Auctions

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Where are We?

Agent architectures (inc. BDI architecture)

Logics for MAS

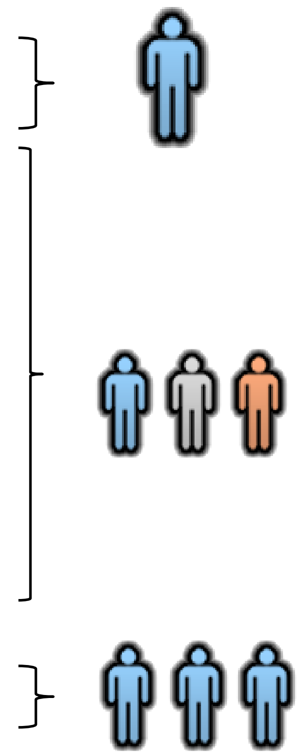
Non-cooperative game theory

Cooperative game theory

Auctions

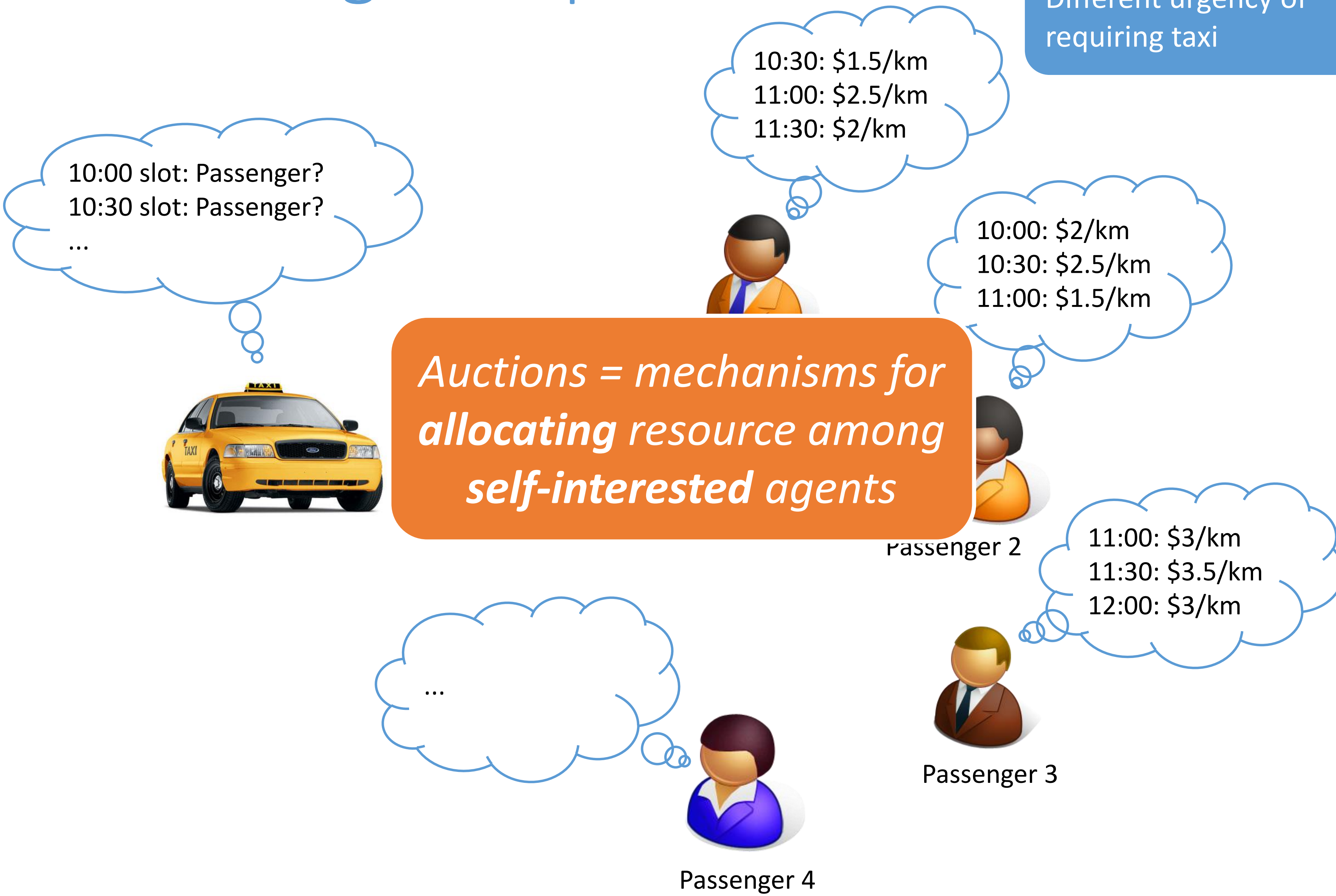
Social choice

Distributed constraint reasoning



Motivating Example

Taxi is a scarce resource
Different urgency of requiring taxi



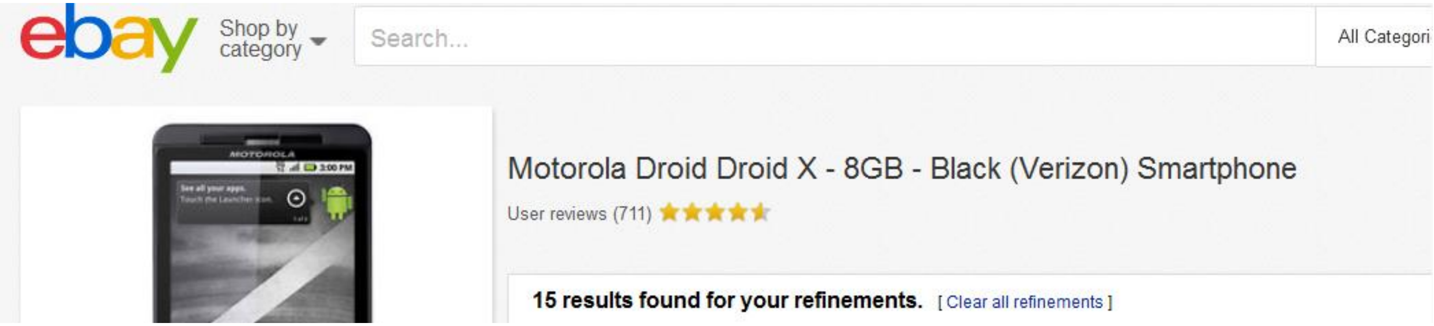
***Auctions** = mechanisms for **allocating** resource among **self-interested** agents*

Auctions: Traditional

Auctions used in Babylon as early as 500 B.C. but used to be rare (not so long ago)

