

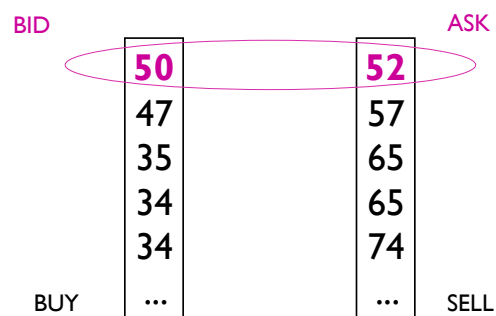
Continuous Double Auction

- ▶ **Double** (two-sided): both buyers and sellers bid
- ▶ **Continuous**:
 - ▶ bids arrive asynchronously
 - ▶ clear as soon as match
 - ▶ quotes updated immediately
- ▶ Abstract version of auction employed in financial and commodity markets



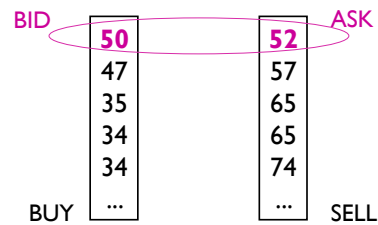
“Bid-Ask” Spread

- ▶ CDA price quotes
- ▶ Read off sorted order book



CDA Studies

- ▶ Huge finance literature: statistical studies, agent-based models
- ▶ Experimental economics
- ▶ Game theory: covers one-shot DA
- ▶ ... but little on dynamic case

