0.54	1.9%	3.8%
Retail	$0.42	$0.43	$0.43	$0.45	4.7%	4.7%

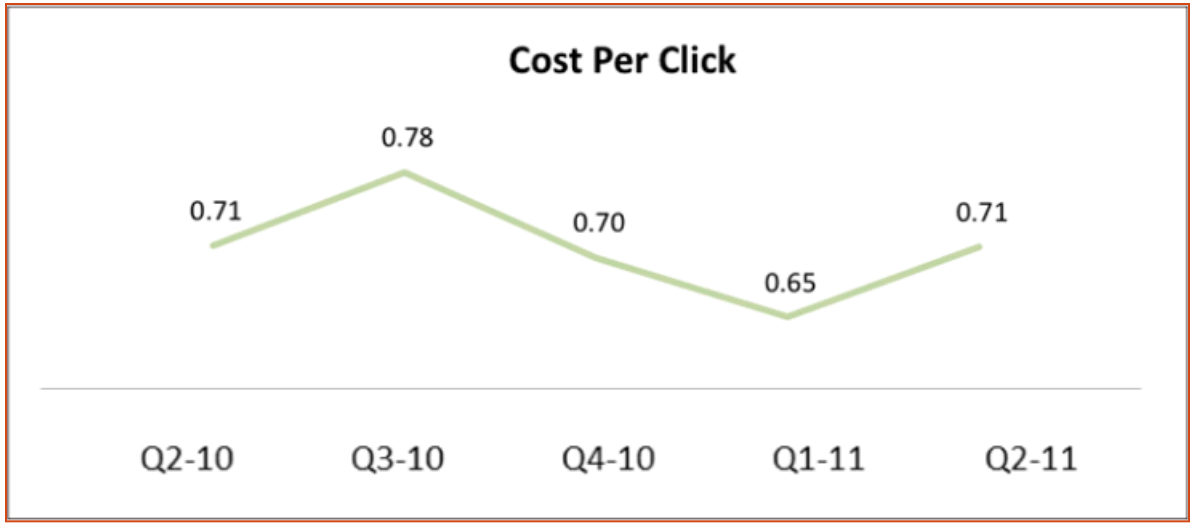
Source: Efficient Frontier as cited in company blog, May 20, 2010

128040 www.eMarketer.com

CTR and CPC

(Source: Marin Software: Paid Search Quarterly Benchmarking Report: July 2011)





Dependency on engine

Paid Search Cost per Click (CPC) Worldwide, by Search Engine, Q3 2010-Q2 2011

	Q3 2010	Q4 2010	2010	Q1 2011	Q2 2011
Bing	$0.99	$0.98	$0.92	$1.02	$1.08
Yahoo!	$0.89	$0.86	$0.79	-	-
Ask.com	$0.76	$0.72	$0.71	$0.69	$0.68
Google	$0.74	$0.75	$0.74	$0.79	$0.81
Yandex	$0.62	$0.63	$0.61	$0.61	$0.62
Baidu	$0.27	$0.32	$0.25	$0.35	$0.42
Rambler	-	-	$0.00	$0.13	$0.13
Total	**$0.77**	**$0.76**	**$0.76**	**$0.79**	**$0.83**

Source: Covario, "Global Search Spending Analysis: Q2 2011," July 8, 2011

129660 www.eMarketer.com

Other twists

- Advertisers can specify budgets
- Budgets can be implemented via
  - Spend it quickly till out of money
  - Spend it slowly till end-of-day
  - Spend it as the SE sees fit (Studied in theory but dubious – engine can use this nefariously to manipulate the price paid by other advertisers)
- There are sometimes “reserve prices” = minimum cost to be shown on a given kw (depends on kw)
- There are sometimes “minimum bids” = minimum bid required to participate in action (could depend on advertiser and keyword)

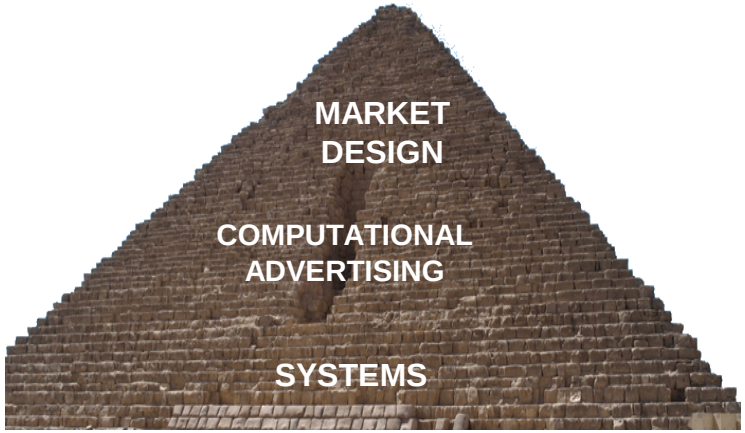
From the search engine perspective: Three sub-problems

1. **Ad retrieval**
   Match to query/context
2. **Ordering** the ads
3. **Pricing** on a click-through

IR / Comp Adv

Economics

Note: This is the **execution** order. The **design** order is the opposite:



1. Ad retrieval

Retrieve ads (more in the next lecture)

- Advertisers bid on keywords/phrases
- For a given query the engine provides:
  - "Exact match" → The advertiser bid on that specific query a certain amount
  - "Advanced match" (AM) or "Broad match" → The advertiser did not bid on that specific keyword, but the query is deemed of interest to the advertiser.
    - Needed to ensure volume + new/rare queries (advertise on the tail queries)
  - "Phrase match" → query matches if sub-phrase = bids, e.g. the query <fresh red flowers> matches the bid <red flowers>
- A lot more in Lecture 3 and 4
- We will ignore AM for now and assume that all ads have bids.

2. Ordering & pricing the ads

An introduction to game theory, auction theory and mechanism design

Definitions

- **<u>Game theory</u>** = branch of applied mathematics that formalizes strategic behavior in the form of *games* =
  - Set of players.
  - A set of *strategies* available to those players (each has its own set)
  - A specification of *payoffs* for each player for each combination of strategies.