Stage 0: No automation

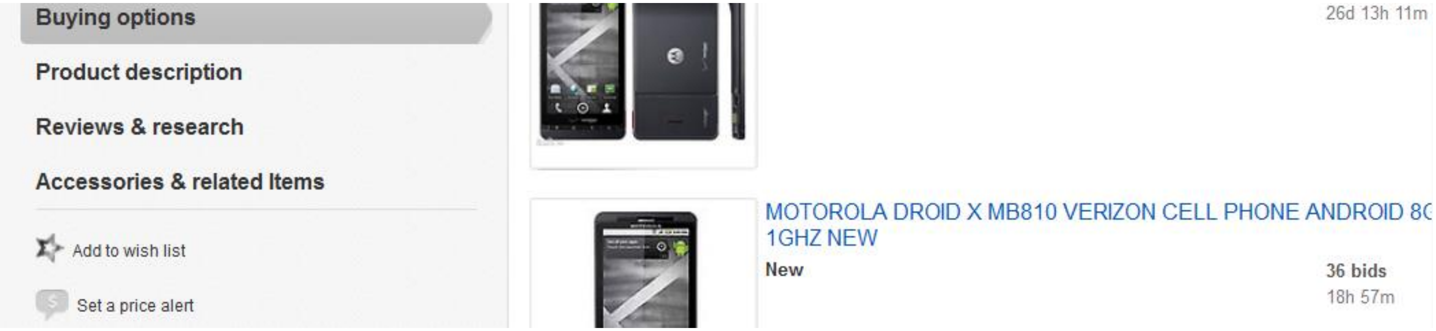
Auctions: Partial Automation



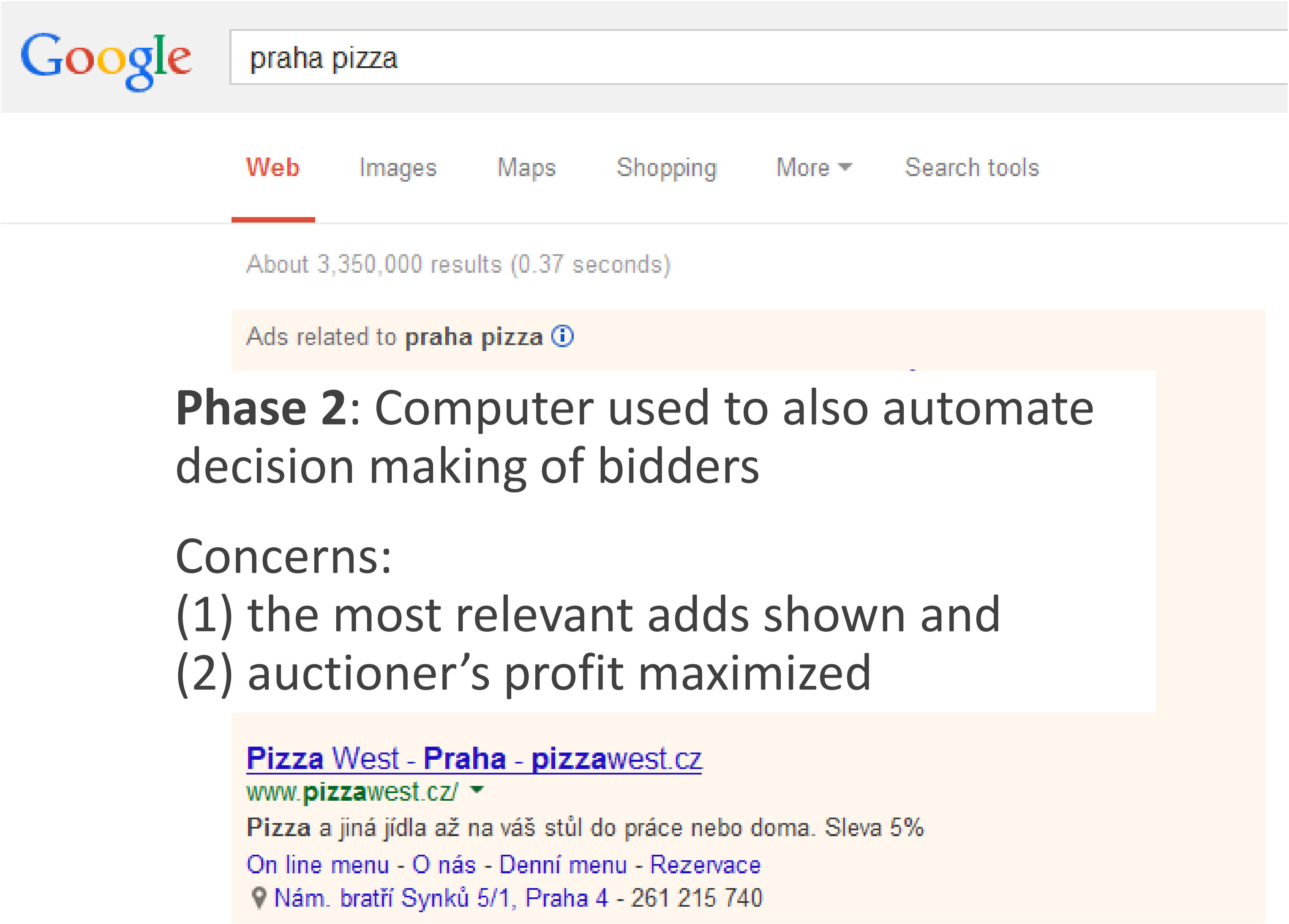
Grown massively with the Web/Internet

→ **Frictionless commerce**: feasible to auction things that weren't previously profitable

Phase 1: Computers used to manage auctions / **run** auction **protocols**



Auctions: (Almost) Full automation



Phase 2: Computer used to also automate decision making of bidders

Concerns:
(1) the most relevant adds shown and
(2) auctioner's profit maximized

Lecture Outline

Basic Definitions

Single-good auction mechanisms

Analysis of auction mechanisms

Combinatorial auctions

Summary

Basic Definitions

What is an auction?

*An **auction** is a protocol that allows agents (=bidders) to indicate their **interests** in one or more **resources** and that uses these indications of interest to determine both an **allocation** of resources and a set of **payments** by the agents.* [Shoham & Leyton-Brown 2009]

Where are auctions used nowadays?

Resource allocation

- Treasury auctions
- Right to drill oil, off-shore oil lease
- Use the electromagnetic spectrum
- Private and public goods and services acquisition
- Internet auctions

