Mechanism Design for Dynamic Double Auctions

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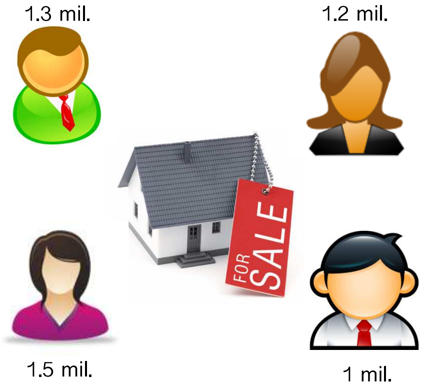
Ph.D. Thesis Defence

An Auction



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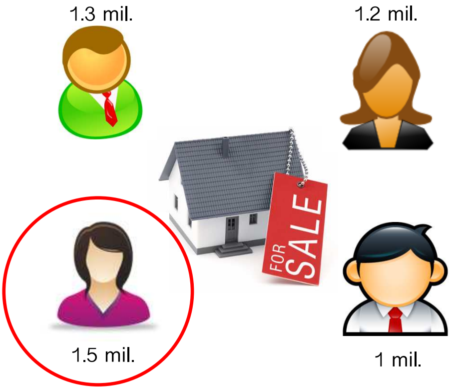
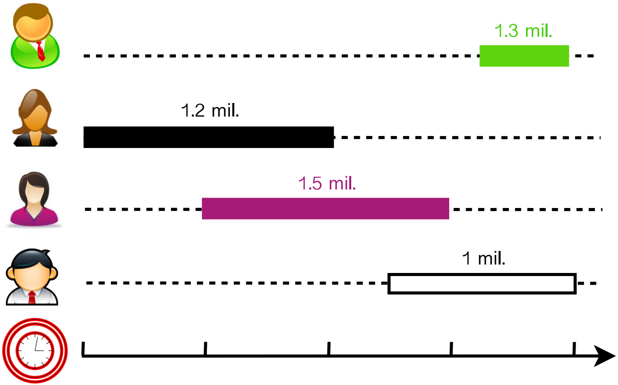
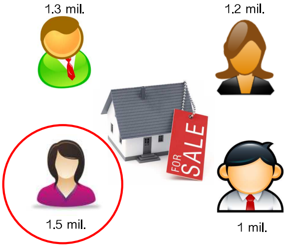


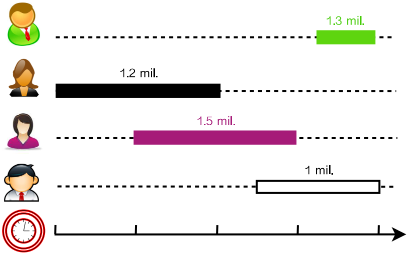
An Online Auction



An Online Auction



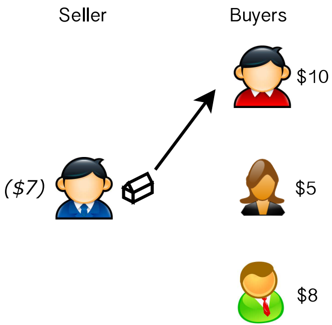
Static Auction



Online Auction

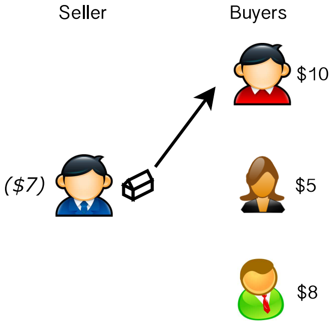
Double Auction

One-sided Auction

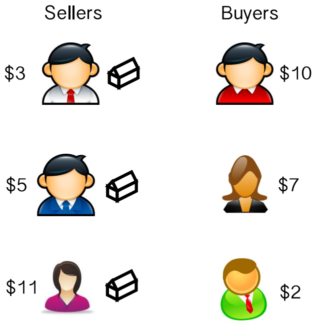


Double Auction

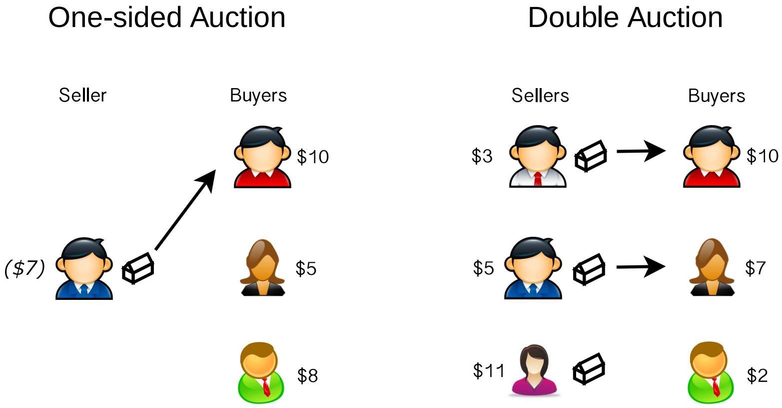
One-sided Auction



Double Auction



Double Auction



Online Double Auction

Online Double Auction?

