IS2006

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16ième conférence canadienne annuelle sur les systèmes intelligents

Computers and Markets:

Exploring the Intersection of Computer Science, Microeconomics and Game Theory

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Multi Agent Systems

- Interface between
  - game theory/microeconomics
  - computer science
- **Defining characteristic**:
  - tackling both computational and incentive problems that arise when multiple self-interested agents interact
- Constraints from **Game Theory/Microeconomics**
  - Agents self-motivated
- Constraints from **Computer Science**
  - Not enough time, storage, bandwidth, …

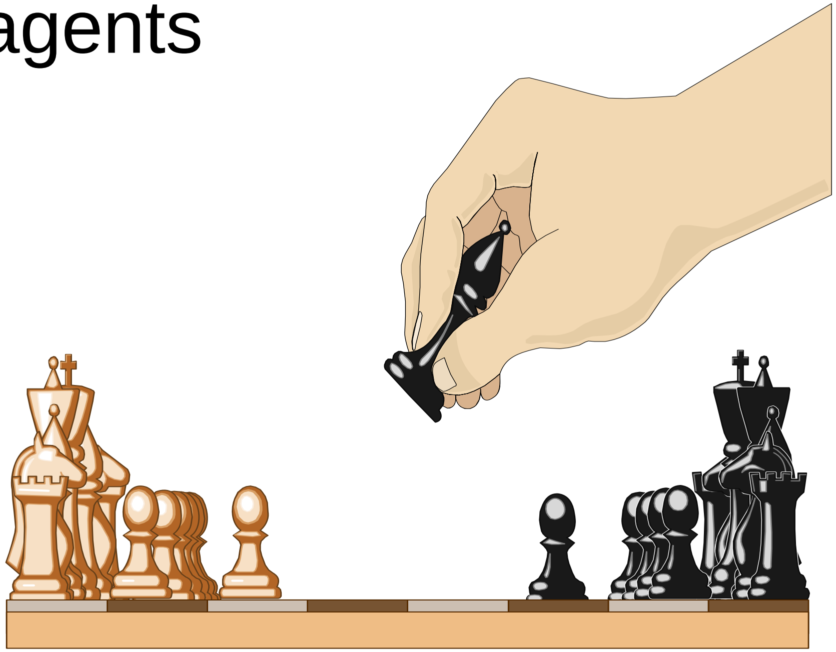
This Talk

- Introduction to work in multi agent systems
  - fielded **applications**
  - core **concepts**
  - recent and ongoing **research problems**

- Topics:
  1. **Game-theoretic models** of large-scale interactions
  2. **Auctions** (single-good; multiple-good)

Game Theory

- Mathematical study of interaction between **self-interested, rational** agents



- **Game:**
  - players/agents
  - actions
  - payoffs
- Strategies:
  - **pure strategy:** picking a single action
  - **mixed strategy:** randomizing over actions

Game Theory

- Should you send your packets using **correctly**-implemented TCP (which has a "backoff" mechanism) or using a **defective** implementation (which doesn't)?

- Consider this situa … game:
  - both use a correct … 1 ms delay
  - one correct, one de … rrect, 0 ms for defective
  - both defective: both …

	C	D
C	$-1, -1$	$-4, 0$
D	$0, -4$	$-3, -3$

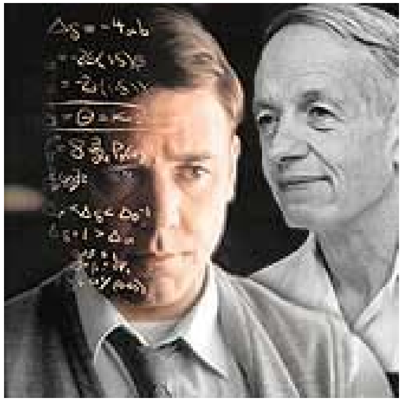
Analyzing Games

- TCP backoff game is a Prisoner's Dilemma
  - both players have a **dominant strategy**: defective
    - if player 2 plays C, D is player 1's best response
    - if player 2 plays D, D is player 1's best response
    - likewise for player 2

	C	D
C	$-1, -1$	$-4, 0$
D	$0, -4$	$-3, -3$

- Not all games are so simple to analyze
  - the best thing for one player to do can **depend** on what the other player does
    - rock-paper-scissors
    - poker
- What can we say about such games?

Game Theory



- Key insight:
  - don't just think about single players' actions
  - find strategy profiles where all players **simultaneously** play best responses

- Such a strategy profile is called a **Nash equilibrium**
  - at least one Nash equilibrium exists in every finite game
    - as long as agents are allowed to **randomize** their strategies
  - best known algorithms for finding Nash equilibrium require **exponential time**

Scaling up

- When we use game theory to **model real systems**, it's usually necessary to consider many more than two agents and actions

- **Examples:**
  - routing on the internet
  - commuters choosing the fastest route home
  - users sharing files P2P
  - students deciding which job skills to learn
  - businesses choosing where to locate

REPORT ON BUSINESS

MONDAY 01.05.06

Real estate agents are happy when Starbucks decides to open a new location in a neighbourhood in which they work. They say the upscale coffee chain's choice of where to locate is usually a harbinger of bidding wars to come.