➔

  - Each player's payoff depends on the strategy chosen by every other player!

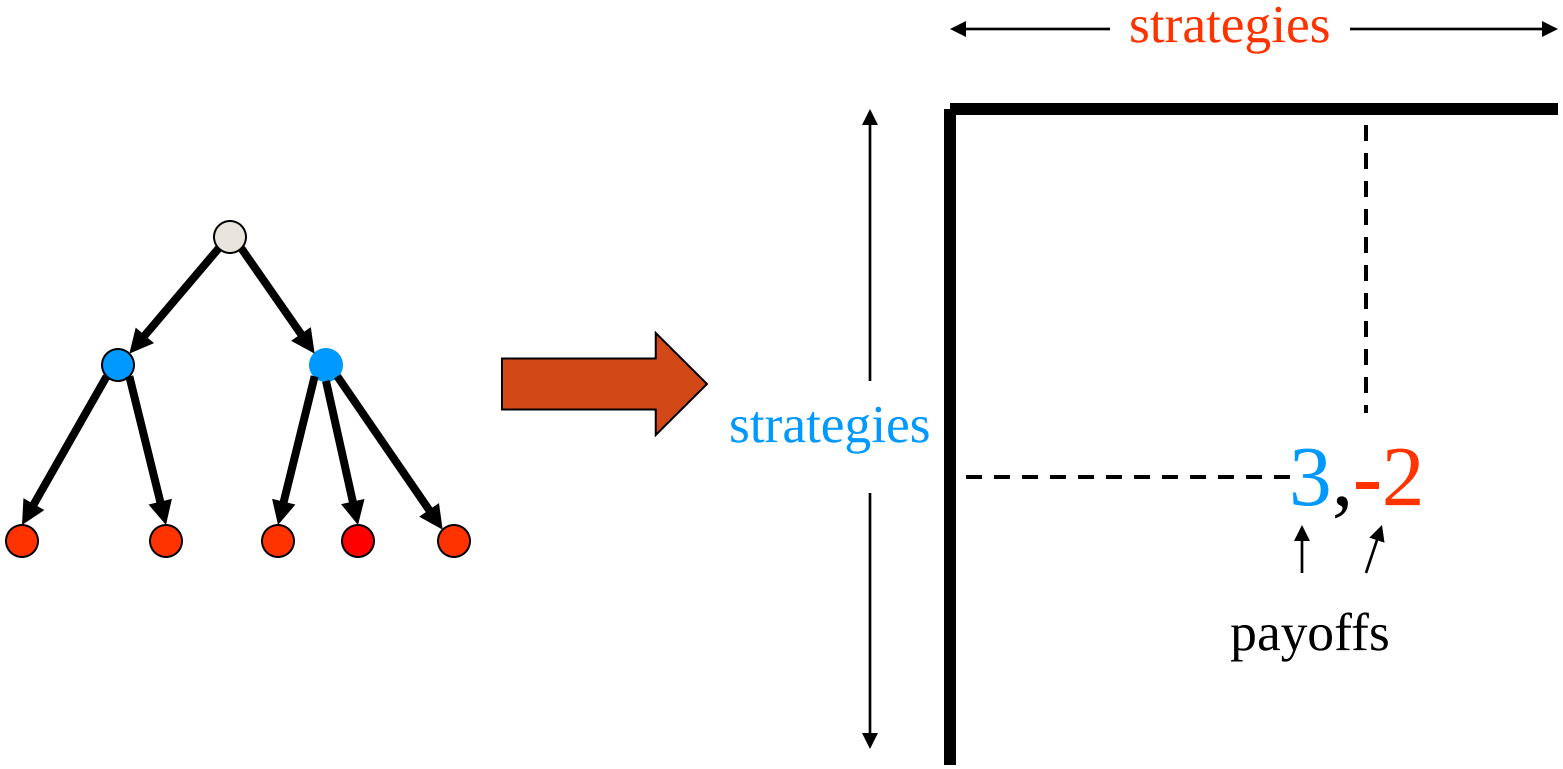
More on game theory

- Study of strategic interactions between two or more **rational** players
- Classic tool for studying markets -- captures competition as well as collaboration

Definitions (cont)

- **Auction theory** = branch of game theory that deals with how participants (players) act in auction markets
- **Mechanism design** = the study of designing the rules of a game or economic system (in particular auctions) to achieve a specific outcome.

2-person games and payoff matrices



Rock-scissors-paper (*roshambo)* (Single instance)

		B		
		Rock	Scissors	Paper
A	Rock	0	1	-1
	Scissors	-1	0	1
	Paper	1	-1	0

Payoffs to A.

Definition: Dominant strategy

- Strategy = a complete definition of how a player will play a game.
- Strategy X (for a player) **dominates** another strategy Y
  - if for all choices by other player(s), X yields at least as much payoff as Y.
- Strategy X is **dominant** if it dominates all other strategies.

Rock-scissors-paper discussion

- **What every 5-year old knows:**
  - There is no ***pure*** (= deterministic) dominant strategy for one shot RSP
- But there is a ***mixed*** (= randomized) strategy that is optimal for both players.

- **What many 5-year olds wrongly believe:**
  - **There is a pure dominant strategy for the repeated RSP game**
    - **E.g. Do whatever your dad did two rounds ago, go rrsspprr.., etc -- You just have to find it! ☺**

Optimal (mixed) strategy

Each player picks one of the 3 choices uniformly at random.

		B		
		Rock	Scissors	Paper
A	Rock	0	1	-1
	Scissors	-1	0	1
	Paper	1	-1	0

Nash equilibria

- This pair of strategies is an example of a *Nash equilibrium:*
- **Nash equilibrium** = choice of strategies in which each player is assumed to know the equilibrium strategies of the other players, and no player has anything to gain by changing his own strategy unilaterally.
- **Pure strategy** = deterministic definition of how a player will play a game
- **Mixed strategy =** an assignment of probabilities to each pure strategy -- the players throw coins to pick the strategy they follow.