- traders (buyers & sellers) dynamically arrive and depart
- traders' valuation (reserve price) varies over time

Real Applications

- Stock Exchange
- Futures Exchange
- Group Buying

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Outline

Outline

The Basic Setting

The roles in a double auction:

1. multiple buyers
   - *submit buy orders (called bids)*
2. multiple sellers
   - *submit sell orders (called asks)*
3. auctioneer (or market owner)
   - *match bids and asks*
   - *calculate prices*

The Basic Setting

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2. multiple sellers
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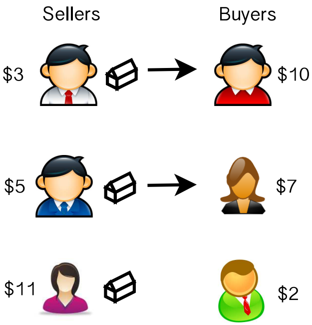
   - *match bids and asks*
   - *calculate prices*

What challenge us?

- How to match bids and asks?
- How to set exchange prices?



Why are they so challenging?

The decision-making of the auctioneer

- depends on traders' private information, called type:
  - variable valuation of the commodity/goods
  - dynamical arrival and departure time
  - ...
- has to satisfy certain properties, e.g. truth-telling, efficiency
- faces uncertainty

Mechanism Design

Mechanism design answers...

How to design a mechanism which leads to a desired outcome?

A double auction mechanism consists of...

- an allocation policy, i.e. a matching between asks and bids
- a payment policy

What are the Desired Outcomes?

Question

What properties should a double auction satisfy?

What are the Desired Outcomes?

Question

What properties should a double auction satisfy?

IC Incentive Compatibility (or Truthfulness)

- telling truth is each trader's dominant strategy

Why IC is important?

- simplifies traders' decision-making
- the base to get other properties, e.g. efficiency

What are the Desired Outcomes?

Question

What properties should a double auction satisfy?

IR Individual Rationality

- no trader receives negative utility/profit

Why IR is important?

- traders are not forced to participate

What are the Desired Outcomes?

Question

What properties should a double auction satisfy?

Eff. Efficiency (or Social Welfare Maximisation)

- goods are allocated to the traders who value them most highly

What are the Desired Outcomes?

Question

What properties should a double auction satisfy?

BB Budget Balance (Weakly Budget Balance)

- no money is injected into or removed from the mechanism

What are the Desired Outcomes?

Question

What properties should a double auction satisfy?

Liq. Liquidity Maximisation

- (mainly) the number of transactions

What are the Desired Outcomes?

Question

What properties should a double auction satisfy?

Pro. (Auctioneer's) Profit Maximisation

- price differences between matched buyers and sellers

What are the Desired Outcomes?

Question

What properties should a double auction satisfy?

Com. Computational Complexity

- how much time a mechanism takes to compute a solution

What are the Desired Outcomes?

Mechanism (DA)		IC	IR	Eff.	BB	Liq.	Pro.	Com.
		Properties						
Mechanism (DA)	Allocation (Matching)	X	X	X		X		X
	Payment	X	X		X		X	X

- **IC** Incentive Compatibility (or Truthfulness)
- **IR** Individual Rationality
- **Eff.** Efficiency (or Social Welfare Maximisation)
- **BB** Budget Balance (Weakly Budget Balance)
- **Liq.** Liquidity Maximisation
- **Pro.** (Auctioneer's) Profit Maximisation
- **Com.** Computational Complexity

The Problem

Design Online Double Auctions, where

- traders dynamically arrive and departure the auction
- traders' valuation is changing over time

Real Applications

- Stock Exchange
- Futures Exchange
- Group Buying

An Incremental Approach

- Static
  - single-unit demand/supply with fixed valuation
- Approaching Online (without uncertainty)
  1. with temporal constraints, *e.g. futures exchange*
     - temporal constraints limit the allocation/matching
  2. under group buying, *e.g. Groupon*
     - valuation varies in terms of the number of goods exchanged
- Online (with uncertainty), *e.g. stock exchange*
  1. dynamic arrival & departure + fixed valuation
  2. dynamic arrival & departure + dynamic valuation

The Results

Environments	Mechanism		Properties						
	Allocation	Payment	IC	IR	Eff.	BB	Liq.	Pro.	Com.
static	Equilibrium Matching				X			O	
	Maximal Matching						X		X
with temporal constraints	Augmentation-based		X	X	X				X
under group buying	*Existence*		X	X		X			
	Impossibility (cond.)		X	X		X			
	Second Price		B	X		X			
	Second Price Plus ...		S	X		X			
	Impossibility		X	X		X	X		
dynamic arrival & departure fixed valuation	*Impossibility*		X		X				
	Greedy (cond.)		X	X	X				
	Reduction (cond.)		X	X	X				
dynamic arrival & departure dynamic valuation	Behaviour-based			X	O		O	O	