Real estate agent Diane Mahon strolls past the site of a soon-to-open Starbucks coffee shop in Toronto's Leslieville area.

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COFFEE WARS
STARBUCKS COFFEE
Careful, the beverage you're about to enjoy is extremely hot.
Attention–La boisson que vous allez savourer est extrêmement chaude.
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CAFÉ

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category: Coffee Houses [Search]

e.g., "hotels in calgary" or "5000 dufferin street, toronto"

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A. Connoisseurs' **Coffee**
1075 Georgia Street West, Vancouver, BC V6E 3C9
(604) 683-1486

B. Melriches Coffeehouse
1244 Davie Street, Vancouver, BC V6E 1N3
(604) 689-5282

C. Hole In The Wall Cappuccino Bar
1030 Georgia Street West, Vancouver, BC V6E 2Y3
(604) 646-4653

D. Starbucks **Coffee** Co
1055 W Georgia, Vancouver, BC V5K 1A1
(604) 685-5882

E. Five Roses Bakery Cafe
1220 Bute Street, Vancouver, BC V6E 1Z8
(604) 669-8989

F. Starbucks **Coffee** Co
1095 Howe Street, Vancouver, BC V6Z 1P6
(604) 685-7083

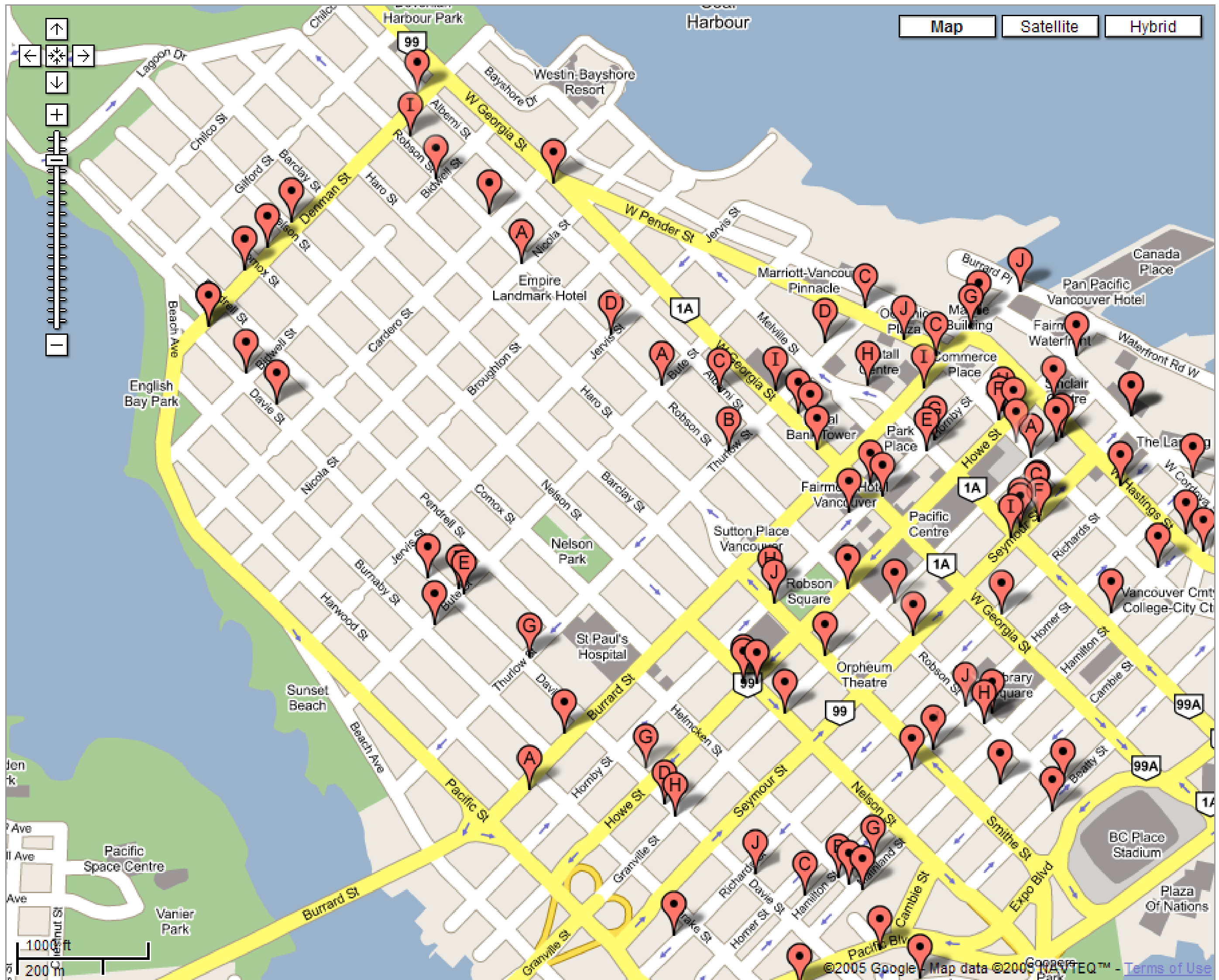
G. Uptown Espresso
808 Nelson Street, Vancouver, BC V6Z 2H2
(604) 689-1920

