Exploring Trading Strategy Spaces

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Trading Games

• Market interaction defines a game
• Complications:
  – infinite action set
  – incomplete information
  – dynamics, information revelation
• Large strategy space \(\Rightarrow\) analytic intractability
Example Trading Games

- Simultaneous Ascending Auction
- Trading Agent Competition Scenarios
  - Travel shopping
  - Supply chain management

Approach

- Empirical game-theoretic methodology
- Three steps
  - Parametrize strategy space
  - Estimate “empirical game”
  - Solve/analyze
- Many recent studies include elements of these methods:
  - IBM group (Kephart, Walsh, …)
  - Armantier et al.
  - others…
An Empirical “Game”

<table>
<thead>
<tr>
<th>#high</th>
<th>agent 2</th>
<th>agent 3</th>
<th>agent 4</th>
<th>agent 5</th>
<th>agent 6</th>
<th>agent 7</th>
<th>agent 8</th>
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<tr>
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<td>9526</td>
<td></td>
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<td>6 (87)</td>
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<td>1389</td>
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<td></td>
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<td></td>
<td></td>
<td>2650</td>
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<td>4 (48)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4015</td>
</tr>
<tr>
<td>3 (21)</td>
<td>5067</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3639</td>
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<td>2 (282)</td>
<td>209</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2710</td>
</tr>
</tbody>
</table>

Table 5: The difference between ATTac-2000’s score and the score of each of the other seven agents averaged over all games in a controlled experiment. …

(Stone et al., 2001)

Trading Agent Competition (TAC)

- Open-invitation int’l tournaments, featuring market games
- 18-43 entrants/year, worldwide
- “Classic” travel-shopping scenario (2000–)
- Supply chain game (2003–)
  - Designed at CMU, SICS
  - Implemented and operated by SICS
  - 2003 tournament: 20 participants from nine countries
TAC/SCM Configuration

Agents’ Daily Decisions

- Issue RFQs to suppliers
- Accept/reject supplier offers
- Plan day’s production mix
- Select completed orders to ship
- Bid on customer RFQs
Day 0 Procurement

- Placing large component RFQs on Day 0
  - Prices as low as they will ever be
  - Availability as high as it will ever be
  - Reduces flexibility to adapt to demand conditions
- Observed increasing adoption of this approach in preliminary rounds
- If everybody does this, supply chain vulnerable to low demand
- Particularly bad for our agent, Deep Maize
- Top 9 agents in seeding round employed significant day 0 procurement (rest did not)

2003 Seeding Round Results

<table>
<thead>
<tr>
<th>Rank</th>
<th>Agent</th>
<th>Affiliation</th>
<th>Score</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>TacTex</td>
<td>U Texas</td>
<td>33.0</td>
</tr>
<tr>
<td>2</td>
<td>RedAgent</td>
<td>McGill U</td>
<td>29.5</td>
</tr>
<tr>
<td>3</td>
<td>Botticelli</td>
<td>Brown U</td>
<td>28.0</td>
</tr>
<tr>
<td>4</td>
<td>Jackaroo</td>
<td>U Western Sydney</td>
<td>19.2</td>
</tr>
<tr>
<td>5</td>
<td>WhiteBear</td>
<td>Cornell U</td>
<td>16.5</td>
</tr>
<tr>
<td>6</td>
<td>PSUTAC</td>
<td>Pennsylvania State U</td>
<td>15.3</td>
</tr>
<tr>
<td>7</td>
<td>HarTAC</td>
<td>Harvard U</td>
<td>10.7</td>
</tr>
<tr>
<td>8</td>
<td>UMBCTAC</td>
<td>U Maryland Baltimore Cty</td>
<td>10.2</td>
</tr>
<tr>
<td>9</td>
<td>Sirish</td>
<td></td>
<td>8.3</td>
</tr>
<tr>
<td>10</td>
<td>Deep Maize</td>
<td>U Michigan</td>
<td>7.5</td>
</tr>
<tr>
<td>11</td>
<td>Tac-o-matic</td>
<td>Uppsala U</td>
<td>7.1</td>
</tr>
<tr>
<td>12</td>
<td>RonaX</td>
<td>Xonar GmbH</td>
<td>4.3</td>
</tr>
<tr>
<td>13</td>
<td>MinneTAC</td>
<td>U Minnesota</td>
<td>−0.3</td>
</tr>
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</table>
Example: HarTAC

<table>
<thead>
<tr>
<th>HarTAC Dossier</th>
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</thead>
<tbody>
<tr>
<td>prepared by M. Wellman, 21 Jul 03</td>
</tr>
</tbody>
</table>

Day 0 strategy:
For each component, each supplier, order:
- **4000@10**
- **3000@20**
- **8000@30**

Accept all complete orders.