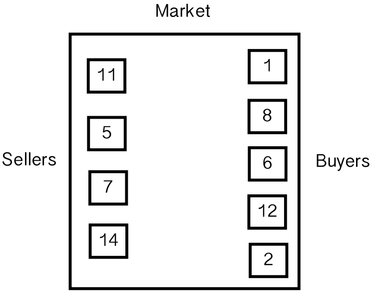
Outline

The Setting

- type: $\theta_i = (v_i)$
  - v_i is trader i's valuation
- an ask $\theta_i = (v_i)$ and a bid $\theta_j = (v_j)$ are matchable iff $v_i \leq v_j$

The Setting

- traders directly report their types as asks/bids (not necessarily truthfully!)



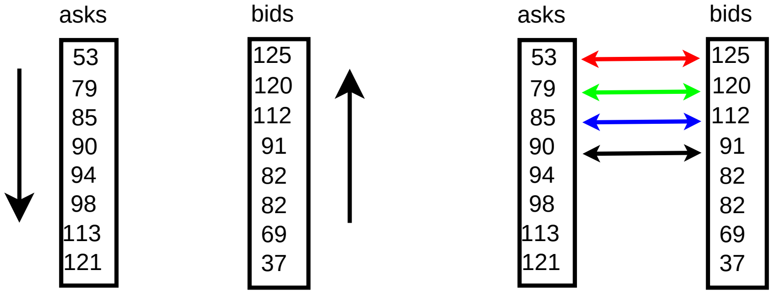
Equilibrium Matching

Environments	Mechanism		Properties						
	Allocation	Payment	IC	IR	Eff.	BB	Liq.	Pro.	Com.
static	Equilibrium Matching				X			O	
	Maximal Matching						X		X
with temporal constraints	Augmentation-based		X	X	X				X
under group buying	*Existence*		X	X		X			
	Impossibility (cond.)		X	X		X			
	Second Price		B	X		X			
	Second Price Plus ...		S	X		X			
	Impossibility		X	X		X	X		
dynamic arrival & departure fixed valuation	*Impossibility*		X		X				
	Greedy (cond.)		X	X	X				
	Reduction (cond.)		X	X	X				
dynamic arrival & departure dynamic valuation	Behaviour-based			X	O		O	O	

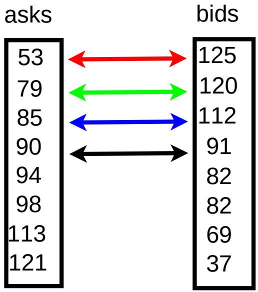
Equilibrium Matching

asks	bids
53	125
79	120
85	112
90	91
94	82
98	82
113	69
121	37

Equilibrium Matching



Equilibrium Matching



Properties:

- efficient
- (potentially) profit maximization

Equilibrium Matching

Environments	Mechanism: Allocation	Mechanism: Payment	IC	IR	Eff.	BB	Liq.	Pro.	Com.
static	Equilibrium Matching				X			O	
	Maximal Matching						X		X
with temporal constraints	Augmentation-based		X	X	X				X
under group buying	*Existence*		X	X		X			
	Impossibility (cond.)		X	X		X			
	Second Price		B	X		X			
	Second Price Plus ...		S	X		X			
	Impossibility		X	X		X	X		
dynamic arrival & departure fixed valuation	*Impossibility*		X		X				
	Greedy (cond.)		X	X	X				
	Reduction (cond.)		X	X	X				
dynamic arrival & departure dynamic valuation	Behaviour-based			X	O		O	O	