H. Caffe Artigiano
763 Hornby Street, Vancouver, BC V6Z 1S2
(604) 696-9222

I. Skyline Expresso
900 Howe Street, Vancouver, BC V6Z 2M4
(604) 683-4234

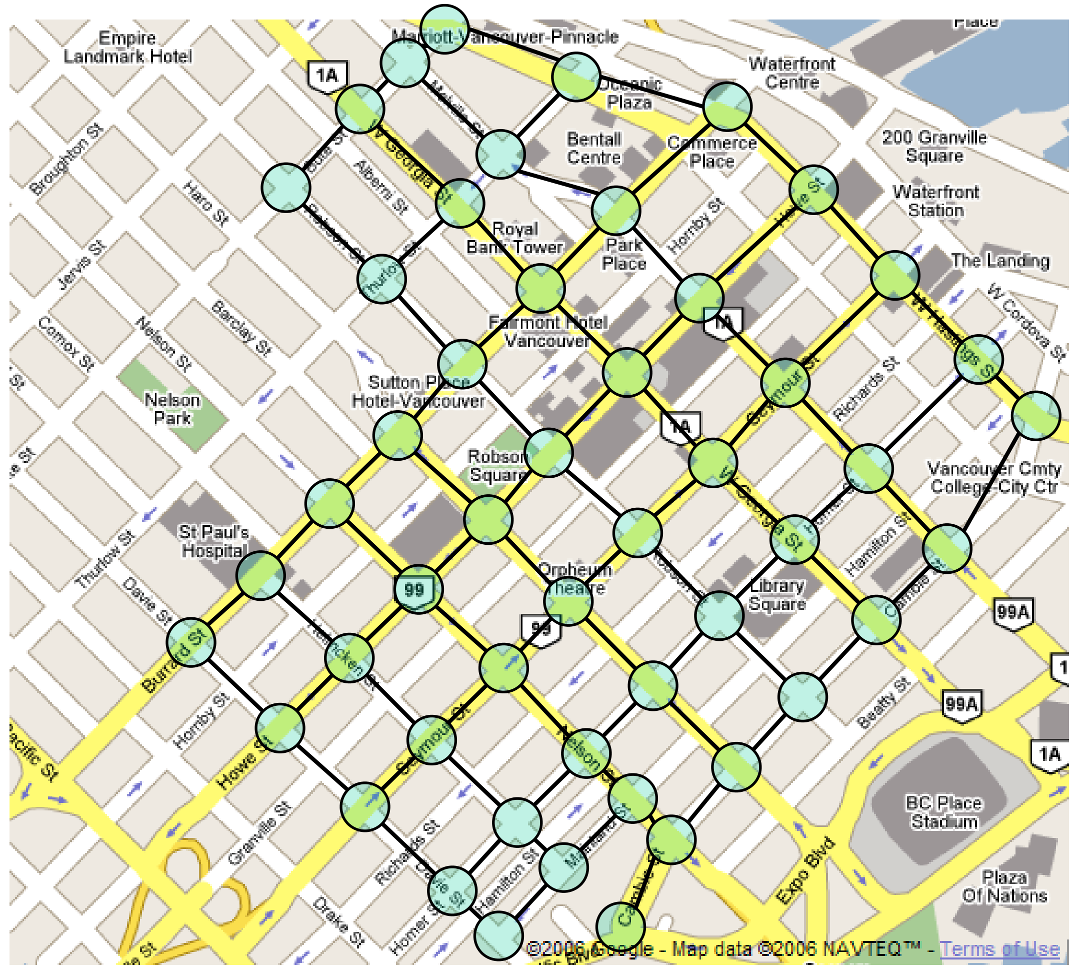
J. Farenheit Celsius **Coffee**
1225 Burrard Street, Vancouver, BC V6Z 1Z5
(604) 682-6675

