Autonomous Bidding
in the
Trading Agent Competition

Amy Greenwald
Brown University

with

Justin Boyan
ITA Software

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Key TAC Features

Simultaneous Auctions

Combinatorial Valuations

- Complements
  - $v(X\bar{Y}) + v(\bar{X}Y) \leq v(XY)$
  - camera, flash, and tripod
- Substitutes
  - $v(X\bar{Y}) + v(\bar{X}Y) \geq v(XY)$
  - Canon AE-1 and Canon A-1

Examples

FCC auctions

eBay auctions

- proxy bidding agents
- bid up to the value of good x

v(Camera + Flash)

- autonomous bidding agents
- bid up to the marginal value of good x

Bid Determination

Allocation

- given the set of goods I hold, what is the maximum valuation I can attain?

Acquisition

- given the set of goods I hold, and given ask prices in any open auctions, on what set of additional goods should I bid to maximize valuation less costs?

Requisition

- given the set of goods I hold, and given bid prices in any open auctions, on what set of goods should I place asks to maximize valuation plus profits?

Completion

- given the set of goods I hold, and given ask and bid prices in any open auctions, on what set of goods should I place bids or asks to maximize my valuation less costs plus profits?

Overview

- TAC Market Game
- TAC Agent Architecture
- RoxyBot Agent Architecture

TAC Market Game

Score = Valuation − Costs + Profits

Supply

- Flights Inbound and Outbound
- Hotels Grand Hotel and Le FleaBag Inn
- Entertainment Red Sox, Symphony, Phantom

Auctions

- Flights infinite supply, prices follow random walk, clear continuously, no resale permitted
- Hotels ascending, multi-unit, 16th price auctions, transactions clear and random auction closes once per minute, no resale permitted
- Entertainment continuous double auctions, initial endowment, resale is permitted

TAC Market Game

Demand

Client	IAD	IDD	HV	RV	SV	TV
1	1	3	99	134	118	65
2	1	4	131	170	47	49
3	1	2	147	13	55	49
4	3	4	145	130	60	85
5	1	4	82	136	68	87
6	2	4	53	94	51	105
7	1	3	54	156	126	71
8	1	5	113	119	187	143

Feasible Packages

- arrival date prior to departure date
- same hotel on all intermediate nights
- at most one entertainment event per night
- at most one of each type of entertainment

TAC Market Game

Valuation

$$1000 - \text{travelPenalty} + \text{hotelBonus} + \text{funBonus}$$

$$\begin{aligned} \text{travelPenalty} &= 100(|\text{IAD} - \text{AD}| + |\text{IDD} - \text{DD}|) \\ \text{hotelBonus} &= \begin{cases} \text{HV} & \text{if H} = \text{G} \\ 0 & \text{otherwise} \end{cases} \\ \text{funBonus} &= \text{entertainment values} \end{aligned}$$

Allocation

Client	AD	DD	H	Ticket	Valuation
1	1	3	G	SV1, RV2	1351
2	1	3	G	RV1	1201
3	1	2	G	—	1147
4	3	4	G	RV3	1275
5	1	3	F	RV1, TV2	1123
6	3	4	G	TV3	1058
7	1	3	F	SV1, RV2	1282
8	1	5	G	TV1, SV3, RV4	1562

TAC Agent Architecture

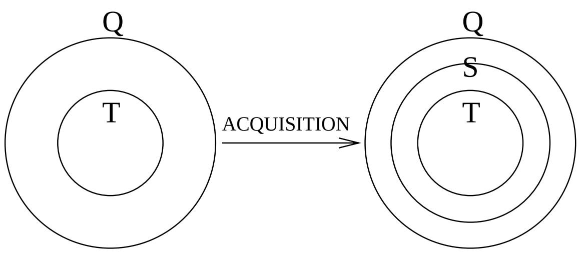
REPEAT

1. how many copies of each good do i want?
2. on the goods i want, should i bid now or later?
3. for the goods i want now, what am i willing to pay?