Maximal Matching

Environments	Mechanism: Allocation	Mechanism: Payment	Properties: IC	IR	Eff.	BB	Liq.	Pro.	Com.
static	Equilibrium Matching				X			O	
	Maximal Matching						X		X
with temporal constraints	Augmentation-based		X	X	X				X
under group buying	*Existence*		X	X		X			
	Impossibility (cond.)		X	X		X			
	Second Price		B	X		X			
	Second Price Plus ...		S	X		X			
	Impossibility		X	X		X	X		
dynamic arrival & departure fixed valuation	*Impossibility*		X		X				
	Greedy (cond.)		X	X	X				
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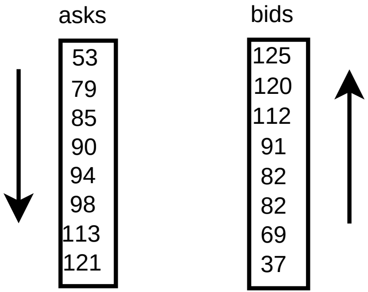
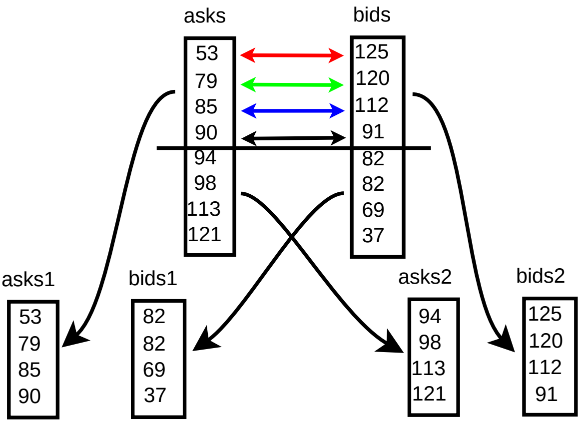
dynamic arrival & departure dynamic valuation	Behaviour-based			X	O		O	O	

Maximal Matching



Maximal Matching



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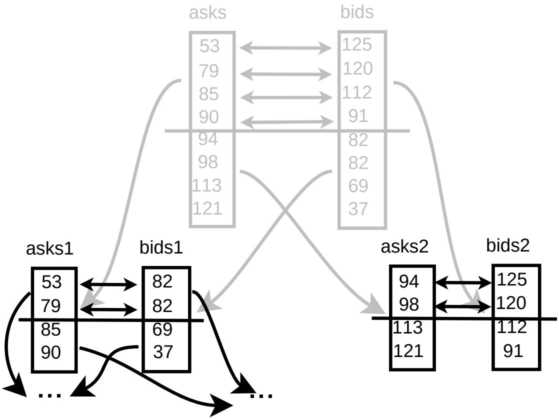

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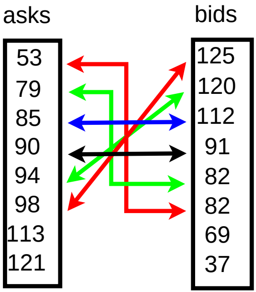

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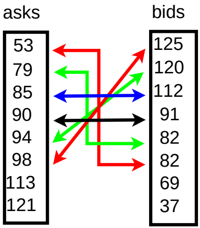

Properties:

- liquidity maximization
- more computationally efficient

Maximal Matching

Environments	Mechanism (Allocation)	Mechanism (Payment)	IC	IR	Eff.	BB	Liq.	Pro.	Com.
static	Equilibrium Matching				X			O	
static	Maximal Matching						X		X
with temporal constraints	Augmentation-based		X	X	X				X
under group buying	*Existence*		X	X		X			
under group buying	*Impossibility (cond.)*		X	X		X			
under group buying	Second Price		B	X		X			
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under group buying	*Impossibility*		X	X		X	X		
dynamic arrival & departure fixed valuation	*Impossibility*		X		X				
dynamic arrival & departure fixed valuation	Greedy (cond.)		X	X	X				
dynamic arrival & departure fixed valuation	Reduction (cond.)		X	X	X				
dynamic arrival & departure dynamic valuation	Behaviour-based			X	O		O	O	

Outline

Double Auction with Temporal Constraints

- type: $\theta_i = (v_i, s_i, e_i)$
  - v_i is trader i's valuation of a single unit of the commodity
  - s_i (e_i) is the starting (ending) point of time constraint $[s_i, e_i]$
- an ask $\theta_i = (v_i, s_i, e_i)$ and a bid $\theta_j = (v_j, s_j, e_j)$ are matchable iff $v_i \leq v_j$ and $[s_i, e_i] \cap [s_j, e_j] \neq \varnothing$

Application Examples

- Futures Exchange
- Stock Exchange

Augmentation-based Mechanism

Environments	Mechanism		Properties						
	Allocation	Payment	IC	IR	Eff.	BB	Liq.	Pro.	Com.
static	Equilibrium Matching				X			O	
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under group buying	*Existence*		X	X		X			
	Impossibility (cond.)		X	X		X			
	Second Price		B	X		X			
	Second Price Plus ...		S	X		X			
	Impossibility		X	X		X	X		
dynamic arrival & departure fixed valuation	*Impossibility*		X		X				
	Greedy (cond.)		X	X	X				
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The Mechanism

1. represent asks and bids in a bipartite graph
2. maximum-weighted bipartite matching allocation
3. min-max payment

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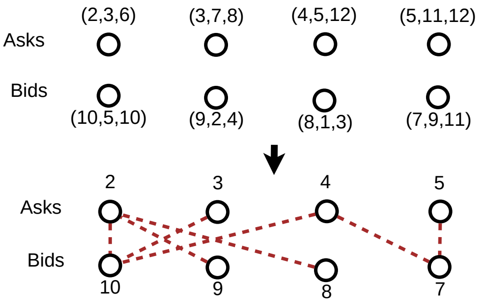