Chicco Dall Oriente
1504 Robson Street, Vancouver, BC V6G 1C2

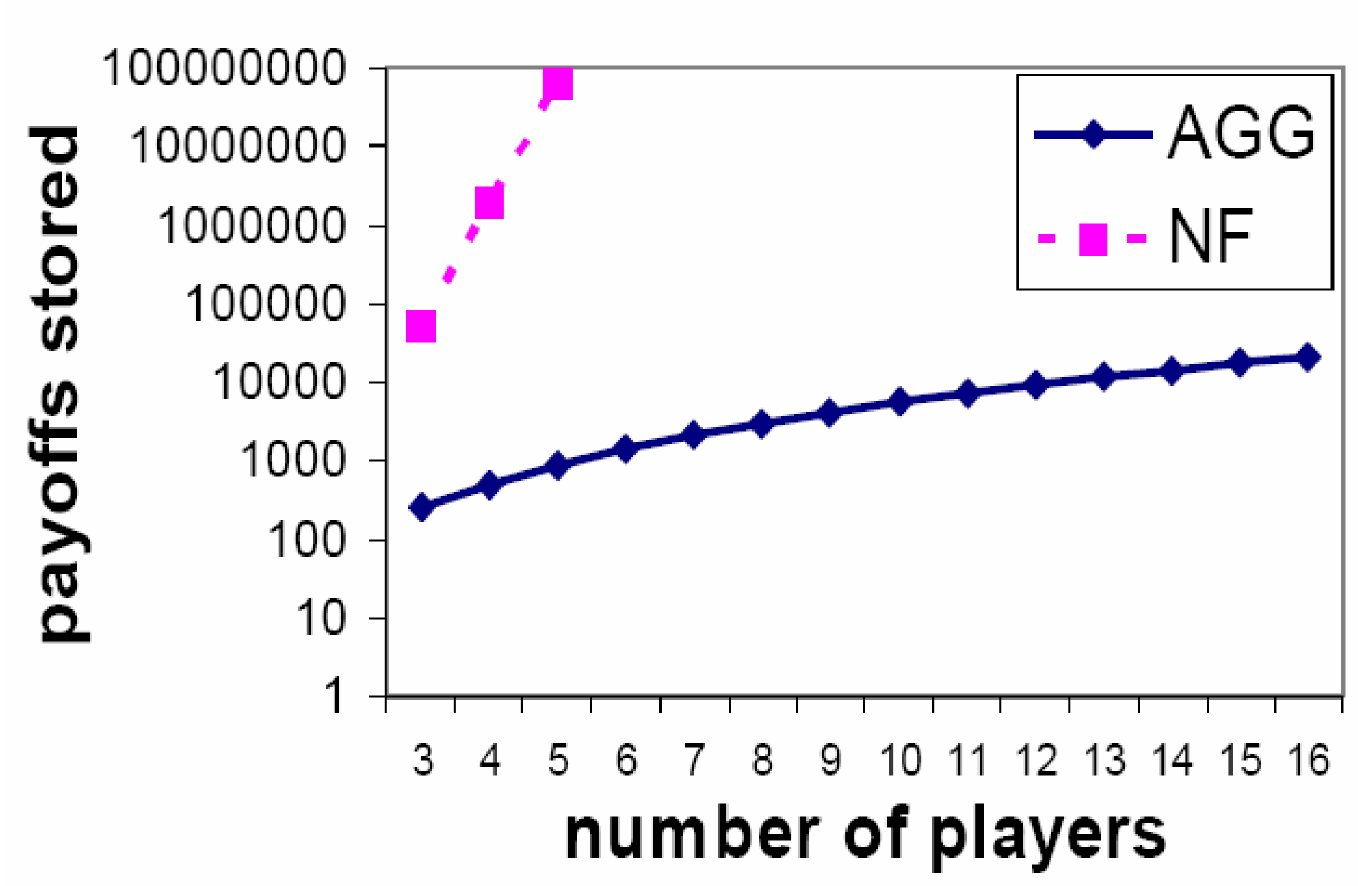


Action-Graph Games

- set of **players:** want to open coffee shops
- **actions:** locations where a shop could be opened
- **utility:** profitability of a location
  - depends only on number of other players who choose same or adjacent location