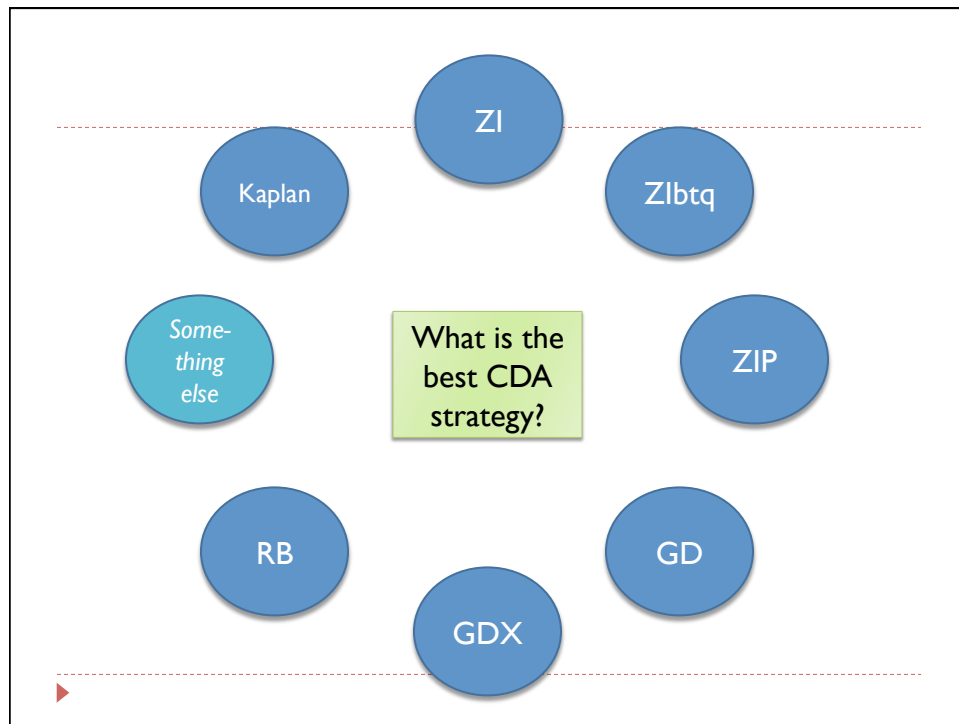


Strategic Issues

strategy: obs* × time → bid

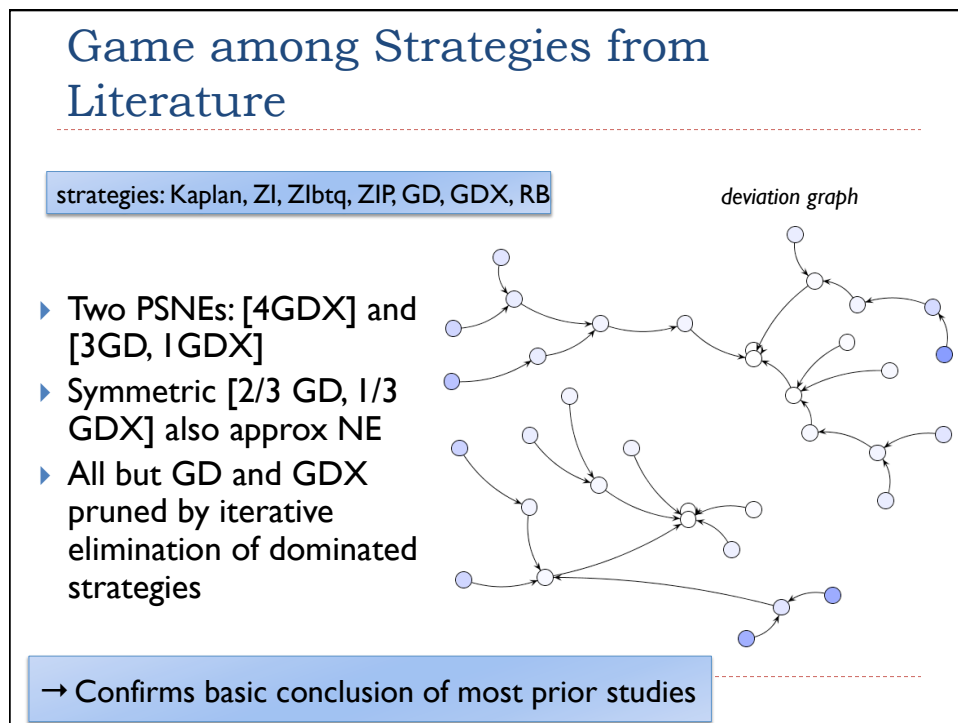
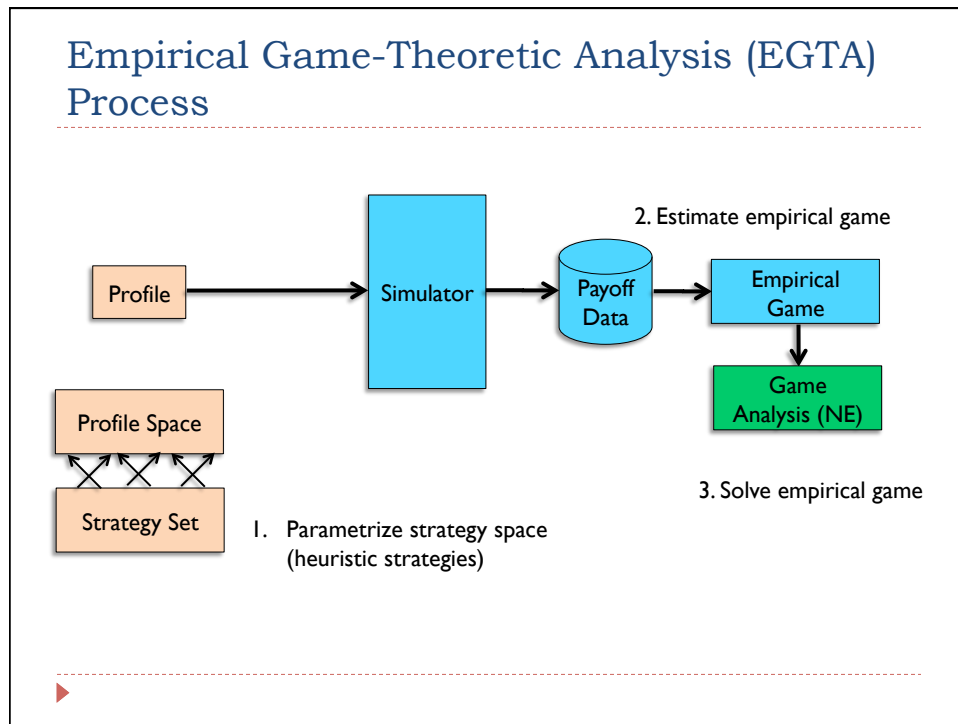
- ▶ Key tradeoff (buyer perspective)
 - ▶ Higher bid increases probability of trade
 - ▶ Lower bid increases profitability of trade
- ▶ Accounting for *multiple* units
 - ▶ Timing: impatience lowers profits on current trade, leaves time for more trades
- ▶ Dynamically assess tradeoffs based on observations from current and past trading periods