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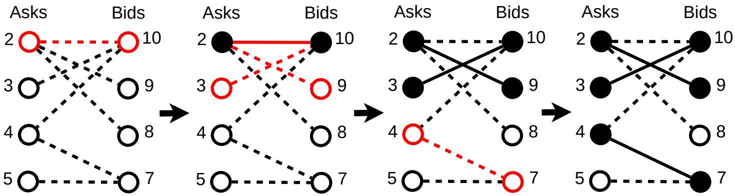

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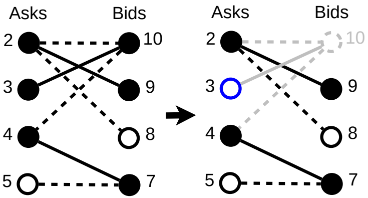
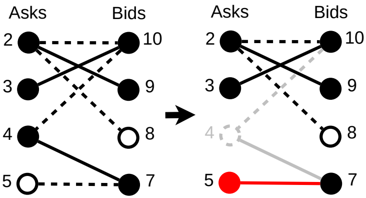


the lowest price to win



the highest price to win

The Properties

- truthful, efficient, individually rational (i.e. VCG mechanism)
- complexity
  - can be implemented $O(n)$ times faster than the classical VCG mechanism

Augmentation-based Mechanism

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	Second Price		B	X		X			
	Second Price Plus ...		S	X		X			
	Impossibility		X	X		X	X		
dynamic arrival & departure fixed valuation	*Impossibility*		X		X				
	Greedy (cond.)		X	X	X				
	Reduction (cond.)		X	X	X				
dynamic arrival & departure dynamic valuation	Behaviour-based			X	O		O	O	

Group Buying

GROUPON
Collective Buying Power

livingsocial

The Setting

Trader i has valuation function $v_i : \mathbb{Z} \rightarrow \mathbb{R}$.

- Seller:
  - unlimited supply
  - monotonic: $v_i(k) \leq v_i(k+1)$
  - group buying discount: $\frac{v_i(k)}{k} \geq \frac{v_i(k+1)}{k+1}$
- Buyer:
  - demands c_i units
  - $v_i(k) = v_i(c_i) > 0$ for all $k \geq c_i$, otherwise $v_i(k) = 0$

Existence of IC, IR, BB Auctions

Environments	Mechanism		Properties						
	Allocation	Payment	IC	IR	Eff.	BB	Liq.	Pro.	Com.
static	Equilibrium Matching				X			O	
	Maximal Matching						X		X
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under group buying	*Existence*		X	X		X			
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	Second Price		B	X		X			
	Second Price Plus ...		S	X		X			
	Impossibility		X	X		X	X		
dynamic arrival & departure fixed valuation	*Impossibility*		X		X				
	Greedy (cond.)		X	X	X				
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Existence of IC, IR, BB Auctions

Existence Example

- fixed-price auctions, i.e. price doesn't depend on traders

Existence of IC, IR, BB Auctions

Existence Example

- fixed-price auctions, i.e. price doesn't depend on traders

Question

Can we have something other than these kind of "trivial" auctions?

Impossibility I

Environments	Mechanism		Properties						
	Allocation	Payment	IC	IR	Eff.	BB	Liq.	Pro.	Com.
static	Equilibrium Matching				X			O	
	Maximal Matching						X		X
with temporal constraints	Augmentation-based		X	X	X				X
under group buying	*Existence*		X	X		X			
	Impossibility (cond.)		X	X		X			
	Second Price		B	X		X			
	Second Price Plus ...		S	X		X			
	Impossibility		X	X		X	X		
dynamic arrival & departure fixed valuation	*Impossibility*		X		X				
	Greedy (cond.)		X	X	X				
	Reduction (cond.)		X	X	X				
dynamic arrival & departure dynamic valuation	Behaviour-based			X	O		O	O	

Why?

Impossibility I

given that

- both the trading size and the payment are neither seller-independent nor buyer-independent

there is no auction that is incentive compatible, individually rational and (weakly) budget-balanced.

Why?

buyers want to form a bigger group while sellers might not!

- buyers with larger group will lower their payments
- a seller's profit might not maximised when selling more

Impossibility I

given that

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Partially Truthful Auctions

Environments	Mechanism		Properties						
	Allocation	Payment	IC	IR	Eff.	BB	Liq.	Pro.	Com.
static	Equilibrium Matching				X			O	
static	Maximal Matching						X		X
with temporal constraints	Augmentation-based		X	X	X				X
under group buying	*Existence*		X	X		X			
under group buying	*Impossibility (cond.)*		X	X		X			
under group buying	Second Price		B	X		X			
under group buying	Second Price Plus ...		S	X		X			
under group buying	*Impossibility*		X	X		X	X		
dynamic arrival & departure fixed valuation	*Impossibility*		X		X				
dynamic arrival & departure fixed valuation	Greedy (cond.)		X	X	X				
dynamic arrival & departure fixed valuation	Reduction (cond.)		X	X	X				
dynamic arrival & departure dynamic valuation	Behaviour-based			X	O		O	O	

Partially Truthful Auctions

Second Price Auction

Given type profile report $v = (v^B, v^S)$, assume that $v_1^B(1) \geq v_2^B(1) \geq \cdots \geq v_m^B(1)$.