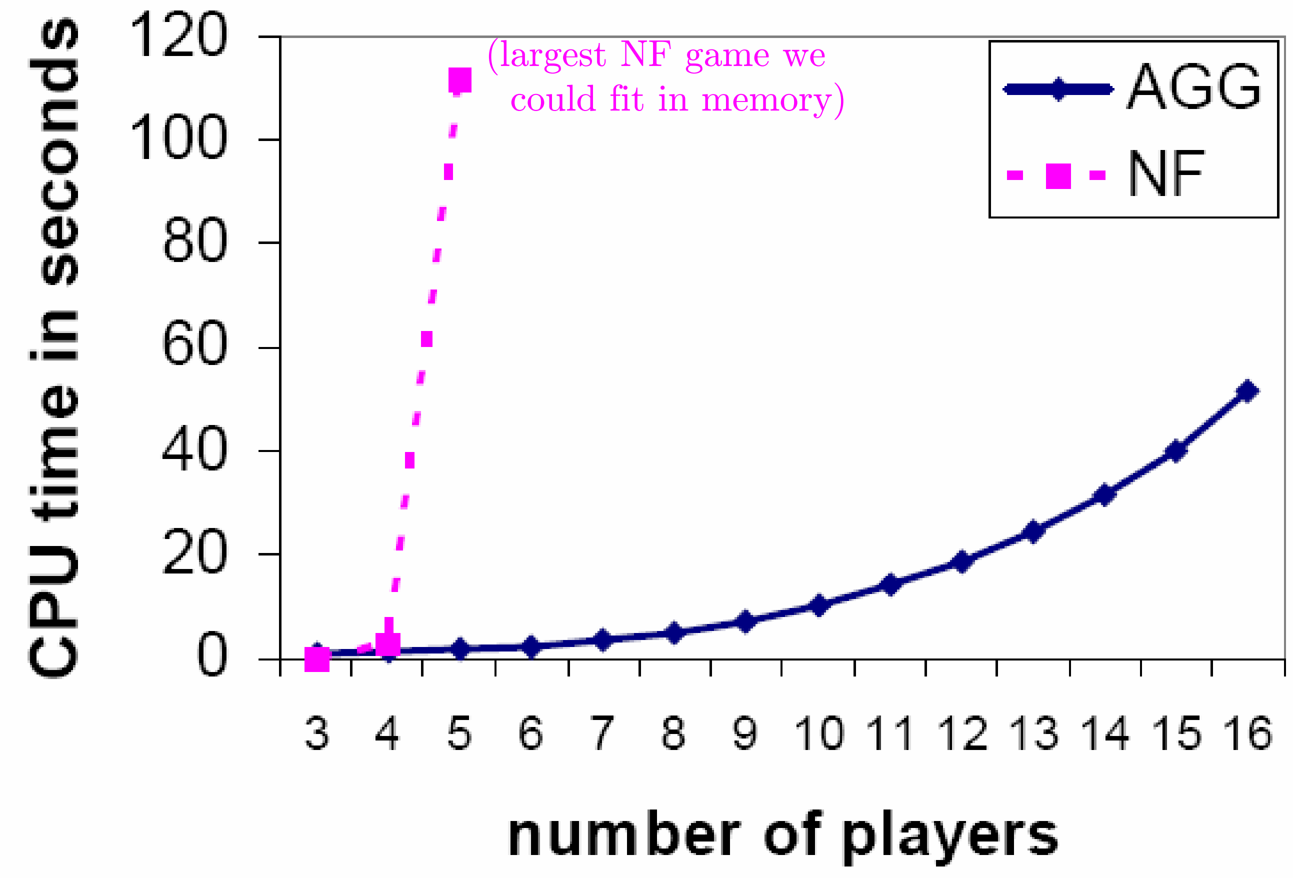
Experimental Results: Representation Size



Coffee shop game, 5 $\times$ 5 grid

NF grows exponentially; AGG grows polynomially

Experimental Results: Expected Payoff



Coffee Shop Game, 5×5 grid, 1000 random strategy profiles

NF grows exponentially; AGG grows polynomially

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  2. **Auctions** (single-good; multiple-good)

Why auctions?

- **Efficient resource allocation**
  - a core interest of computer science
  - auctions solve this problem when agents are self interested
- They're **big** ($$$)
  - and the internet is changing the way they're used

Virgin Mary In Grilled Cheese NOT A HOAX ! LOOK & SEE !

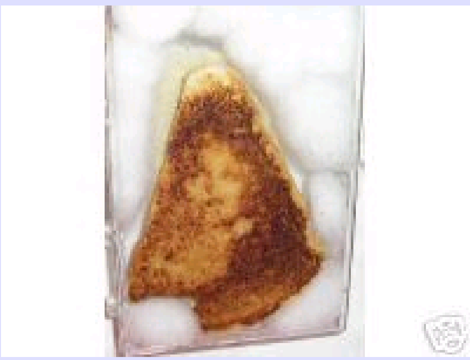
Item number: 5535890757

Bidder or seller of this item? Sign in for your status

Email to a friend | **Watch this item** in My eBay

Note: This listing is restricted to pre-approved bidders or buyers only.

Email the seller to be placed on the pre-approved bidder/buyer list.