Market-based computing: The use of a market-based method, such as an auction to compute the outcome of a distributed problem.

- Air-conditioning control
- Production control
- Robot navigation
- Sensor networks

Why Auctions?

Market-based price setting: for objects of unknown value, the value is dynamically assessed by the market!

Flexible: any object type can be allocated

Can be **automated**

- use of simple rules reduces complexity of negotiations
- well-suited for computer implementation

Revenue-maximising and **efficient allocations** are achievable

Auctions Rules

Auction mechanism is **specified** by **auction rules**

Bidding rules: How offers are made:

- by whom
- when
- what their content is

Clearing rules: Who gets which goods (**allocation**) and what money changes hands (**payment**).

Information rules: What information about the state of the negotiation is revealed to whom and when.

Valuation Models

Common value: the good has the same value to all agents

- a 100 dollar note

Private value: an agent A's valuation of the good is independent from other agent's valuation of the good

- a painting, John Lennon's last dollar bill

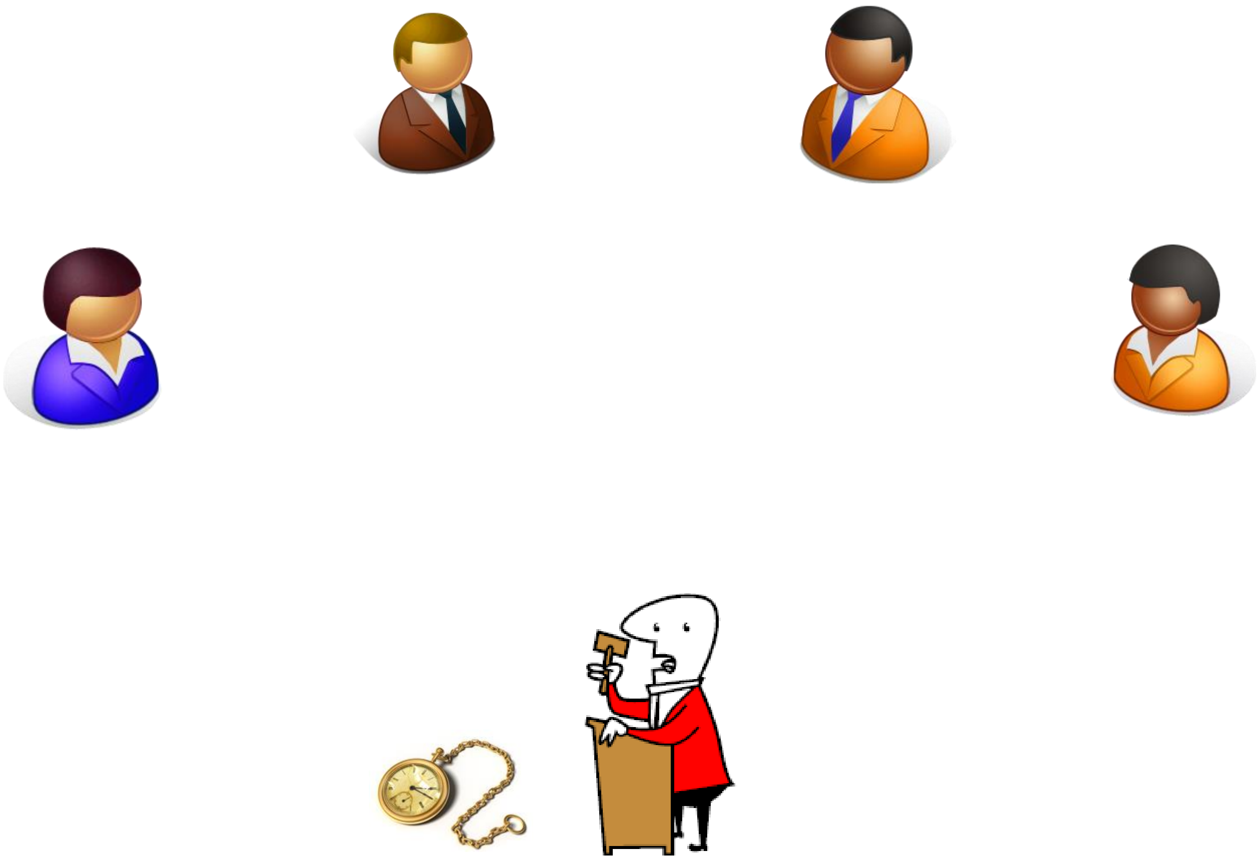
Correlated value: valuations of the good are related