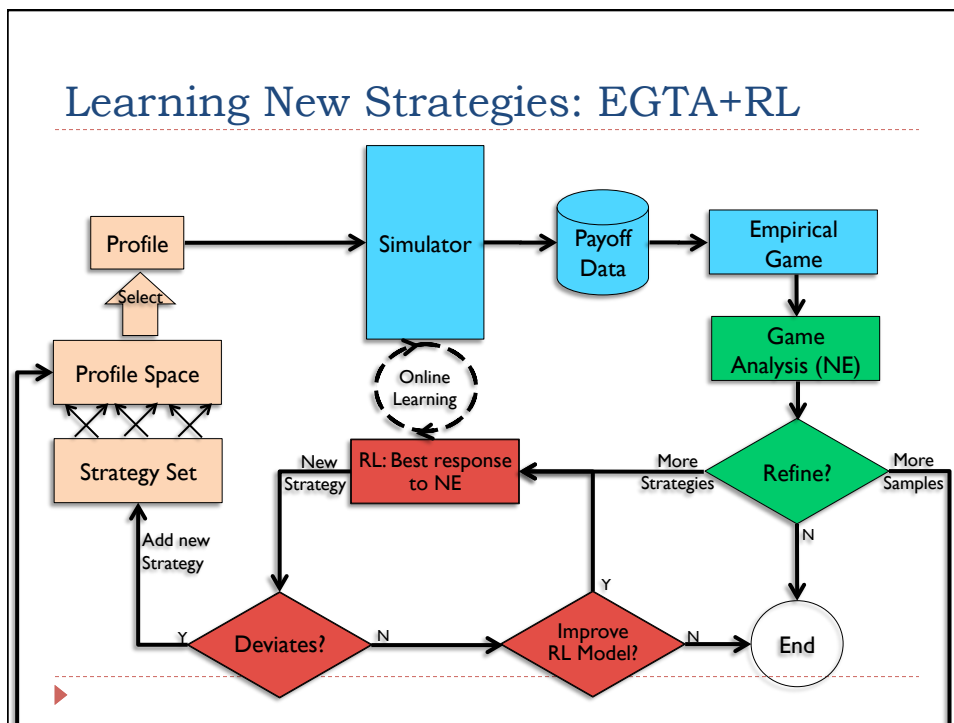
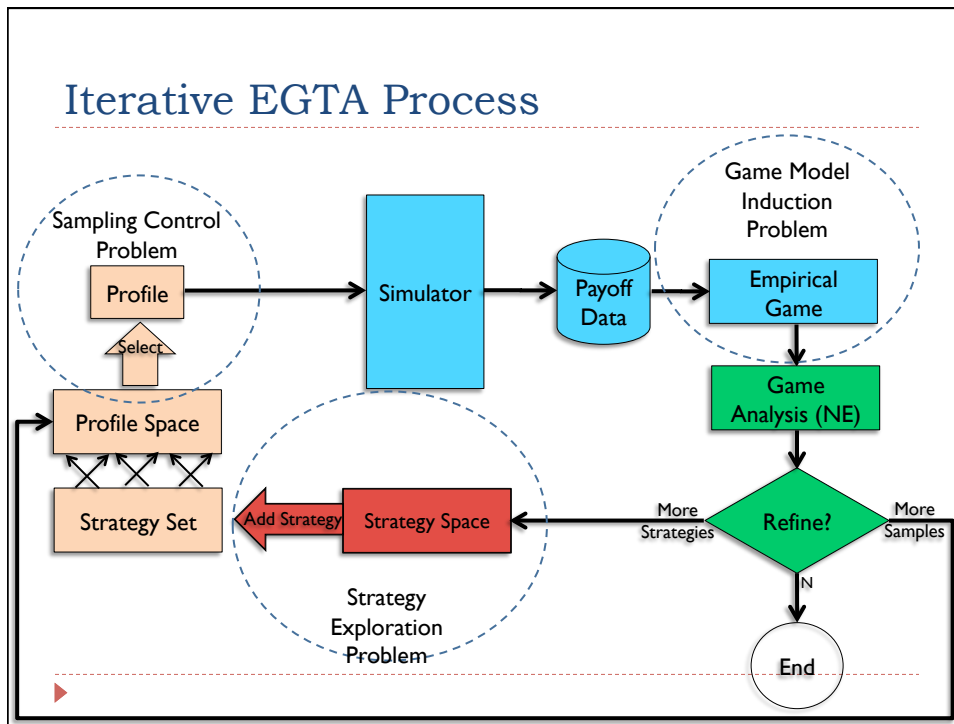