1. Let $w(k) = \min \operatorname{argmin}_i v_i^S(k)$ and $p(k) = \min_{i \neq w(k)} \frac{v_i^S(k)}{k}$ or ∞ if there is only one seller.
2. Let $k^* = \max\{k | v_k^B(1) \geq p(k)\}$.
3. The first k^* buyers, i.e. buyers of valuation $v_1^B, v_2^B, \cdots, v_{k^*}^B$, receive one unit of the commodity each and each of them pays $p(k^*)$.
4. Seller $w(k^*)$ sells k^* units of the commodity and receives payment $p(k^*) \cdot k^*$.
5. The remaining traders lose without payment.

Partially Truthful Auctions

Environments	Mechanism		Properties						
	Allocation	Payment	IC	IR	Eff.	BB	Liq.	Pro.	Com.
static	Equilibrium Matching				X			O	
static	Maximal Matching						X		X
with temporal constraints	Augmentation-based		X	X	X				X
under group buying	*Existence*		X	X		X			
under group buying	*Impossibility (cond.)*		X	X		X			
under group buying	Second Price		B	X		X			
under group buying	Second Price Plus ...		S	X		X			
under group buying	*Impossibility*		X	X		X	X		
dynamic arrival & departure fixed valuation	*Impossibility*		X		X				
dynamic arrival & departure fixed valuation	Greedy (cond.)		X	X	X				
dynamic arrival & departure fixed valuation	Reduction (cond.)		X	X	X				
dynamic arrival & departure dynamic valuation	Behaviour-based			X	O		O	O	

Impossibility II

Environments	Mechanism		Properties						
	Allocation	Payment	IC	IR	Eff.	BB	Liq.	Pro.	Com.
static	Equilibrium Matching				X			O	
	Maximal Matching						X		X
with temporal constraints	Augmentation-based		X	X	X				X
under group buying	*Existence*		X	X		X			
	Impossibility (cond.)		X	X		X			
	Second Price		B	X		X			
	Second Price Plus ...		S	X		X			
	Impossibility		X	X		X	X		
dynamic arrival & departure fixed valuation	*Impossibility*		X		X				
	Greedy (cond.)		X	X	X				
	Reduction (cond.)		X	X	X				
dynamic arrival & departure dynamic valuation	Behaviour-based			X	O		O	O	

Impossibility II

- There is no (weakly) budget balanced, individually rational, truthful auctions that can guarantee trading size.

Impossibility II

Environments	Mechanism		Properties						
	Allocation	Payment	IC	IR	Eff.	BB	Liq.	Pro.	Com.
static	Equilibrium Matching				X			O	
	Maximal Matching						X		X
with temporal constraints	Augmentation-based		X	X	X				X
under group buying	*Existence*		X	X		X			
	Impossibility (cond.)		X	X		X			
	Second Price		B	X		X			
	Second Price Plus ...		S	X		X			
	Impossibility		X	X		X	X		
dynamic arrival & departure fixed valuation	*Impossibility*		X		X				
	Greedy (cond.)		X	X	X				
	Reduction (cond.)		X	X	X				
dynamic arrival & departure dynamic valuation	Behaviour-based			X	O		O	O	

Outline

Online Double Auctions

1. dynamic arrival & departure + fixed valuation
2. dynamic arrival & departure + dynamic valuation

Dynamic Arrival and Departure with Fixed Valuation

- type: $\theta_i = (v_i, a_i, d_i)$
  - v_i is trader i's (fixed) valuation of a single unit of the commodity
  - a_i (d_i) is the arrival (departure) time of trader i
- an ask $\theta_i = (v_i, a_i, d_i)$ and a bid $\theta_j = (v_j, a_j, d_j)$ are matchable iff $v_i \leq v_j$ and $[a_i, d_i] \cap [a_j, d_j] \neq \varnothing$

Application Example

- Stock Exchange

Impossibility

Environments	Mechanism		Properties						
	Allocation	Payment	IC	IR	Eff.	BB	Liq.	Pro.	Com.
static	Equilibrium Matching				X			O	
	Maximal Matching						X		X
with temporal constraints	Augmentation-based		X	X	X				X
under group buying	*Existence*		X	X		X			
	Impossibility (cond.)		X	X		X			
	Second Price		B	X		X			
	Second Price Plus ...		S	X		X			
	Impossibility		X	X		X	X		
dynamic arrival & departure fixed valuation	*Impossibility*		X		X				
	Greedy (cond.)		X	X	X				
	Reduction (cond.)		X	X	X				
dynamic arrival & departure dynamic valuation	Behaviour-based			X	O		O	O	

Impossibility

- There is no deterministic and truthful online double auction that can guarantee efficiency.