- i.e. the more other agents are prepared to pay, the more agent A prepared to pay.
- i.e. purchase of items for later resale

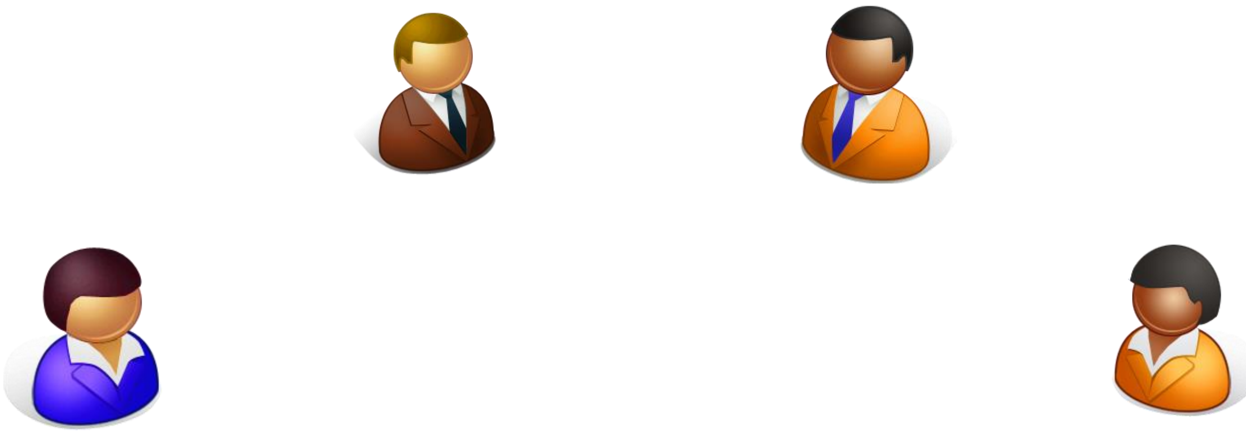
Agent's payoff from participating in an auction

- if winner: payoff = item's valuation – price paid for the item
- if not winner: payoff = zero