Total procurement:
- 15000 each CPU, 30000 each nonCPU (expenditure = $60M)

Production:
- produce at up to full capacity as soon as components show up.
- full production run from initial components equals 60000 PCs, utilization = 75%

Customer bidding: start bidding for orders once production starts

Evidence:
- game 5-631: detailed analysis of supplier orders from log
  - Apparently followed this basic strategy throughout seeding2. Vast majority of games have exactly 60M expenditures, 74% utilization (meaning some PCs left over). Most exceptions look like clear bugs/crashes/other-abnormals.
  - Started to increase to 62M expenditure on tac6 last few days. This corresponds to getting 1000 extra of each nonCPU component (500 ea. CPU), utilization of 77.5%.
  - Not seen on tac5 or tac6 since end of seeing round (as of games 720, 874). Practicing on kalamari.

Anticipating the Finals

- Seeding results suggest aggressive day 0 is successful.
- If everyone else purchases aggressively on day 0, only way to make profits is to do so even more.
- But then risk of chronic global overcapacity…
- What to do?
Preemptive Day 0 Strategy

- Ask for 85000 units, due day 30
  - Designed to preempt subsequent RFQs
  - Accept partial offer, if any
- Very likely to reduce average day-0 procurement
- Deep Maize incurs large hit on reputation

Effective Preemption

- Average day-0 procurement / supplier-component
  - No preemption (Semifinals 2, non-DM heat): 71K
  - With preemption (Semifinals 2, DM heat): 27K
Effect on Aggregate Profits

- Profits highly demand-dependent
- Fit relation with and without preemption
- Preemption beneficial if low demand, detrimental if high
- Improves aggregate profits, on average (!) – $6.6M DAP

Final Tournament Results

1. RedAgent $11.9M McGill
2. Deep Maize 9.5M U Michigan
3. TacTex 5.0M U Texas
4. Botticelli 3.3M Brown
5. PackaTAC –1.7M NC State
6. Whitebear –3.5M Cornell
Post-Tournament Experiments

• Try to establish in more controlled environment:
  – Inherent tendency toward day-0 aggressiveness
  – Damaging impact of same
  – Effectiveness of preemption as remedy

Empirical Game Analysis

• Define A(gressive), B(aseline), and P(reeptive) strategies
  – Variations of Deep Maize
  – Differ only on day-0 procurement
• Collect data for multiple instances (~30) of every profile
• Sampling summarizes stochastic effects
Demand Adjusted Profit (DAP)

- Small numbers of games (30 / profile)
- Reduce variance by accounting for influence of customer demand
  - Avg Q as control variate
  - DAP Estimator

\[ E[x] = \int_{\bar{Q}} E[x|\bar{Q}] Pr(\bar{Q})d\bar{Q} \]

Profits vs. Demand (Finals)
Demand Distribution

Two-Strategy Game (Unpreempted)
Two-Strategy Game (Unpreempted)

Two-Strategy Game

Single Preemptor

Two-Strategy Game

Single Preemptor
Symmetric Equilibrium

- $\alpha$ is prob of playing A in symmetric mixed strategy
- $V(X, \alpha)$ payoff for playing X when others play $\alpha$
- Intersection point is equilibrium