Larger Picture

Current bid:	**US $7,600.00**
	Place Bid >
Time left:	**3 days 23 hours** 7-day listing Ends Nov-22-04 17:22:07 PST
Start time:	Nov-15-04 17:22:07 PST
History:	4 bids (US $3,000.00 starting bid)
High bidder:	User ID kept private

Seller information

dltdesigns2002 (47 ☆)

Feedback Score: 47

Positive Feedback: 96.1%

Member since Jul-03-02 in United States

Read feedback comments

Add to Favorite Sellers

Ask seller a question

View seller's other items

Safe Buying Tips

Auctions

- A **broader category** than often perceived
- Generally, auctions are **markets** in which:
  - agents make binding declarations of interest in one or more resources
  - these resources are allocated according to known rules
  - payments to/from agents may be imposed
- Modeled using **game theory**. Some new wrinkles:
  - infinite action space
  - imperfect information about payoffs (other agents' valuations)
- How do sellers choose the **particular auctions** they do?
  - mechanism design: "inverse game theory"

Second-Price Auctions

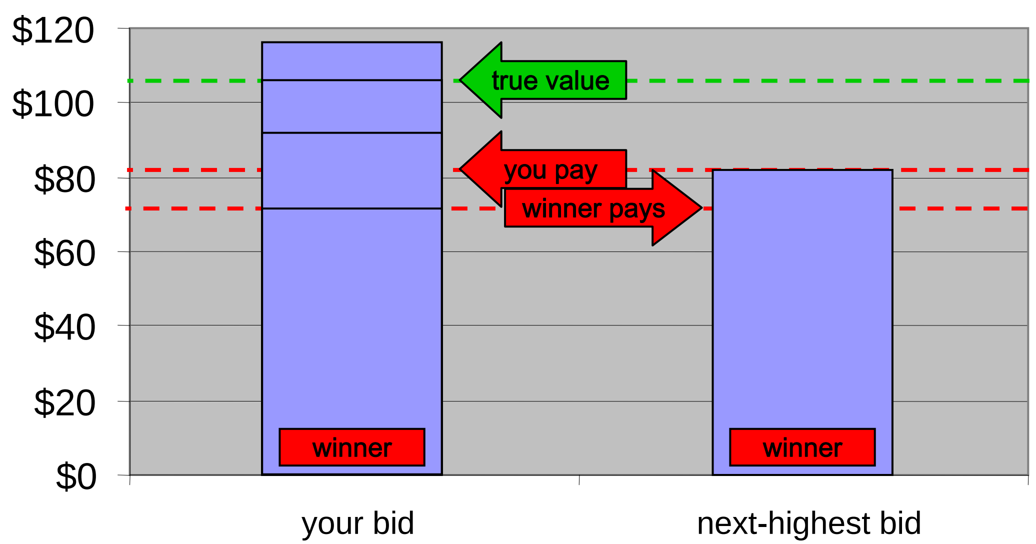
- An auction that might initially seem strange: **second-price**
  1. all bidders submit sealed bids
  2. the high bid wins
  3. the winner pays the **second**-highest bid amount

- **Theorem:** it is a dominant strategy in a second-price auction to bid your true value for the good.
- **Proof:**
  - **Case 1:** bidding truthfully **would** make you the high bidder
    - you can't gain by changing your bid
  - **Case 2:** bidding truthfully **would not** make you the high bidder
    - you can't gain by changing your bid

Second-Price Auctions

- **Theorem**: it is a dominant strategy in a second-price auction to bid your true value for the good.

- **Case 1:** bidding truthfully, you're the high bidder

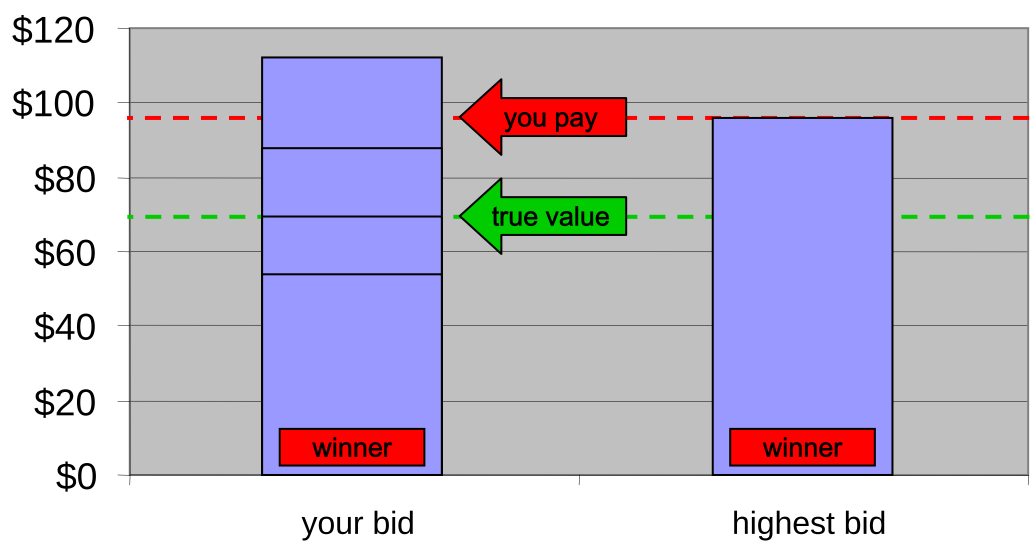


- bid more:
  - no difference (still win, pay same)
- bid less:
  1. no difference
  2. you lose