Single Good Auctions



Multi-Unit Auctions

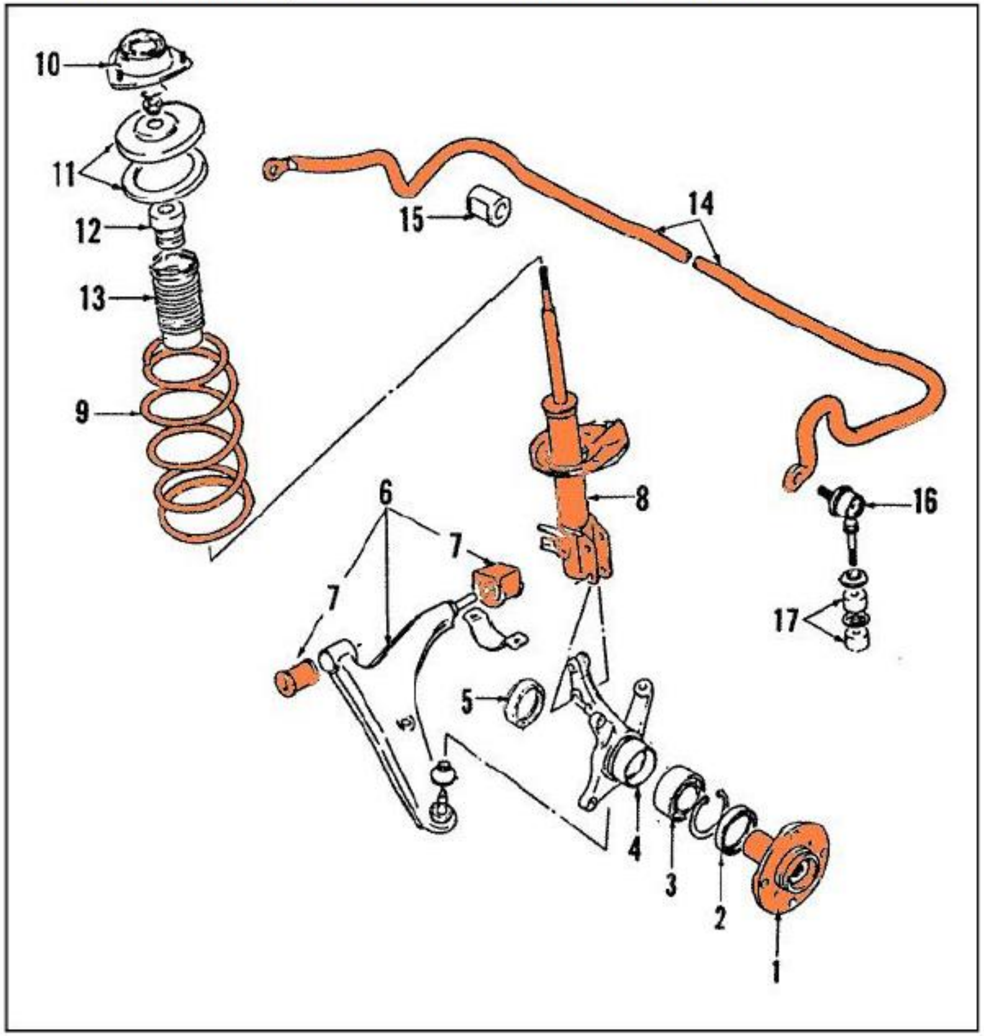


single-unit vs. multiple-unit demand

Multi-Item Auctions

Reverse Auctions

FRONT SUSPENSION, FRONT WHEEL BEARING ACQUISITION



- Goal: Buy parts to produce a front suspension.
- The buyer issues a request for bids to his providers.

PART #	DESCRIPTION
1	FRONT HUB
7	LOWER CONTROL ARM BUSHINGS
8	STRUT
9	COIL SPRING
14	STABILIZER BAR

Multi-Attribute Auctions

Negotiation over further **attributes beyond price**

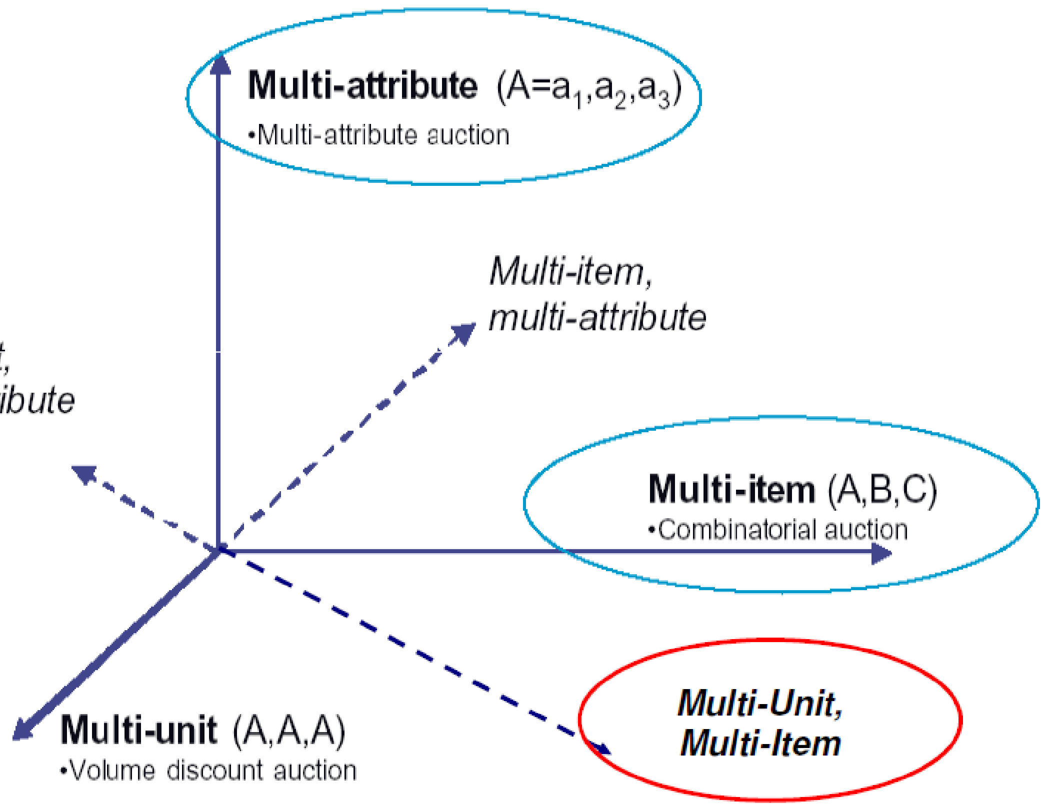
- e.g. color, weight, or delivery time

For instance: Provider John Doe offers to deliver a stainless-steel stabilizer bar that weighs 500 g at the cost of 200 EUR by July 18th 2011.

Promise **higher market efficiency** through a more **effective information exchange** of buyer’s preferences and supplier’s offerings.

Least understood type of auctions.

Auction Mechanism Taxonomy



Other: First-price vs. *k*-th price, open cry vs. sealed bid, single. vs. double-sided, sell-side vs. buy-side

Single-Item Auctions

Basic Auction Mechanisms

English

Japanese

Dutch

First-Price

Second-Price

English Auction

Auctioneer starts the bidding at some **reservation price**

Bidders then shout out **ascending** prices

- minimum increments

Once bidders stop shouting, the *high bidder* gets the good at that price

Japanese Auctions

Same as an English auction except that the auctioneer calls out the prices

All bidders start out **standing**

When the price reaches a level that a bidder is not willing to pay, that bidder **sits down**

Once a bidder sits down, they **can't get back up** the **last** person **standing** gets the good

Dutch Auction

The auctioneer starts a clock at some high value; it descends

At some point, a bidder shouts "mine!" and gets the good at the price shown on the clock

Good when items need to be sold quickly (similar to Japanese)

No information is given away during auction

First-, Second-Price Sealed Bid Auctions

First-price sealed bid auction

- bidders write down bids on pieces of paper
- auctioneer **awards** the good to the bidder with the **highest bid**
- that bidder pays the amount of **his bid**