Nash equilibria (cont)

- A game could have **many** Nash equilibria …
- … or **none**, if players must follow pure strategies.
- **Famous Nash theorem**

In every n-player game in which every player has finitely many pure strategies there exists a set of mixed strategies that forms a Nash equilibrium.

Relation to our setting (preview)

- Advertisers make bids (their moves)
- Advertiser seek attention and volume – prefer higher positions (not 100% true)
- Engines order ads and price clicks according to some rules known to all bidders
- The bidders can all keep reacting to each other – does this ever end?

Auctions

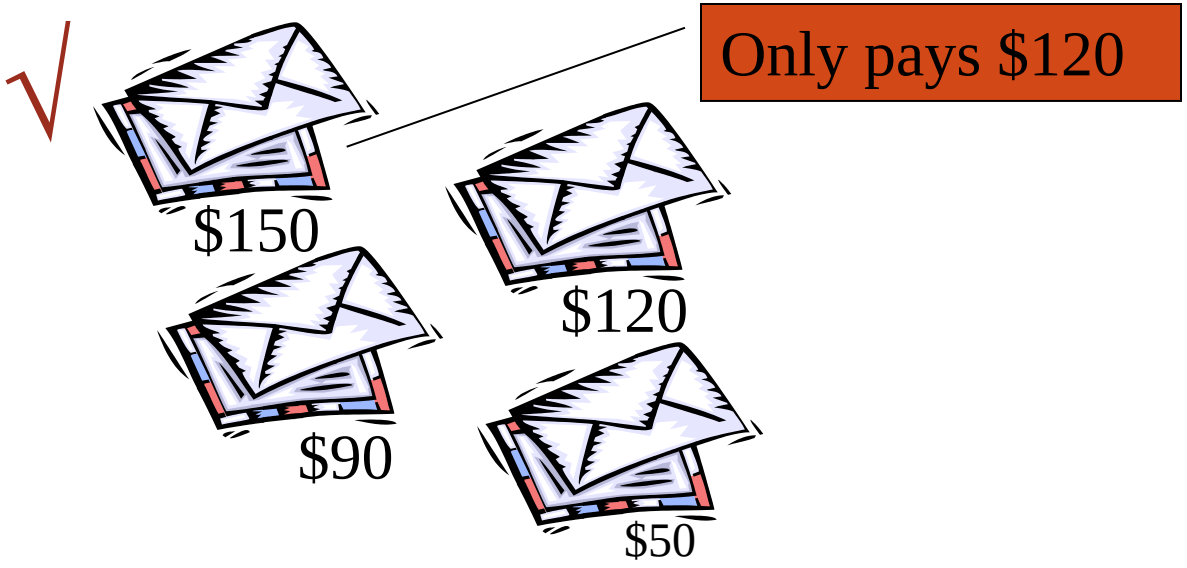
Types of auctions

- **First-price sealed-bid →**
  1. Bidders place their bid in a sealed envelope
  2. Simultaneously give them to the auctioneer.
  3. Highest bidder wins, pays his bid.
- **Second-price sealed-bid auctions (Vickrey auctions) →**
  1. Bidders place their bid in a sealed envelope
  2. Simultaneously give them to the auctioneer.
  3. Highest bidder wins, pays price equal to the second highest bid.
- **Open Ascending-bid auctions (English auctions) →**
  1. Price is steadily raised by the auctioneer
  2. Bidders drop out once the price becomes too high.
  3. Eventually there is only one bidder who wins the auction at the current price.
- **Open Descending-bid auctions (Dutch auctions) →**
  1. Price starts at infinity and is steadily lowered by the auctioneer
  2. The first bidder to accept the current price, wins
  3. Pays the current price.

- Where is E-bay on this spectrum? (discussion)

Second price auction (Vickrey auction)

- All buyers submit their bids privately
- buyer with the highest bid wins;
  pays the price of the *second* highest bid



Truthfulness (Incentive Compatibility) of Vickrey Auction

- An auction mechanism is **truthful**, if the dominant strategy for every player is to truthfully bid their own value.

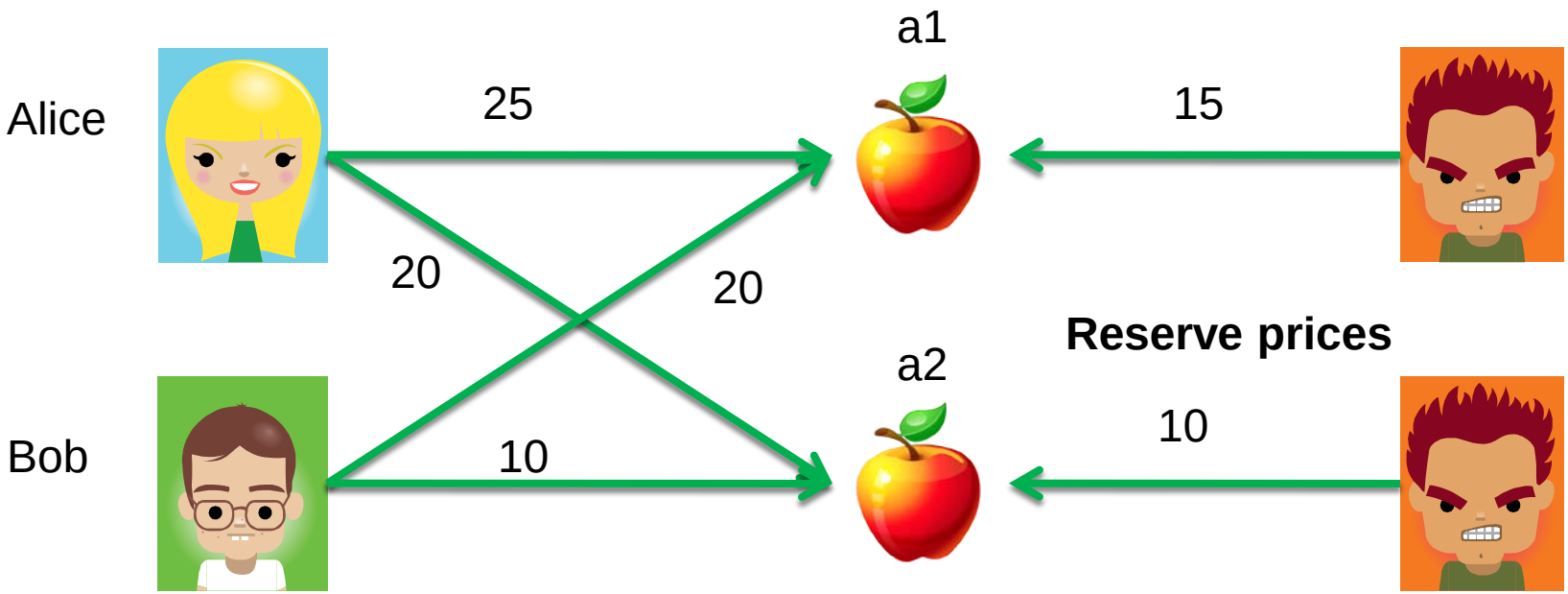
- Telling the truth is optimal in second-price (Vickrey) auction
- Suppose your value for the item is $100;
  if you win, your net gain (loss) is $100 - price
- If you bid more than $100:
  - you increase your chances of winning at price >$100
  - you do not improve your chance of winning for < $100
- If you bid less than $100:
  - you reduce your chances of winning at price < $100
  - there is no effect on the price you pay if you do win
- Dominant optimal strategy: bid $100
  - Key: the price you pay is out of your control
- Vickrey's Nobel Prize due in large part to this result!