Deterministic and Efficient Mechanism

Environments	Mechanism		Properties						
	Allocation	Payment	IC	IR	Eff.	BB	Liq.	Pro.	Com.
static	Equilibrium Matching				X			O	
	Maximal Matching						X		X
with temporal constraints	Augmentation-based		X	X	X				X
under group buying	*Existence*		X	X		X			
	Impossibility (cond.)		X	X		X			
	Second Price		B	X		X			
	Second Price Plus ...		S	X		X			
	Impossibility		X	X		X	X		
dynamic arrival & departure fixed valuation	*Impossibility*		X		X				
	Greedy (cond.)		X	X	X				
	Reduction (cond.)		X	X	X				
dynamic arrival & departure dynamic valuation	Behaviour-based			X	O		O	O	

Deterministic and Efficient Mechanism

given that:

- sellers are relatively stable
- demand is not more than supply

a *greedy* deterministic auction can be truthful and individually rational and guarantees efficiency.

Deterministic and Efficient Mechanism

Environments	Mechanism		Properties						
	Allocation	Payment	IC	IR	Eff.	BB	Liq.	Pro.	Com.
static	Equilibrium Matching				X			O	
	Maximal Matching						X		X
with temporal constraints	Augmentation-based		X	X	X				X
under group buying	*Existence*		X	X		X			
	Impossibility (cond.)		X	X		X			
	Second Price		B	X		X			
	Second Price Plus ...		S	X		X			
	Impossibility		X	X		X	X		
dynamic arrival & departure fixed valuation	*Impossibility*		X		X				
	Greedy (cond.)		X	X	X				
	Reduction (cond.)		X	X	X				
dynamic arrival & departure dynamic valuation	Behaviour-based			X	O		O	O	

The Reduction Framework

Environments	Mechanism: Allocation / Payment	IC	IR	Eff.	BB	Liq.	Pro.	Com.
static	Equilibrium Matching			X			O	
	Maximal Matching					X		X
with temporal constraints	Augmentation-based	X	X	X				X
under group buying	*Existence*	X	X		X			
	Impossibility (cond.)	X	X		X			
	Second Price	B	X		X			
	Second Price Plus ...	S	X		X			
	Impossibility	X	X		X	X		
dynamic arrival & departure fixed valuation	*Impossibility*	X		X				
	Greedy (cond.)	X	X	X				
	Reduction (cond.)	X	X	X				
dynamic arrival & departure dynamic valuation	Behaviour-based		X	O		O	O	

The Reduction Framework

given that:

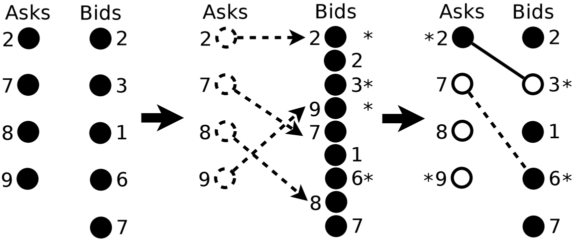
- sellers are relatively stable
- demand is not more than the supply
- demand is known

The Reduction Framework

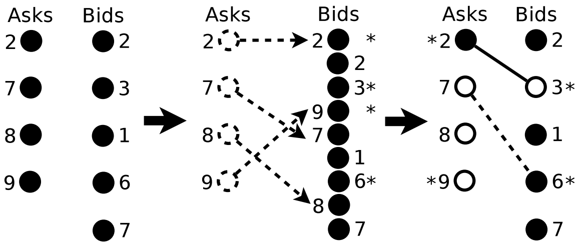
given that:

- sellers are relatively stable
- demand is not more than the supply
- demand is known

The Reduction Framework



The Reduction Framework



Properties:

- the truthfulness and efficiency of the reduced double auction follow that of the one-sided auction.