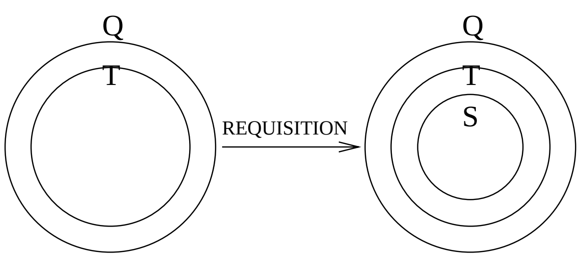
UNTIL game over

Bid Determination

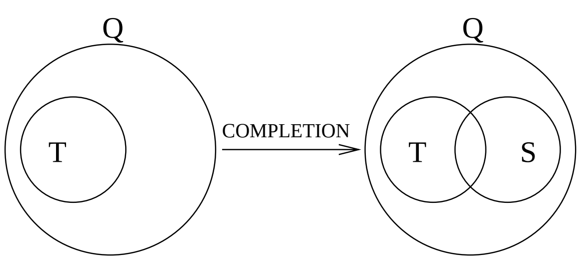
Bid on $S \setminus T$



Ask for $T \setminus S$



Bid on $S \setminus T$
Ask for $T \setminus S$



Observations

WD $\cong$ Allocation

- WD: auctioneer seeks the set of combinatorial bids that maximizes profits, given feasibility constraints

WDR $\cong$ Acquisition

- WDR (WD with reserve prices): auctioneer seeks the set of combinatorial bids that maximizes the difference between profits and reserve prices

BD problems in simultaneous auctions $\cong$
WD problems in combinatorial auctions

Pricelines

Buying Priceline

$\vec{p}_g = \langle 0, 0, 0, 0, 20, 30, \infty, \infty, \ldots \rangle$

$$\begin{aligned}
\forall g, \quad n\text{Buy}(S, g) &= \sum_{\vec{q} \in S} q_g \\
\forall g, \quad \text{Cost}_g(S, P) &= \sum_{n=1}^{n\text{Buy}(S,g)} p_{gn} \\
\text{Cost}(S, P) &= \sum_{g \in G} \text{Cost}_g(S, P)
\end{aligned}$$

Selling Priceline

$\vec{\pi}_g = \langle 10, 5, 2, 1, 0, 0, 0, 0, -\infty, -\infty, \ldots \rangle$

$$\begin{aligned}
\forall g, \quad n\text{Sell}(S, g) &= \sum_{\vec{q} \notin S} q_g \\
\forall g, \quad \text{Profit}_g(S, \Pi) &= \sum_{n=1}^{n\text{Sell}(S,g,\Pi)} \pi_{gn} \\
\text{Profit}(S, \Pi) &= \sum_{g \in G} \text{Profit}_g(S, \Pi)
\end{aligned}$$

Formalization

Acquisition

Inputs: set of packages Q

set of buying pricelines P

valuation function $v : Q \to \mathbb{R}^+$

Output: $S^* \in \arg\max_{S \subseteq Q}(\text{Valuation}(S, v) - \text{Cost}(S, P))$

Requisition

Inputs: set of packages Q

set of selling pricelines Π

valuation function $v : Q \to \mathbb{R}^+$

Output: $S^* \in \arg\max_{S \subseteq Q}(\text{Valuation}(S, v) + \text{Profit}(S, \Pi))$

Completion

Inputs: set of packages Q

set of buying pricelines P

set of selling pricelines Π

valuation function $v : Q \to \mathbb{R}^+$

Output: $S^* \in \arg\max_{S \subseteq Q}(\text{Val}(S, v) - \text{Cost}(S, P) + \text{Profit}(S, \Pi))$

Formalization

Acquisition

Inputs: set of packages Q

set of buying pricelines P

valuation function $v : Q \rightarrow \mathbb{R}^+$

Output: $S^* \in \arg\max_{S \subseteq Q}(\text{Valuation}(S, v) - \text{Cost}(S, P))$

Requisition

Inputs: set of packages Q

set of selling pricelines Π

valuation function $v : Q \rightarrow \mathbb{R}^+$

Output: $T^* \in \arg\max_{T \subseteq Q}(\text{Valuation}(T, v) + \text{Profit}(T, \Pi))$

Completion

Inputs: set of packages Q

set of buying pricelines P

set of selling pricelines Π

valuation function $v : Q \rightarrow \mathbb{R}^+$

Output: $S^*, T^* \in \arg\max_{S,T \subseteq Q}(\text{Valuation}(S, v) - \text{Cost}(S, P) + \text{Profit}(T, \Pi) - \text{Cost}(T, P))$

Completion $\longmapsto$ Acquisition

Buying Priceline
$\vec{p}_g = \langle 0, 0, 0, 0, 20, 30, \infty, \infty, \ldots \rangle$

Selling Priceline
$\vec{\pi}_g = \langle 10, 5, 2, 1, 0, 0, 0, 0, -\infty, -\infty, \ldots \rangle$

1st Reduction

- add reverse of selling pricelines to buying pricelines:
  $\vec{p}_g + \text{reverse}(\vec{\pi}_g) = \langle 1, 2, 5, 10, 20, 30, \infty, \infty, \ldots \rangle$