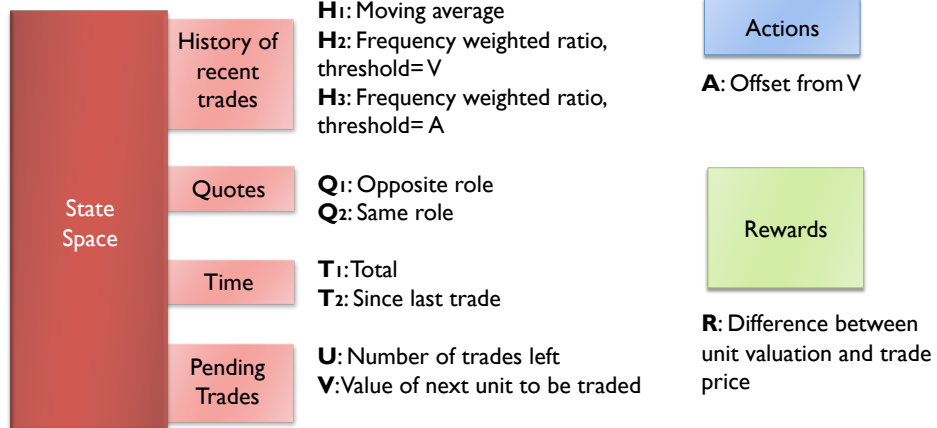
Experimenting w/CDA Strategies

- ▶ Set # agents, distribution of valuation schedules
- ▶ Strategies a function of valuation, time, and observation history
- ▶ Execute strategies for fixed time (or #rounds)
- ▶ Evaluate profitability, convergence to competitive equilibrium
- ▶ Issue: evaluate strategies in **what strategic context?**





Learning Problem Setup



EGTA/RL Round 1

Strategies	Payoff	NE	Learning	
			Strategy	Dev. Payoff
Kaplan ZI Zlbtq	248.1	1.000 ZI	LI	268.7
LI	242.5	1.000 LI		

EGTA/RL Round 2

Strategies	Payoff	NE		Learning	
				Strategy	Dev. Payoff
Kaplan ZI Zlbtq	248.1	1.000	ZI	L1	268.7
L1	242.5	1.000	L1		
ZIP	248.0	1.000	ZIP		
GD	248.6	1.000	GD	L2-L8 L9	--- 251.8
L9	246.1	0.531 0.469	GD L9	L10	252.1



EGTA/RL Rounds 3+

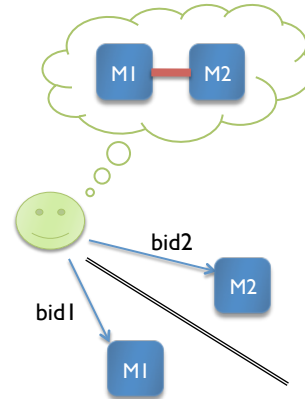
Strategies	Payoff	NE		Learning	
				Strategy	Dev. Payoff
...
L10	248.0	0.191 0.809	GD L10	L11	251.0
L11	246.2	1.000	L11		
GDX	245.8	0.192 0.808	GDX L11	L12	248.3
L12	245.8	0.049 0.951	L11 L12	L13	245.9
L13	245.6	0.872 0.128	L12 L13	L14	245.6
RB	245.6	0.872 0.128	L12 L13		

Final champion



Simultaneous Markets

- ▶ Agent interested in multiple goods
 - ▶ Preferences are interdependent (complements, substitutes): value for goods depends on which others obtained
 - ▶ Yet markets operate independently and simultaneously
 - ▶ Examples: hiring, bidding on contracts, ...
 - ▶ Exposure problem
- ▶ One-shot (sealed-bid) mechanisms: first-price, second-price, ...