Second-Price Auctions

- **Theorem**: it is a dominant strategy in a second-price auction to bid your true value for the good.

- **Case 2:** bidding truthfully, you're **not** the high bidder



- bid **less**:
  - no difference
    (still lose, pay nothing)
- bid **more**:
  1. no difference
  2. you win, pay too much

Help

Bidding on eBay

eBay uses an automatic bidding system to make bidding on auctions more convenient and less time-consuming for buyers. There is nothing you have to set up in order to bid in this way. When you bid on an auction style listing you will be placing bids using this method. Practice bidding on eBay from this test auction!

Here's how bidding on eBay works:

1. When you place a bid, you enter the maximum amount you'd be willing to pay for the item. Your maximum amount is kept confidential from other bidders and the seller.
2. The eBay system compares your bid to those of the other bidders.
3. The system places bids on your behalf, using only as much of your bid as is necessary to maintain your high bid position (or to meet the reserve price). The system will bid up to your maximum amount.
4. If another bidder has a higher maximum, you'll be outbid. BUT, if no other bidder has a higher maximum, you win the item. And you could pay significantly less than your maximum price! This means you don't have to keep coming back to re-bid every time another bid is placed.

Google AdWords

kevinlb@gmail.com | Help | Contact us | Sign Out
Customer ID:696-0296

Campaig

Campaign S

Tools > Traf

- Ranking: descending by (quality score) × (bid amount)
  - quality score is click-through rate plus other measures of advertisement relevance

- “The AdWords Discounter will charge you the lowest CPC you can be charged while still maintaining your position”

ed Search

Search

Traffic E

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All estimate ... ositions may vary. To vie ... opriate Ad Group. Lea

Average CP

Estimated clicks per day: **309 - 445** (at a daily budget of $100.00)