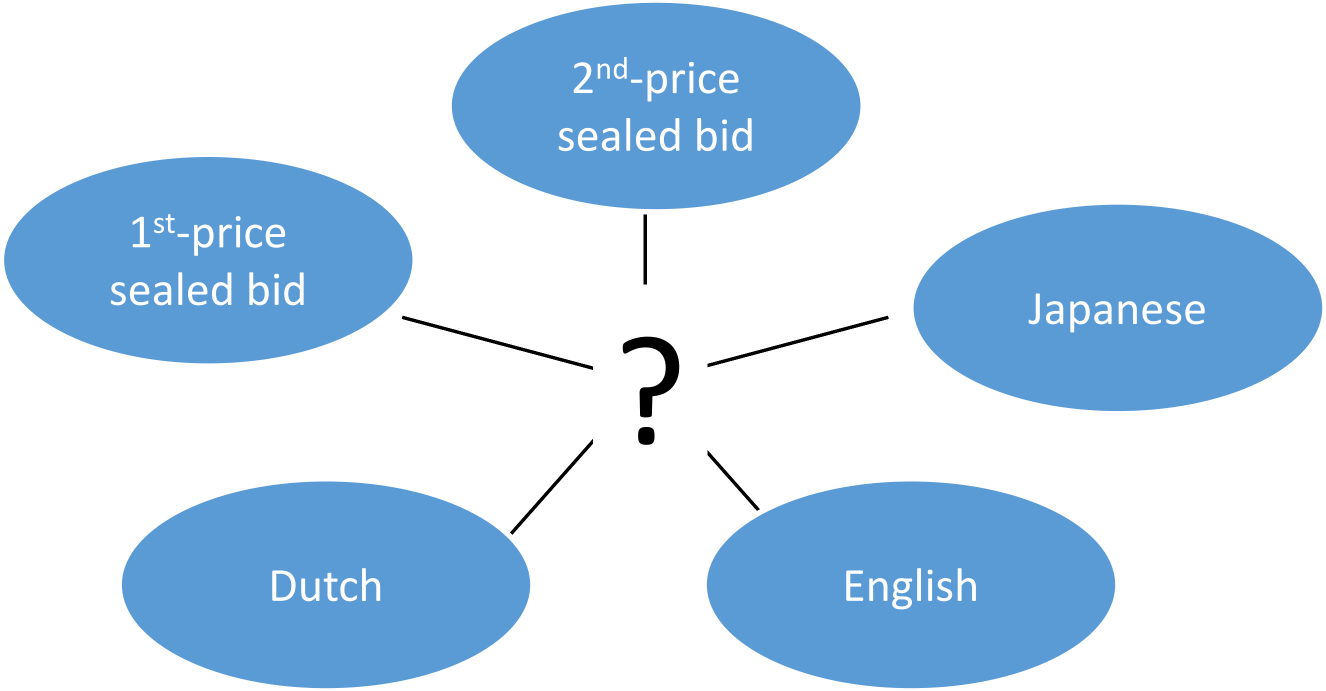
Second-price sealed bid auction (Vickerey auction)

- bidders write down bids on pieces of paper
- auctioneer **awards** the good to the bidder with the **highest bid**
- that bidder pays the amount bid by **the second-highest** bidder

Intuitive Comparison

	English	Dutch	Japanese	1^{st}-Price	2^{nd}-Price
Duration	#bidders, increment	starting price, clock speed	#bidders, increment	fixed	fixed
Info Revealed	2^{nd}-highest val; bounds on others	winner's bid	all val's but winner's	none	none
Jump bids	yes	n/a	no	n/a	n/a
Price Discovery	yes	no	yes	no	no

Analysing Auctions



Are there fundamental similarities / differences between mechanisms described?

(Desired) Properties

Strategy: existence of dominant strategy

Truthfulness: bidders are incentivized to bid their true valuations

Efficiency (Pareto-optimality): the aggregated utility, measured as the sum of valuations, is maximized

Optimality: maximization of seller's revenue

Manipulation vulnerability: Lying auctioner, Shills, Bidder collusion

Other consideration: communication complexity, private information revelation, ...

Dutch and First-price Sealed Bid

Strategically equivalent: an agent bids without knowing about the other agents’ bids

- a bidder must decide on the amount he's willing to pay, conditional on having placed the highest bid

Differences

- First-price auctions can be held asynchronously
- Dutch auctions are fast, and require minimal communication

Bidding in Dutch / First Price Sealed Bid?

Bidders strategy?

- Bidders would normally bid less than own valuation but just enough to win ⇒ **not incentive compatible** and incentive to counter-speculate

Bidders don't have a **dominant strategy** any more:

- there's a **trade-off** between **probability of winning** vs. **amount paid** upon winning
- **individually optimal** strategy depends on **assumptions** about **others' valuations**

Theorem

In a first-price sealed bid auction with n **risk-neutral** agents whose valuations $v_1, v_2, \ldots, v_n$ are **independently** drawn from a **uniform distribution** on the **same** bounded **interval** of the real numbers, the **unique** symmetric **equilibrium** is given by the **strategy profile** $\left(\frac{n-1}{n}v_1, \ldots, \frac{n-1}{n}v_n\right)$.