2nd Reduction

- extend package input set with singleton packages, one for each copy of each good in selling pricelines; assign selling prices as dummy package valuations:
  $\vec{\pi}_g \longmapsto$ 4 new packages with valuations 10, 5, 2, 1

Bid Determination in double-sided auctions $\longmapsto$
Bid Determination in single-sided auctions

Utility

Acquisition

Inputs: set of packages Q

set of buying pricelines P

valuation function $v : Q \to \mathbb{R}^+$

Output: $S^* \in \arg\max_{S \subseteq Q}(\text{Valuation}(S, v) - \text{Cost}(S, P))$

$u(S^*) = \max_{S \subseteq Q}(\text{Valuation}(S, v) - \text{Cost}(S, P))$

Example

valuations

$v(XYZ) = v(XY) = v(YZ) = 500$

$v(X) = v(Y) = v(Z) = v(XZ) = 0$

pricelines

$p(X) = p(Y) = p(Z) = 100$

utilities

$u(XY) = u(YZ) = 300$

Marginal Utility

for the goods i want now, what am i willing to pay?

Acquisition

Inputs: set of packages Q

set of buying pricelines P

valuation function $v : Q \rightarrow \mathbb{R}^+$

Output: $S^* \in \arg\max_{S \subseteq Q}(\text{Valuation}(S, v) - \text{Cost}(S, P))$

$u(S^*) = \max_{S \subseteq Q}(\text{Valuation}(S, v) - \text{Cost}(S, P))$

Answer

$u(x) = u(A \cup \{x\}) - u(A)$, with $p(x) = 0$ & $p(x) = \infty$

Example

$u(X) = u(XYZ) - u(YZ) = 400 - 300 = 100$

$u(Y) = u(XYZ) - u(XZ) = 400 - 0 = 400$

$u(Z) = u(XYZ) - u(XY) = 400 - 300 = 100$

Bids

$b(Y) = 300$, $b(X) = b(Z) = 100$

$v(Y) - p(Y) = 200$

RoxyBot

how many copies of each good do i want?

Acquisition

Inputs: set of packages Q

set of buying pricelines P

valuation function $v : Q \to \mathbb{R}^+$

Output: $S^* \in \arg\max_{S \subseteq Q}(\text{Valuation}(S, v) - \text{Cost}(S, P))$

$u(S^*) = \max_{S \subseteq Q}(\text{Valuation}(S, v) - \text{Cost}(S, P))$

Answer

$n\text{Buy}(S^*, g) = \sum_{\vec{q} \in S^*} q_g$

Example

$n\text{Buy}(\{XY\}, X) = 1$

$n\text{Buy}(\{XY\}, Y) = 1$

$n\text{Buy}(\{XY\}, Z) = 0$

XOR

$n\text{Buy}(\{YZ\}, X) = 0$

$n\text{Buy}(\{YZ\}, Y) = 1$

$n\text{Buy}(\{YZ\}, Z) = 1$

Marginal Utility, Revisited

for the goods i want now, what am i willing to pay?

Acquisition

Inputs: subset of packages Q

set of buying pricelines P

valuation function $v : Q \rightarrow \mathbb{R}^+$

Output: $S^* \in \arg\max_{S \subseteq Q}(\text{Valuation}(S, v) - \text{Cost}(S, P))$