Strategy Variations

- ▶ Point vs Distribution Predictor (EV)
- ▶ Straight vs Avg MU
- ▶ Target vs Target*
- ▶ Self-Confirm: Price vs High Bid (HB)
- ▶ BidEval
 - ▶ candidate generator: heuristics, mixes, #cands
 - ▶ evaluating price prediction (incl. self-confirm)
- ▶ LocalBid

Table 8: Strategies and profiles simulated for the environments addressed in our EGTA study.

Strategy Name	Class	PP based on	MU samples	BE cand gen	BE samples	BE candidates
AverageMU64	AverageMU	self	64	—	—	—
AverageMU64_HB	AverageMU	self	64	—	—	—
AverageMU64Z_HB	AverageMU	self	64	—	—	—
AverageMU64ZI_HB	AverageMU	self	64	—	—	—
BidEvaluator_HB	BidEval	TargetMU_HB	8	TargetMU	32	4
BidEvaluatorAMU_HB	BidEval	AverageMU64_HB	8	AverageMU	32	4
BidEvaluatorMix	BidEval	StraightMU	8	mix	32	4
BidEvaluatorMix_E8S32K8_HB	BidEval	StraightMU_HB	8	mix	32	8
BidEvaluatorMix_HB	BidEval	StraightMU_HB	8	mix	32	4
BidEvaluatorMix_K16_HB	BidEval	StraightMU_HB	8	mix	32	16
BidEvaluatorMixA	BidEval	StraightMUa	8	mix	32	4
BidEvaluatorMixA_K16_HB	BidEval	StraightMUa_HB	8	mix	32	16
BidEvaluatorSMU	BidEval	StraightMU	8	StraightMU	32	4
BidEvaluatorSMU_E4S32K8	BidEval	StraightMU	4	StraightMU	32	8
BidEvaluatorSMU_E8S32K8_HB	BidEval	StraightMU_HB	8	StraightMU	32	8
BidEvaluatorSMU_HB	BidEval	StraightMU_HB	8	StraightMU	32	4
BidEvaluatorStar	BidEval	TargetMUStar	8	TargetMU*	32	4
BidEvaluatorStar_HB	BidEval	TargetMUStar_HB	8	TargetMU*	32	4
BidXEvaluatorMix_K16_HB	BidEval	StraightMUa_HB	8	mix	—	16
BidXEvaluatorMixA	BidEval	StraightMUa	8	mix	—	4
BidXEvaluatorMixA_K16_HB	BidEval	StraightMUa_HB	8	mix	—	16
BidXEvaluatorMix3_K16_HB	BidEval	AverageMU64_HB	3	mix	—	16
LocalBidSearch_K16_HB	LocalBid	AverageMU64_HB	—	—	—	16
SCBidEvaluatorFix_HB	BidEval	self	8	TargetMU	32	4
SCBidEvaluatorMix_HB	BidEval	self	8	mix	32	4
SCBidEvaluatorMixA_K16_HB	BidEval	self	8	mix	32	16
SCBidXEvaluatorMixA_K16	BidEval	self	8	mix	—	16
SCBidXEvaluatorMixA_K16_HB	BidEval	self	8	mix	—	16
SCBidXEvaluatorMix3_K16_HB	BidEval	self	3	mix	—	16
SCLocalBidSearch_K16_HB	LocalBid	self	—	—	16	1
SCLocalBidSearch_K16Z_HB	LocalBid	self	—	—	16	1
SCLocalBidSearchS5K6_HB	LocalBid	self	—	—	5	6
StraightMUa	StraightMU	self	—	—	—	—
StraightMUa_HB	StraightMU	self	—	—	—	—
TargetMUa	TargetMU	self	—	—	—	—
TargetMUa_HB	TargetMU	self	—	—	—	—
TargetMUStara	TargetMU*	self	—	—	—	—
TargetMUStara_HB	TargetMU*	self	—	—	—	—
TargetMUStaraZ_HB	TargetMU*	self	—	—	—	—
BaselineBidding	<i>ad hoc</i>	—	—	—	—	—
StraightMV	StraightMV	self	—	—	—	—
TargetMV	TargetMV	self	—	—	—	—
TargetMVStar	TargetMV*	self	—	—	—	—
TargetMVStar_HB	TargetMV*	self	—	—	—	—