Second-Price Sealed Bid

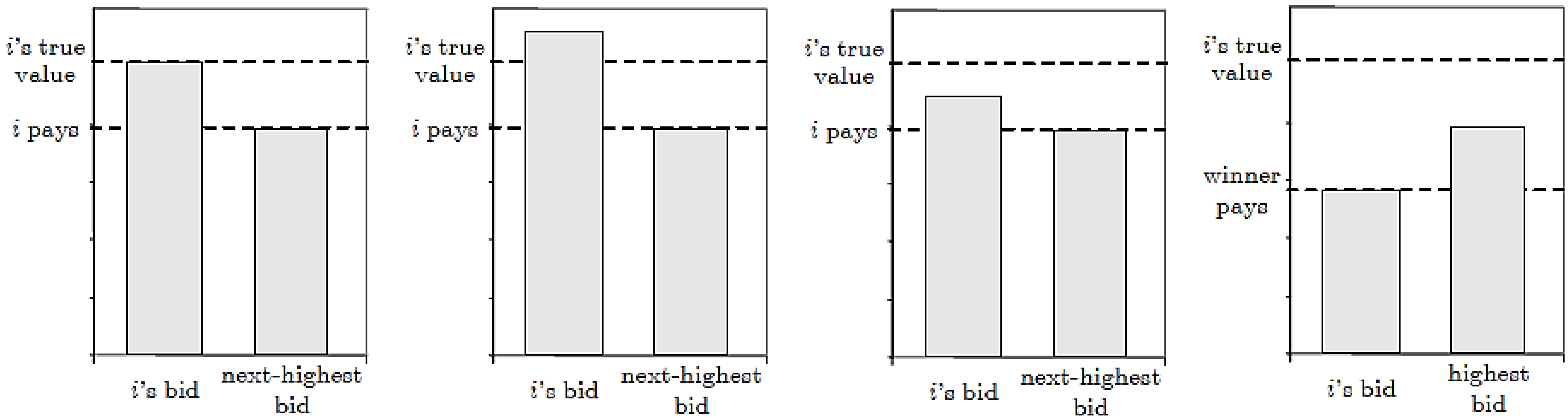
Theorem

Truth-telling is a **dominant strategy** in a second-price sealed bid auction.

Proof: Assume that the other bidders bid in some arbitrary way. We must show that i's best response is always to bid truthfully. We'll break the proof into two cases:

- Bidding honestly, i would win the auction
- Bidding honestly, i would lose the auction

Second-Price Sealed Bid Proof



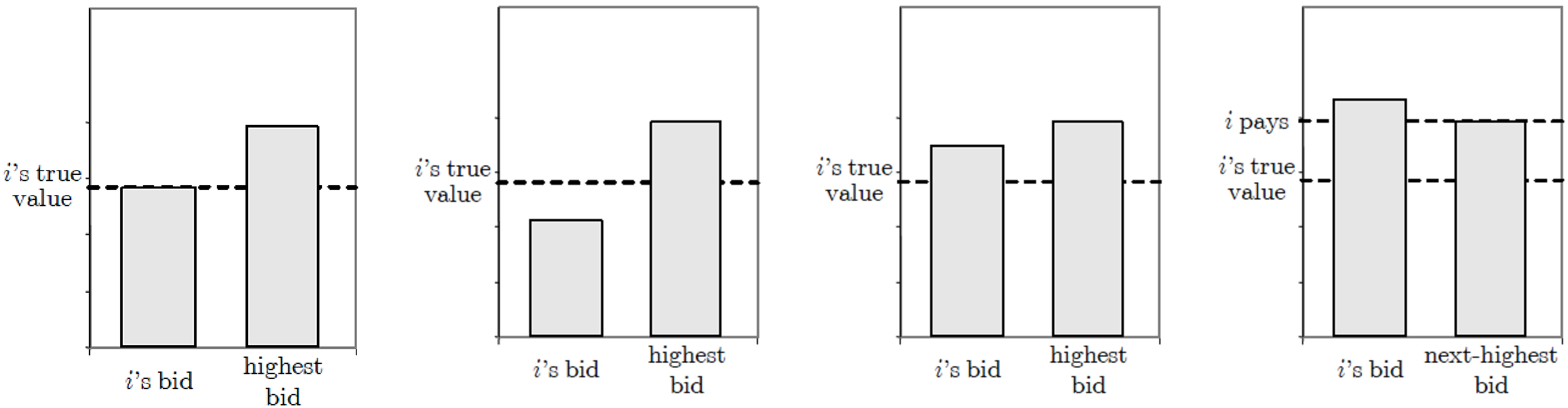
Bidding honestly, i is the winner

If i bids higher, he will still win and still pay the same amount

If i bids lower, he will either still win and still pay the same amount. . .

... or lose and get utility of zero.

Second-Price Sealed Bid Proof



Bidding honestly, i is not the winner

If i bids lower, he will still lose and still pay nothing

If i bids higher, he will either still lose and still pay nothing...

... or win and pay more than his valuation.

Second-Price Sealed Bid

Advantages:

- Truthful bidding is dominant strategy
- No incentive for counter-speculation
- Computational efficiency

Disadvantages:

- Lying auctioneer
- Bidder collusion self-enforcing

Unfortunately, the auction is not very popular in real life due to its counter-intuitiveness

- but very successful in computational auction systems

English and Japanese Auctions Analysis

A much more complicated **strategy space**

- extensive form game
- bidders are able to condition their bids on information revealed by others
- in the case of English auctions, the ability to place jump bids

Intuitively, though, the **revealed information** doesn't make any **difference** in the **independent-private value** (IPV) setting.

- proxy bidding

English and Japanese Auctions Analysis

Theorem

Under the **independent private values** model (IPV), it is a **dominant strategy** for bidders to bid **up to** (and not beyond) their valuations in both Japanese and English auctions.