Vickrey-Clark-Groves (VCG)

- Generalization of Vickrey
- Works for arbitrary number of goods, including allowing combination bids
- Auction procedure:
  - Collect bids
  - Allocate goods to maximize *total social value* (goods go to those who claim to value them most) = maximum weighted matching
  - Payments: Each bidder b pays his externality = (max TSV without b's participation) – (max TSV for everyone else when b participates)
  - NB: (max TSV for everyone else when b participates) = max weighted matching without b & without b's items.

- Incentive compatible (truthful) = all the bidders do best when they bid their true value i.e. reveal their private information

VCG example



- Max matching = 40 → A gets a2, B gets a1
- Max matching without Bob = 25
- Max matching without Bob, without a1 = 20
  - **Bob pays 5**
- Max matching without Alice = 20
- Max matching without Alice, without a2 = 20
  - **Alice pays 0**

Homework: Prove that seller always gets at least the reserve price for every item actually sold.

VCG Truthfulness Informal "Proof" (not really!)

- Max matching without Alice does not depend on her bids
- Max matching without Alice and her assigned apple does not depend on her bids
  - ➔Price paid by Alice for her apple does not depend on her bid
    - Should not bid more than her value – might pay too much!
    - Should not bid less – might not get it!

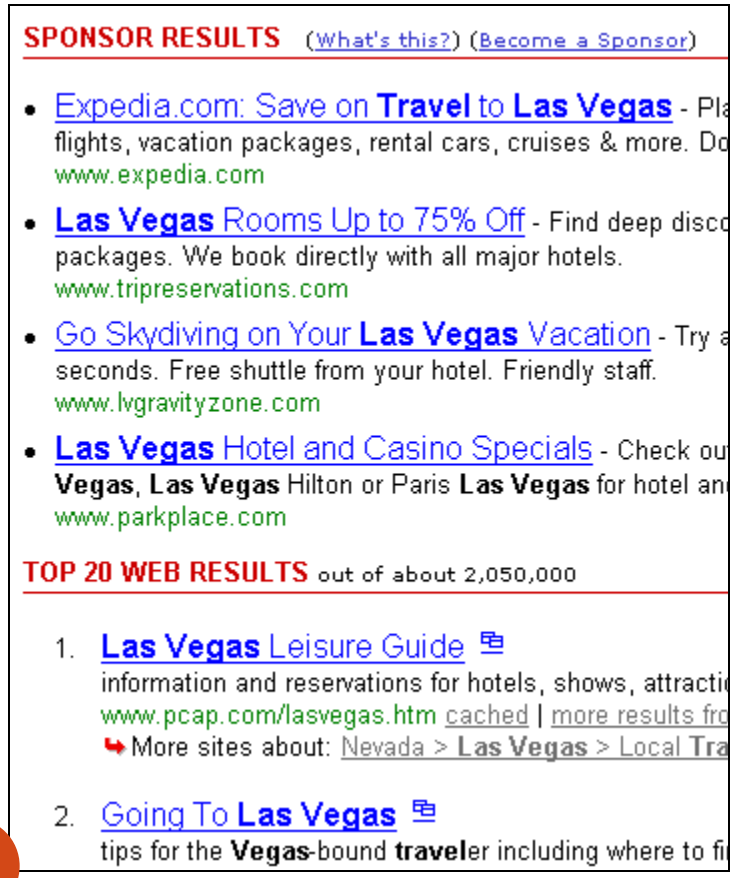
How does the sponsored search auction work?

- Search engines
  - run keyword auctions to sell available inventory of ad positions
- Advertisers
  - submit bids which indicate their willingness-to-pay per click
    - for example, bid of $1.75 per click for the keyword “laptop”
- The search engine orders the ads in descending order
  - Bid is a key determinant of ad position
  - Other factors such as CTR are also factored in
    - More on the exact mechanism later