Environments

- ▶ scheduling valuation functions
 - ▶ agents with job length λ distributed uniformly
 - ▶ get value v_d if completes job by time d

goods	agents	strategie s	dom	profiles	%eval
6	4	34	25	1165	1.76
5	5	30	21	5219	1.88
5	8	29	0	9096	0.03

- ▶ homogeneous goods, decreasing MV

goods	agents	strategie s	dom	profiles	%eval
5	3	32	22	608	10.16
5	5	34	6	13219	2.63

EGTA Profile Sampling

- ▶ Initialize strategy set S , seed profiles
- ▶ Identify candidate SMSNE with support Σ
 - ▶ **for every** strategy s in $S \setminus \Sigma$
 - ▶ evaluate all profiles over $\Sigma + s$
 - ▶ **until** SMSNE refuted or confirmed
- ▶ Identify another candidate SMSNE
- ▶ Add another strategy



Symmetric Nash Equilibria

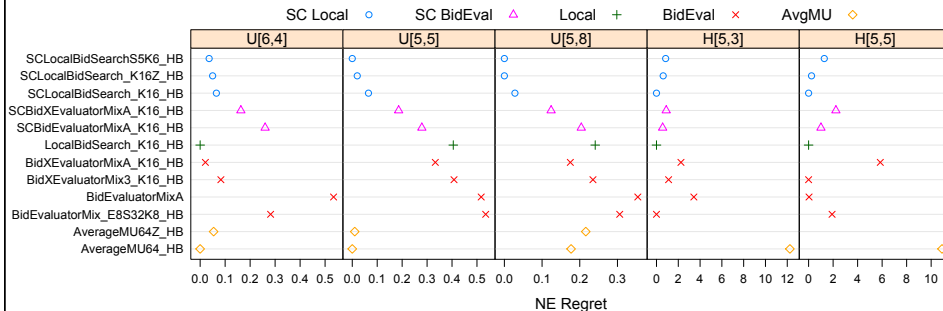
	SCLocal	Local	AvgMU	BEMix	BXE3
U[6,4]	—	0.15	0.85	—	—
U[5,5]	0.91	—	0.09	—	—
U[5,8]	1.0	—	—	—	—
H[5,3]	0.51	0.41	—	0.09	—
H[5,5]	0.64	0.27	—	—	0.09



Nash Equilibrium Regret

[Jordan et al., AAMAS-07]

► Loss to playing strategy when others play NE



bottom line:

SC Local most effective overall, robust across environments

Symmetric Profile Regret

► Loss to playing strategy when others play same

strategy	SymmReg(r) U[5,5]	R(r) U[6,4]	R(r) H[5,3]	R(r) H[5,5]
SCLocalBid	0.05 (1)	0.43 (2)	3.53 (3)	2.60 (1)
SCBidEval	0.53 (3)	0.93 (4)	2.55 (1)	3.09 (2)
AvgMU	0.50 (2)	0.34 (1)	29.08 (6)	25.05 (5)
BidEval	1.35 (5)	1.50 (5)	3.99 (4)	4.63 (3)
LocalBid	1.67 (6)	2.15 (6)	2.63 (2)	9.82 (4)
StraightMU	0.87 (4)	0.89 (3)	42.54 (7)	31.57 (6)
TargetMU	1.99 (7)	2.59 (7)	26.17 (5)	41.46 (7)

Conclusion

Trading Agents

- ▶ Significant AI domain
 - ▶ economically consequential
 - ▶ aligns with current automation technology
 - ▶ in widespread use in several contexts
- ▶ TADA principles
 - ▶ strategic thinking
 - ▶ auction theory
 - ▶ price-prediction + optimization architecture

EGTA for Trading Agent Design & Analysis

- ▶ Produced “champion” strategies/approaches for canonical auctions:
 - ▶ CDA
 - ▶ SimAA
 - ▶ SimSPSB
- ▶ Actively improving methodology
- ▶ More trading applications...