$u(S^*) = \max_{S \subseteq Q}(\text{Valuation}(S, v) - \text{Cost}(S, P))$

Answer

$u(x) = u(A \cup \{x\}) - u(A)$, with $p(x) = 0$ & $p(x) = \infty$

Example

$u(X) = u(XY) - u(Y) = 400 - 0 = 400$

$u(Y) = u(XY) - u(X) = 400 - 0 = 400$

Bids

$b(X) = b(Y) = 400$, $b(Z) = 0$

$v(XY) - p(X) - p(Y) = 300$

RoxyBot 2000 Architecture

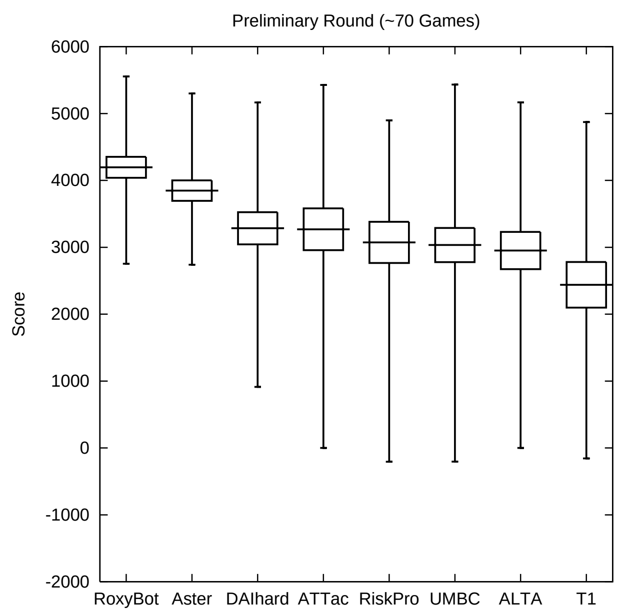
(A) REPEAT

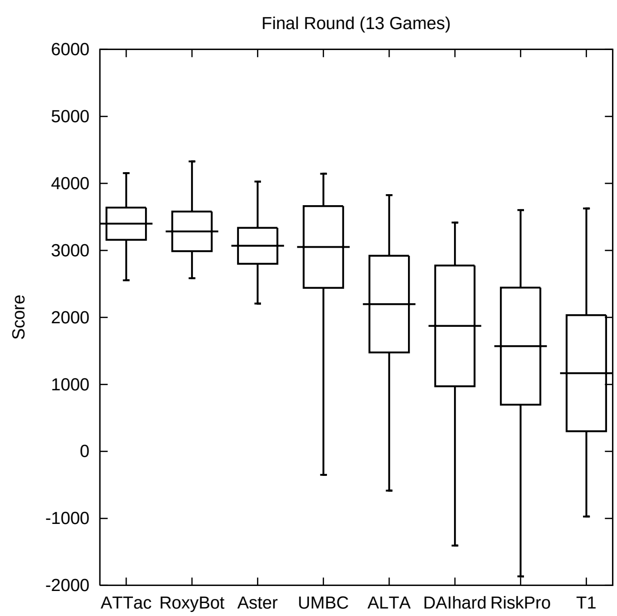
1. Ping server to update current prices and holdings
2. Estimate clearing prices and build buy/sell pricelines
3. Run completer to find optimal buy/sell quantities
4. Bid/ask marginal valuations

   UNTIL game over

(B) Run allocator

TAC 2000 Statistics





Price Uncertainty

for the goods i want now, what am i willing to pay?

Example

$p(x) = 0$, with probability $\frac{1}{2}$, and

$p(x) = 200$, with probability $\frac{1}{2}$,

for all $x \in \{X, Y, Z\}$

Answer

average marginal utility

Bidding Policy

X	Y	Z	$u(X)$	$u(Y)$	$u(Z)$
0	0	0	0	500	0
200	0	0	0	500	200
0	200	0	0	500	0
0	0	200	200	500	0
200	200	0	0	500	200
200	0	200	200	300	200
0	200	200	200	500	0
200	200	200	200	300	200
Bids			100	450	100

RoxyBot Under Uncertainty

how many copies of each good do i want?

Answer

sound and complete set of packages

Example

nBuy$(\{XY\}, X) = 1$

nBuy$(\{XY\}, Y) = 1$

nBuy$(\{XY\}, Z) = 0$

Bidding Policy

X	Y	$u(X)$	$u(Y)$
0	0	500	500
200	0	500	300
0	200	300	500
200	200	300	300
Bids		400	400

Bidding Under Uncertainty

X	Y	Z	ATTac	RoxyBot
0	0	0	500	500
200	0	0	500	300
0	200	0	300	300
0	0	200	500	500
200	200	0	300	100
200	0	200	0	300
0	200	200	300	300
200	200	200	−200	100
Scores			275	300

RoxyBot 2001 Architecture

INPUTS
Truncation Parameter $t_0 \in [0.5, 1.0]$
Schedule by which to Decay t_0

(A) REPEAT
1. Updates prices and winnings
2. Estimate clearing price distributions
3. Initialize $d = 0$, $s = 8$, $n = 0$, and $t = t_0$
4. REPEAT
   (a) Sample clearing price distributions
   (b) Compute optimal completion D_n
   (c) Store D_n in completion list
   (d) Increment n
   (e) Tally results
      i. for all items i
         ∘ initialize $\#i = 0$
         ∘ for all completions D_n
           – if $i \in D_n$, increment $\#i$
         ∘ if $\#i/n > t$
           – increment d
           – add i to D
         ∘ if $\#i/n < 1 - t$
           – decrement s
           – delete i from S
   (f) Discard from list inconsistent completions
   (g) Set n equal to length of completion list
   (h) Decay t
   UNTIL $d = s$ or TIME OUT

(B) Run allocator

Future Work

Empirical Testing

- Completion vs. No Completion
- Sampling vs. No Sampling
- ILP vs. LP Relaxation

Theoretical Study

- timing—optimal stopping problem
- estimate joint price distributions