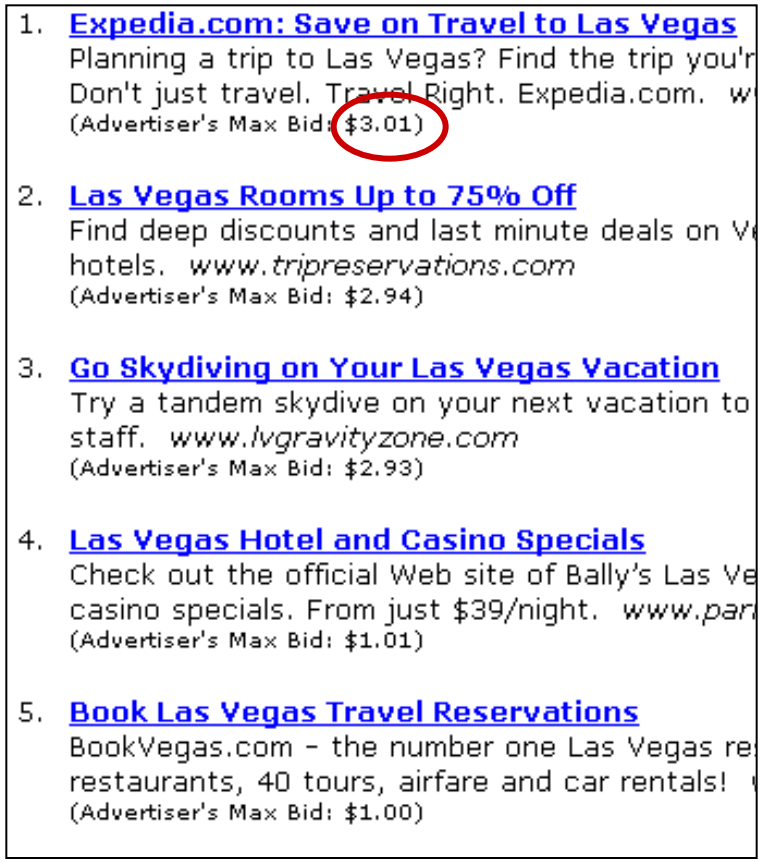
Sponsored search auctions

The space next to search results is sold in an auction with sealed (max) bids

search “las vegas travel”, Yahoo!



“las vegas travel” auction



Unique Features of the Market for Internet Ads

Market design

- Bidding takes place continuously
- The search engines effectively sell **flows** (clicks/hour)
- Not unlike electricity markets unused capacity is wasted
- On the other hand, user utility might be impaired by excessive advertisement

Features of the environment = not easily changeable

No Obvious Definition of a "Unit" of Advertisement

1. Advertiser's perspective: transaction is a "unit"
   ➔ Pricing model: pay per transaction (CPT/CPA)
2. Search engine's perspective: exposure is a "unit" (CPM)
   ➔ Pricing model: pay per exposure
3. Middle ground: click is a "unit"
   ➔ Pricing model: pay per click (CPC)

- All three pricing models are widely used
- Pay per click dominates sponsored search
- (Remember also the risk assumption discussion)

Early Internet Advertising

- In *1994 history begins:*
  - Per-impression pricing, mostly referral to services, insane prices.
  - Person to person negotiations
  - Sometime unclear who should pay: search engine for being able to provide extra services (e.g. maps) or provider for getting traffic/exposure.
  - Even smallest contracts are large (> $10K)
  - Key word targeting not available
  - Entry slow, "unused capacity"