Maximum CPC: .25 **Daily budget:** 100 Get New Estimates

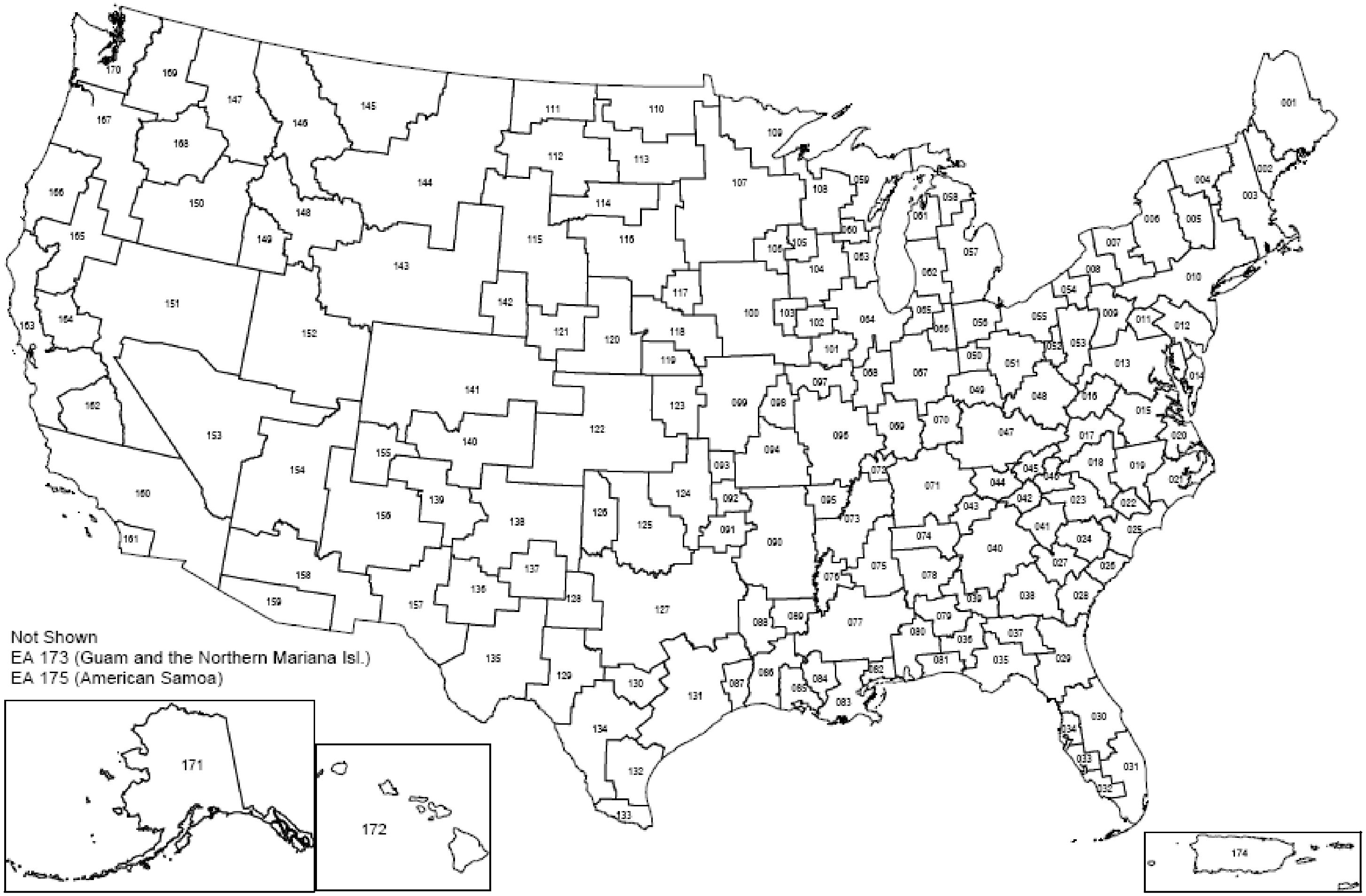
Keywords ▼	Search Volume	Estimated Avg. CPC	Estimated Ad Positions	Estimated Clicks / Day	Estimated Cost / Day
Search Total		**$0.10 - $0.23**	**4 - 6**	**309 - 445**	**$30 - $100**
computer science		$0.09 - $0.20	1 - 3	8 - 11	$1 - $3
game theory		$0.08 - $0.12	1 - 3	2	$1
insurance		$0.11 - $0.25	4 - 6	156 - 235	$20 - $60
kevin		$0.08 - $0.16	1 - 3	84 - 108	$7 - $20
mortgage		$0.11 - $0.25	4 - 6	59 - 88	$7 - $30
university of british columbia		$0.08 - $0.15	1 - 3	1	$1

Estimates for these keywords are based on clickthrough rates for current advertisers. Some of the keywords above are subject to review by Google and may not trigger your ads until they are approved. Please note that your traffic estimates assume your keywords are approved.

Beyond Single-Good Auctions

- What if the seller has **multiple distinct goods**?
  - ordinarily, sell them separately
- What if bidders **value the goods more in groups** than they value them individually?
  - e.g., a TV and VCR are worth more together than the sum of what they're each worth on their own
- Let's consider a **practical example**…

Economic Areas from FCC’s Auction #30: 39 GHz Band



Details of the FCC's Auction #30 (simplified)

- 175 economic areas, 14 licenses each: 2,450 goods
- **"Simultaneous Multiple Round"** auction:
  - all licenses sold simultaneously
  - multiple discrete rounds, in which bidders make bids on one or more licenses
  - after each round, provisionally winning bids announced
  - when nothing changes, auction ends
- Held April – May 2000
  - 29 winning bidders, revenue of **US $410,649,085**
  - many similar auctions held since; total revenue **> $40B**

Combinatorial Auctions

- **Exposure** problem
  - bidders: may bid aggressively to win a bundle, but win only some of the goods and thus pay too much
  - seller: inefficient allocation of resources
- Solution: **combinatorial auction**
  - sell all the goods in the same auction
  - allow bidders to bid on arbitrary bundles
  - winners: non-overlapping set of bundles with max value
  - generalized version of second-price works here
- FCC planned to run a (small) CA, but it's on hold…

Combinatorial Auctions: Ongoing Research

- **Determining the winners** of a CA
  - $\mathcal{NP}$-hard problem: weighted set packing. Approximation also hard.
  - economic incentives change when sub-optimal solutions are possible
- Designing new CA **mechanisms**
  - based on polynomial-time winner determination
  - ascending (information revelation)
  - revenue maximization
- Mitigating **communication complexity**
  - bidding languages; query-based mechanisms
- Developing **bidding strategies** for complex environments

Conclusions

1. **Game-theoretic models** of large systems
   - simulate user behaviour to understand how the system will behave
   - this should be part of the design process when a system's users are self-interested

2. **Resource allocation** among self-interested agents
   - auctions are a natural framework here
   - when only one good is sold, pretty straightforward
   - multiple goods: trickier to get right, but many benefits

http://www.cs.ubc.ca/~kevinlb

google://"Kevin Leyton-Brown"