In correlated-value auctions, it can be worthwhile to counter=speculate

Revenue Equivalence

Which auction should an auctioneer choose?

To some extent, it doesn't matter...

Theorem (Revenue Equivalence)

Assume that each of n **risk-neutral** agents has an **independent private valuation** for a single good at auction, drawn from a **common cumulative distribution** $F(v)$ that is **strictly increasing** and **atomless** on $[\underline{v}, \overline{v}]$. Then any auction mechanism in which

1. the good will be allocated to the agent with the highest valuation; and
2. any agent with valuation $\underline{v}$ has an expected utility of zero

yields the **same expected revenue**, and hence results in any bidder with valuation v making the same expected payment.

Further Issues

Pareto efficiency: all protocols allocate auction item to the bidder who values it most (in isolated private value/common value auctions)

Revenue equivalence in terms of expected revenue among all protocols if valuations independent, bidders risk-neutral and auction is private value

Winner's curse in correlated/common value auctions: If I win, I always know I won't get to re-sell at the same price, because others value the goods less!

Undesirable private **information revelation**

- Example: truthful bidding in EA/VA may lead sub-contractors to re-negotiate rates after finding out that price was lower than they thought

Multi-Unit Auction

Position Auctions

Multi-Item Auctions

Combinatorial Auctions

Auctions for **bundles of goods**

Let $\mathcal{Z} = \{z_1, \ldots, z_n\}$ be a set of items to be auctioned

A **valuation function** $v_i: 2^{\mathcal{Z}} \mapsto \Re$ indicates how much a bundle $Z \subseteq \mathcal{Z}$ is worth to agent i

Properties

- **normalization**: $v(\emptyset) = 0$
- **free disposal**: $Z_1 \subseteq Z_2$ implies $v(Z_1) \leq v(Z_2)$

Combinatorial auctions are interesting when the valuation function is **not additive**

- **complementarity**: $v(Z_1 \cup Z_2) > v(Z_1) + v(Z_2)$ (e.g. left and right shoe)
- **substitutability**: $v(Z_1 \cup Z_2) < v(Z_1) + v(Z_2)$ (e.g. cinema tickets for the same time)

Allocation

Allocation is a list of sets $Z_1, \ldots, Z_n \subseteq \mathcal{Z}$, one for each agent i such that $Z_i \cap Z_j = \emptyset$ for all $i \neq j$ (i.e. not good allocated to more than one agent)

Allocation is determined by the auction mechanism

- trivial for single-good auctions

How to define allocation for combinatorial auction?

Maximize **social welfare**: $U(Z_1, \ldots, Z_n, v_1, \ldots, v_n) = \sum_{i=1}^{n} v_i(Z_i)$

Winner Determination Problem

Definition

The **winner determination problem** for a combinatorial auctions, given the agents' declared valuations v_i is to find the social-**welfare-maximizing allocation** of goods to agents. This problem can be expressed as the following integer program

$$\text{maximize} \sum_{i \in N} \sum_{Z \subseteq \mathcal{Z}} v_i(Z) x_{Z,i}$$

$$\text{subject to} \sum_{Z, j \in Z} \sum_{i \in N} x_{Z,i} \leq 1 \quad \forall j \in \mathcal{Z}$$

$$\sum_{Z \subseteq \mathcal{Z}} x_{Z,i} \leq 1 \qquad \forall i \in N$$

$$x_{Z,i} = \{0,1\} \qquad \forall Z \subseteq \mathcal{Z}, i \in N$$

Issues with Winner Determination

Communication complexity

Computation complexity

- Solution 1: Require bids to come from a restricted set, guaranteeing that the WDP can be solved in polynomial time
  - problem: these restricted sets are very restricted...
- Solution 2: Use heuristic methods to solve the problem
  - this works pretty well in practice, making it possible to solve WDPs with many hundreds of goods and thousands of bids.

Bidding Languages

Exchanges

Summary

Auctions Summary

Auctions are mechanisms for **allocating scarce resource** among **self-interested agent**

Mechanism-design and game-theoretic perspective

Vast range of auctions mechanisms: English, Dutch, Japanese, First-price sealed bid, Second-price sealed bid

Desirable properties: truthfulness, efficiency, optimality, ...

Rapidly expanding list of **applications** worth billions of dollars

MAS Course Summary

Logics for MAS: Formally describe and analyze agents

Agent architectures: acting rationally in an environment

Non-cooperative game theory: acting rationally in strategic interactions

Coalitional game theory: making rational decisions about collaboration

Distributed constraint reasoning: coordinating cooperative action

Social choice: making fair collective choices

Auctions: allocating scarce resources

Many topics not covered: bargaining / negotiation, multiagent learning, multiagent planning, mechanism design, agent-oriented software engineering

Many interconnections

Final Notes

Rapidly evolving field with the exploding number of applications
→ http://agents.cz for (Ph.D.) opportunities

Exam

- 6th Jan + 2 more dates
- mostly written

Survey/Anketa: be as specific possible: we *do* care

Going Beyond IPV

common value model

- motivation: oil well
- winner's curse
- things can be improved by revealing more information

Affiliated Values

- Definition: a high value of one bidder's signal makes high values of other bidders' signals more likely
  - common value model is a special case
- generally, ascending auctions lead to higher expected prices than second price, which in turn leads to higher expected prices than first price
  - intuition: winner's gain depends on the privacy of his information.
  - The more the price paid depends on others' information (rather than expectations of others' information), the more closely this price is related to the winner's information, since valuations are affiliated
  - thus the winner loses the privacy of his information, and can extract a smaller "information rent"