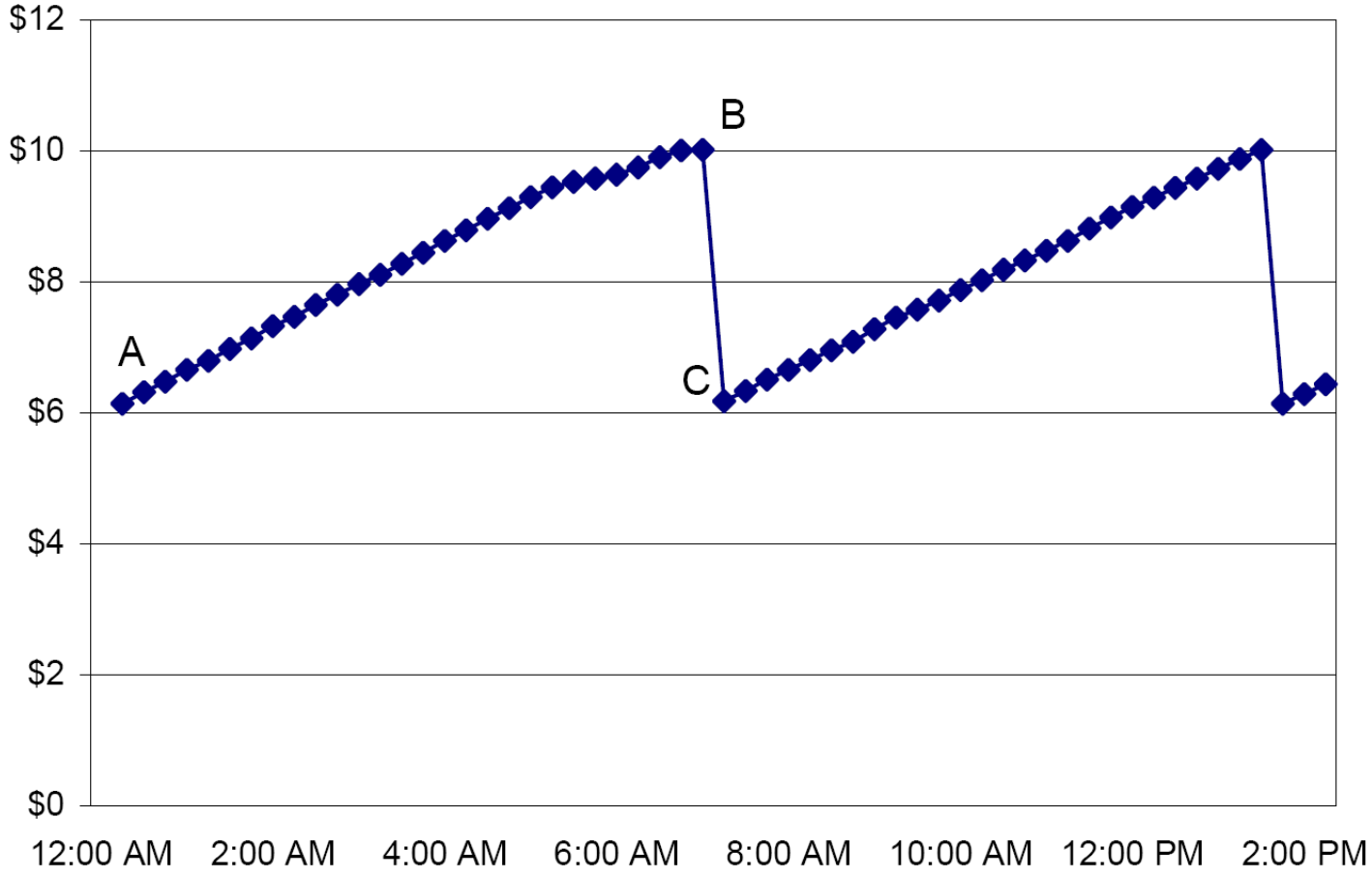
Generalized First-Price Auctions

- 1997 *auction revolution* by Overture (then GoTo.com, created at Idealab)
- Pay per-click for a particular keyword
  - Initially crazy idea, meant to combat search spam
  - Search engine “destination” that ranks results based on who is willing to pay the most
  - With algorithmic SEs out there, who would use it?
  - Commercial web sites would! (Much better than to depend on ranking!)
- Results:
  - Much better targeting & much smaller contracts than display advertising
  - Links arranged in descending order of bids
  - Pay your bid (First price)
  - Overture became a platform for Yahoo! and MSN-- Imperfect mechanism: unstable due to dynamic nature of the environment

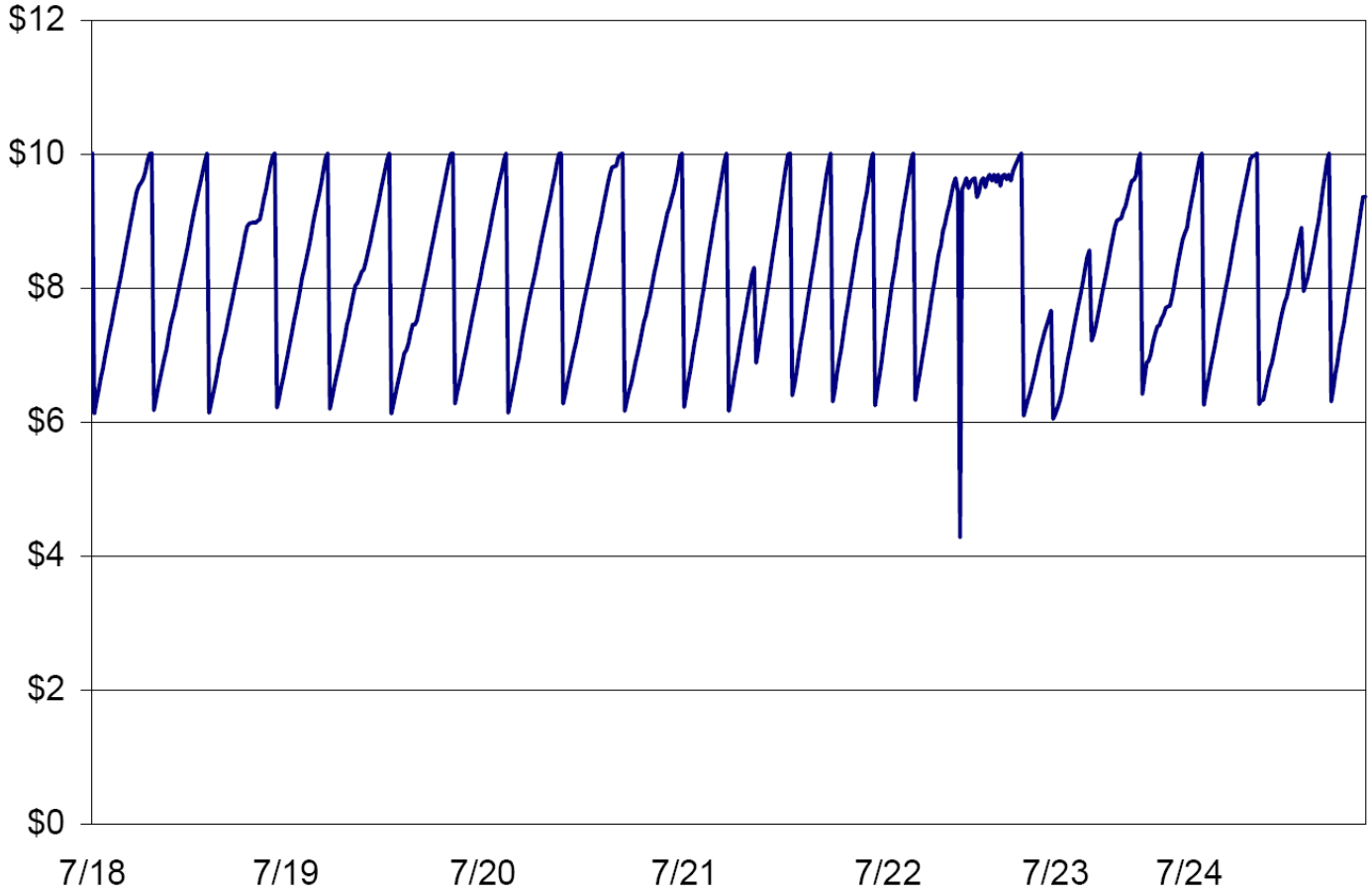
Example

- Two slots and three bidders.
  - First slot 200 clicks per hour
  - Second slot gets 100 clicks per hour.
  - Bidders 1, 2, and 3 have values per click of $10, $4, and $2, respectively.
- Pay-off for bidder *i* = # clicks * (value(i) – CPC)
- There is no pure strategy equilibrium in the one-shot version of the game (one hour). If bidders best respond to each other, they will want to revise their bids as often as possible. (HW, [0pt]: Prove this fact)

Generalized First Price: 14 hours in the “life of the top bid” -- real data on a particular kw! (not previous example)



GFP: one week of changes in top bid



Generalized Second-Price (GSP) Auctions

- 2002 GSP implemented by Google
- Yahoo!/Overture and others switched to GSP
- Two way of generalizing:

  - **Bid ranking: Order the ads by their bids.** Rename ads so ad *i* ends in position i. Bidder in position *i* pays *bid(i+1).*

  - **Revenue ranking: Order the ads by expected revenue in position 1 assuming maximum bids, that is by b(j)*ctr(j) .** Rename ads so ad *i* ends in position i. Bidder in position *i* pays *bid(i+1)*ctr(i+1)/ctr(i).*

    Note that bidder *i* pays less than *bid(i)* since *bid(i)*ctr(i)* > *bid(i+1)*ctr(i+1)*

    If all CTRs are the same, revenue ranking is the same as bid ranking!