The Reduction Framework

Environments	Mechanism		Properties						
	Allocation	Payment	IC	IR	Eff.	BB	Liq.	Pro.	Com.
static	Equilibrium Matching				X			O	
	Maximal Matching						X		X
with temporal constraints	Augmentation-based		X	X	X				X
under group buying	*Existence*		X	X		X			
	Impossibility (cond.)		X	X		X			
	Second Price		B	X		X			
	Second Price Plus ...		S	X		X			
	Impossibility		X	X		X	X		
dynamic arrival & departure fixed valuation	*Impossibility*		X		X				
	Greedy (cond.)		X	X	X				
	Reduction (cond.)		X	X	X				
dynamic arrival & departure dynamic valuation	Behaviour-based			X	O		O	O	

Dynamic Arrival, Departure and Valuation

- multiple dynamic arrival and departure
- valuation is changing over time

Application Example

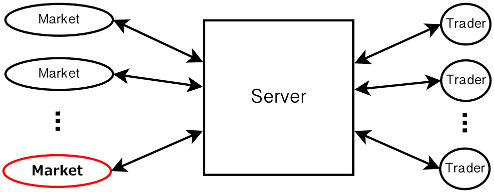
- Stock Exchange

Dynamic Arrival, Departure and Valuation

- multiple dynamic arrival and departure
- valuation is changing over time

Application Example

- Stock Exchange

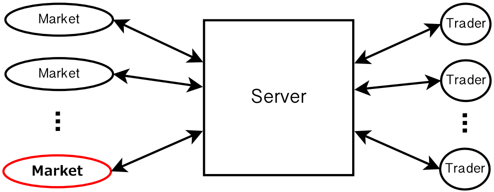


Behaviour-based Auction Design

Environments	Mechanism		Properties						
	Allocation	Payment	IC	IR	Eff.	BB	Liq.	Pro.	Com.
static	Equilibrium Matching				X			O	
static	Maximal Matching						X		X
with temporal constraints	Augmentation-based		X	X	X				X
under group buying	*Existence*		X	X		X			
under group buying	*Impossibility (cond.)*		X	X		X			
under group buying	Second Price		B	X		X			
under group buying	Second Price Plus ...		S	X		X			
under group buying	*Impossibility*		X	X		X	X		
dynamic arrival & departure fixed valuation	*Impossibility*		X		X				
dynamic arrival & departure fixed valuation	Greedy (cond.)		X	X	X				
dynamic arrival & departure fixed valuation	Reduction (cond.)		X	X	X				
dynamic arrival & departure dynamic valuation	Behaviour-based			X	O		O	O	

Behaviour-based Auction Design

1. behaviour recognition
2. behaviour-based classification of traders
3. behaviour-based mechanism design
4. environment adaptation



Experimental Results

Results (based on Trading Agent Competition Market Design Tournament):

- our trading agent, *jackaroo*, achieved 1st, 2nd and 1st in CAT Tournament 2009, 2010 and 2011, respectively

Experimental Results

Environments	Mechanism		Properties						
	Allocation	Payment	IC	IR	Eff.	BB	Liq.	Pro.	Com.
static	Equilibrium Matching				X			O	
	Maximal Matching						X		X
with temporal constraints	Augmentation-based		X	X	X				X
under group buying	*Existence*		X	X		X			
	Impossibility (cond.)		X	X		X			
	Second Price		B	X		X			
	Second Price Plus ...		S	X		X			
	Impossibility		X	X		X	X		
dynamic arrival & departure fixed valuation	*Impossibility*		X		X				
	Greedy (cond.)		X	X	X				
	Reduction (cond.)		X	X	X				
dynamic arrival & departure dynamic valuation	Behaviour-based			X	O		O	O	

Outline

Results Overview

Environments	Mechanism (Allocation / Payment)	IC	IR	Eff.	BB	Liq.	Pro.	Com.
static	Equilibrium Matching			X			O	
	Maximal Matching					X		X
with temporal constraints	Augmentation-based	X	X	X				X
under group buying	*Existence*	X	X		X			
	Impossibility (cond.)	X	X		X			
	Second Price	B	X		X			
	Second Price Plus ...	S	X		X			
	Impossibility	X	X		X	X		
dynamic arrival & departure fixed valuation	*Impossibility*	X		X				
	Greedy (cond.)	X	X	X				
	Reduction (cond.)	X	X	X				
dynamic arrival & departure dynamic valuation	Behaviour-based		X	O		O	O	

How did I achieve the results?

Reduction reduce online double auctions to online one-sided auctions

Behaviour-based Design utilize market behaviours of traders to guide market decisions

Augmentation-based Design use augmentation techniques from graph theory to design computationally efficient auctions

What are the potential impacts of the results?

- Static Double Auctions
  - more applicable allocation in stock exchange
- Approaching Online Double Auctions
  - augmentation-based
    - application in exchange markets, e.g. futures exchange
  - group buying related
    - a guideline for further study of the dynamic problem
- Online Double Auctions
  - an efficient approach to control/guide complex exchange markets

Future Work

1. Group buying with dynamic advertising effect
   - how many buyers will come back?
   - will they tell their friends of the product?
2. How to apply the results in real applications
   - how to deal with bounded rationality of human traders?
3. Extending the results to other dynamic environments
   - dynamic kidney exchange
   - online advertising

Q & A

Thank **YOU** very much
for your attention :)