Example

- Same example under GSP mechanism with bid ranking

- Two slots and three bidders.
  - First slot 200 clicks per hour regardless of ad
  - Second slot gets 100 regardless of ad
  - Bidders 1, 2, and 3 have values per click of $10, $4, and $2, respectively.

- If all advertisers bid truthfully, then bids are $10, $4, $2.
  - Payments for slot one and two are $4 and $2 per click.
  - Total payment of bidder 1 is $800 = $1200 pay-off
  - Total payment of bidder 2 is $200 = $200 pay-off
  - In this example truth-telling is an equilibrium because no bidder can benefit by changing his bid.

GSP in the original Overture system = Bid Ranking

"las vegas travel" auction bidders

1. **Expedia.com: Save on Travel to Las Vegas**
   Planning a trip to Las Vegas? Find the trip you'r
   Don't just travel. Travel Right. Expedia.com. w
   (Advertiser's Max Bid: $3.01)

2. **Las Vegas Rooms Up to 75% Off**
   Find deep discounts and last minute deals on V
   hotels. *www.tripreservations.com*
   (Advertiser's Max Bid: $2.94)

3. **Go Skydiving on Your Las Vegas Vacation**
   Try a tandem skydive on your next vacation to
   staff. *www.lvgravityzone.com*
   (Advertiser's Max Bid: $2.93)

4. **Las Vegas Hotel and Casino Specials**
   Check out the official Web site of Bally's Las Ve
   casino specials. From just $39/night. *www.par*
   (Advertiser's Max Bid: $1.01)

5. **Book Las Vegas Travel Reservations**
   BookVegas.com - the number one Las Vegas re
   restaurants, 40 tours, airfare and car rentals!
   (Advertiser's Max Bid: $1.00)

"las vegas travel", bid ranking

SPONSOR RESULTS (What's this?) (Become a Sponsor)

- Expedia.com: Save on **Travel** to L
  flights, vacation packages, rental cars, c
  www.expedia.com
- **Las Vegas** Rooms Up to 75% Off
  packages. We book directly with all majo
  www.tripreservations.com
- Go Skydiving on Your **Las Vegas**
  seconds. Free shuttle from your hotel. Fr
  www.lvgravityzone.com
- **Las Vegas** Hotel and Casino Specials - Check ou
  Vegas, **Las Vegas** Hilton or Paris **Las Vegas** for hotel an
  www.parkplace.com

TOP 20 WEB RESULTS out of abo

1. **Las Vegas** Leisure Gui
   information and reservations for hotels, shows, attracti
   www.pcap.com/lasvegas.htm cached | more results fr
   More sites about: Nevada > **Las Vegas** > Local Tra
2. Going To **Las Vegas**
   tips for the **Vegas**-bound **travel**er including where to fi

pays $2.95 per click

pays $2.94

pays $1.02

... bidder i pays bid_{i+1}+.01

GSP as implemented by Google = revenue ranking taking into account the "attraction" of ads

- Assume that each advertiser *i* has a certain attraction factor adv_i that impacts its click-through rate (CTR)
- Key "separability" assumption:

$$CTR_i = adv_i * pos_i$$

- Bid_i gets scaled by adv_i
- Advertiser *i* is charged

$price_i = 1/adv_i * bid_i$ = Enough to keep it in position *i*

- Notes
  - Last position may require special handling – usually there is min "floor price" = a form of reserve

Revenue ordering

"las vegas travel" bidders and CTR

1. **Expedia.com: Save on Travel to Las Vegas**
   Planning a trip to Las Vegas? Find the trip you'r
   Don't just travel. Travel Right. Expedia.com. w
   (Advertiser's Max Bid: $3.01) x .1 = .301

2. **Las Vegas Rooms Up to 75% Off**
   Find deep discounts and last minute deals on V
   hotels. *www.tripreservations.com*
   (Advertiser's Max Bid: $2.94) x .2 = .588

3. **Go Skydiving on Your Las Vegas Vacation**
   Try a tandem skydive on your next vacation to
   staff. *www.lvgravityzone.com*
   (Advertiser's Max Bid: $2.93) x .1 = .293

4. **Las Vegas Hotel and Casino Specials**
   Check out the official Web site of Bally's Las Ve
   casino specials. From just $39/night. *www.par*
   (Advertiser's Max Bid: $1.01) x E[CTR] = E[RPS]

5. **Book Las Vegas Travel Reservations**
   BookVegas.com - the number one Las Vegas re
   restaurants, 40 tours, airfare and car rentals!
   (Advertiser's Max Bid: $1.00) x E[CTR] = E[RPS]

"las vegas travel" revenue ordering

TripReservations

pays 3.01*.1/.2+.01 = 1.51 per click

Expedia

pays 2.93*.1/.1+.01 = 2.94

LVGravityZone

etc...

pays $bid_{i+1}*CTR_{i+1}/CTR_i+.01$

We translated everything to RPS and back!

Is Google pricing = VCG?

Put Nobel Prize-winning theories to work.
Google's unique auction model uses Nobel Prize-winning economic theory to eliminate the winner's curse – that feeling that you've paid too much. While the auction model lets advertisers bid on keywords, the AdWords™ Discounter makes sure that they only pay what they need in order to stay ahead of their nearest competitor.

Well, not really …

Generalized Second-Price and VCG Auctions

- GSP is not VCG -- GSP has no dominant strategies
- Truth-telling is generally not an equilibrium
- With only one slot, VCG and GSP are identical
- With several slots, the mechanisms are different:

GSP charges bidder i the *bid* of bidder i+1 (In practice + $0.01)

VCG charges bidder i for his *externality*

Truth-telling is not a dominant strategy under GSP

Proof: Example with three bidders and two slots

- Per click values are \$10, \$4, and \$2
- CTR's are 200 and 199
- (Assume all ads are equally attractive)
- If all bid truthfully bidder 1 bids \$10 and pays \$4 so his payoff is:

$$(\$10-\$4)*200=\$1200$$

- If bidder 1 bids \$3 (and pays \$2) his payoff is:

$$(\$10-\$2)*199=\$1592>\$1200$$

GSP equilibrium

- What are Nash equilibrium strategies? There are many!
- **Locally envy-free equilibrium** [Edelman, Ostrovsky, Schwarz 2005]
  See also **Symmetric equilibrium** [Varian 2006]
  Fixed point where bidders don't want to move ↑ or ↓
  - Bidders first choose the optimal position for them: position i
  - Within range of bids that land them in position i, bidder chooses point of indifference between staying in current position and swapping up with bidder in position i-1

VCG

- Let us compute VCG payments for the example considered before.
  - Two slots and three bidders.
    - First slot 200 clicks per hour
    - Second slot gets 100.
    - Bidders 1, 2, and 3 have values per click of $10, $4, and $2, respectively.

- The second bidder's payment is $200, as before (externality imposed on 3 who loses $200 = value for him of the slot he does not get!)
- However, the payment of the first advertiser is now $600:
  - $200 for the externality that he imposes on bidder 3 (by forcing him out of position 2) +
  - $400 for the externality that he imposes on bidder 2 (by moving him from position 1 to position 2 and thus causing him to lose (200-100)=100 clicks per hour).
- Note that in this example, revenues under VCG are lower than under truth telling equilibrium of GSP!

Edelman, Ostrovsky, and Schwarz, Internet Advertising and the Generalized Second Price Auction, 2005

Not covered in class!!

Definitions

N objects and K bidders (advertisers)

α_i expected number of clicks in position i

s_k the value per click to bidder k

$(\alpha_i s_k - payments)$=bidder k's payoff from position i

$\alpha_1 > \alpha_2 ... > \alpha_N$

$b^{(j)}$ the bid of j-th highest bidder at a given time

$g(j)$ the identity j-th highest bidder

$g(1)$ gets the top slot, $g(2)$ the second slot etc

$p^{(i)}$=$\alpha_i b^{(i+1)}$ is total payment of bidder $g(i)$

$\alpha_i(s^{(i)} - b^{(i+1)})$ is $g(i)$'s payoff

Adaptation of VCG to sponsored search

The higher the bid, the better the position

The last bidder to get a slot pays same as in GSP

$p^{V,(i)}$ total payment of bidder in position i under VCG

$$p^{V,(i)} = (\alpha_i - \alpha_{i+1})b^{(i+1)} + p^{V,(i+1)}$$

Remark. If all advertisers were to bid the same amounts under the two mechanisms, then each advertiser's payment would be at least as large under GSP as under VCG.

Static GSP and Locally Envy-Free Equilibria

- At what values can GSP bids stabilize?
- Intuitively, these restrictions should apply:
  1. All bidders play static best response
  2. Locally envy free equilibrium = No bidder wants to switch with a bidder right above him

Lemma

- The outcome of any locally envy-free equilibrium of auction GSP is a stable assignment ➔ no one does better by unilaterally changing his bid

- Step 1 shows that locally envy-free equilibrium yields an assortative match (the higher bidders get higher positions)

- Step 2 shows that a bidder in position i does not want to "trade places" with bidders above him.

Part 1: Locally envy free implies assortative match (higher value → higher position)

s_i value of player in position i

$\alpha_i s_i - p_i \geq \alpha_{i+1} s_i - p_{i+1}$ (no wish to move one down)

$\alpha_{i+1} s_{i+1} - p_{i+1} \geq \alpha_i s_{i+1} - p_i$ (... or one position up)

$\Rightarrow \alpha_i s_i - \alpha_i s_{i+1} + \alpha_{i+1} s_{i+1} \geq \alpha_{i+1} s_i$

Since $\alpha_i > \alpha_{i+1}$, we have $s_i \geq s_{i+1}$

Part 2: No player wants to re-match with position above

Suppose bidder k is considering re-matching with position $m < k - 1$

$$\begin{aligned} \alpha_k s_k - p_k &\geq \alpha_{k-1} s_k - p_{k-1} \\ \alpha_{k-1} s_{k-1} - p_{k-1} &\geq \alpha_{k-2} s_{k-1} - p_{k-2} \\ &\vdots \\ \alpha_{m+1} s_{m+1} - p_{m+1} &\geq \alpha_m s_{m+1} - p_m. \end{aligned}$$

Since $\alpha_j > \alpha_{j+1}$ for any j, and $s_j > s_k$ for any $j < k$, the above inequalities remain valid after replacing s_j with s_k.

Doing that, then adding all inequalities up, yields $\alpha_k s_k - p_k \geq \alpha_m s_k - p_m$. Thus advertiser k cannot re-match profitably with position m, and we are done.

Summary

Key points

- Rudiments of Game theory, Auction theory, Mechanism Design
- Ordering of ads is the result of a complex interplay between IR considerations and Econ consideration
- GFP is not stable
- GSP is not truthful
- VCG is truthful and stable but not really used
- Sponsored Search mechanisms are still being tweaked → good area of research

Sponsored Search Economics Research

- Key papers, survey, and ongoing research workshop series
  - Edelman, Ostrovsky, and Schwarz, Internet Advertising and the Generalized Second Price Auction, 2005
  - Varian, Position Auctions, 2006
  - Lahaie, Pennock, Saberi, Vohra, Sponsored Search, Chapter 28 in Algorithmic Game Theory, Cambridge University Press, 2007
  - Workshops on Sponsored Search Auctions (1-6)
  - We'll put papers and pointers on web site.

Questions?

We welcome suggestions about all aspects of the course: msande239-aut0910-staff

Thank you!

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