Symmetric Mixed-Strategy Equilibria

<table>
<thead>
<tr>
<th></th>
<th>aggressive</th>
<th>baseline</th>
<th>preemptive</th>
<th>Expected Payoff</th>
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<tbody>
<tr>
<td>Non-preemptive</td>
<td>0.82</td>
<td>0.18</td>
<td></td>
<td>$-9.59$ M</td>
</tr>
<tr>
<td>Single Preemptor</td>
<td>0.3</td>
<td>0.7</td>
<td>0.01</td>
<td>$5.92$ M</td>
</tr>
<tr>
<td>Full Three-Strategy</td>
<td>0.23</td>
<td>0.19</td>
<td>0.58</td>
<td>$7.01$ M</td>
</tr>
</tbody>
</table>
Empirical Game Results

- Profits have strong negative to predominance of As
- Equilibrium w/o P is predominantly A
- Presence of P neutralizes difference betw A and B
- P increases DAP in equilibrium by ~$15M

TAC/SCM Summary

- Pivotal strategic decision regarding initial component procurement
- Entrant field heading toward self-destructive mutually unprofitable equilibrium
- Deep Maize introduced preemptive strategy neutralizing aggressive bidding and improving aggregate scores
- Empirical game-theoretic analysis confirms finding from “organic” TAC experiment
TAC Travel-Shopping

• Original ("classic") TAC game
• 8-player symmetric game
• Agents acquire trips for clients, by assembling:
  – Flights
  – Hotels
  – Entertainment
• Interacting goods, various market rules…

Flight Purchase Decision Tree

![Flight Purchase Decision Tree](image-url)
Searching for Walverine…

- Michigan’s TAC Classic agent
- Parametrized strategy space
  - Flight delay parameters
  - Entertainment trading policy
  - Hotel bid shading…
- Restrict attention to a discrete set of $S$ strategies (parameter settings).

Profile Space

$49$ million

$\binom{N + S - 1}{N}$
Reduced Games

- Let each “player” control two TAC agents
- Transformed to 4-player game
  - Less fidelity
  - More tractable
  - \((S = 31, \text{ only } 46,376 \text{ profiles})\)
- 2-player: 496 profiles
- 1-player: 31 profiles

Why Trust Reduced-Game Results?

- Claim: Equilibria in reduced game likely to be relatively stable in full game
- Evidence:
  - Random instances of local-effect games
  - 2-strategy
  - 8-player
More LEG Instances

LEGs with $S=2$, $N=4,6,8,10,12$

Searching $N$-Player TAC Classic ($S=31$)

<table>
<thead>
<tr>
<th>N</th>
<th>Profiles</th>
<th>Explored</th>
<th>Expl %</th>
<th>samples /profile</th>
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</thead>
<tbody>
<tr>
<td>4</td>
<td>46,376</td>
<td>1429</td>
<td>3.1</td>
<td>16.8</td>
</tr>
<tr>
<td>2</td>
<td>496</td>
<td>344</td>
<td>69.4</td>
<td>26.5</td>
</tr>
<tr>
<td>1</td>
<td>31</td>
<td>31</td>
<td>100.0</td>
<td>96.4</td>
</tr>
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</table>
Mapping the 2-Player Game

Analyzing (Partial) Reduced Games

• \(N=1\) (31 profiles)
  – Identified unique pure-strategy NE (PSNE)

• \(N=2\) (344)
  – “Confirmed” 1 PSNE, refuted 340 \(\varepsilon > 10\)
  – 3 confirmed eq. mixture pairs
  – Refuted 304 candidate mixture pairs \(\varepsilon > 10\); 292 \(\varepsilon > 20\)

• \(N=4\) (1429)
  – Refuted 1423 candidate PSNE \(\varepsilon > 10\); 1421 \(\varepsilon > 20\)
  – Est. 114 candidate mixture pairs
    • Confirmed 1 \(\varepsilon < 1\)
    • Refuted 99 \(\varepsilon > 10\); 83 \(\varepsilon > 20\)
Conclusion

- Empirical game methodology bridges simulation and game theory
- Supports conclusions about strategic issues short of exhaustive analysis
- Application to SAA
  - Supports stability of strategy based on self-confirming price predictions

TAC-05

- To be held at IJCAI-05, Edinburgh, 1–3 August
- Supply chain game
  - Substantially revised to eliminate day-0 issue
  - John Collins, GameMaster
- Classic travel-shopping game
  - Still interesting…
  - Ioannis Vetsikas, GameMaster
- Stay tuned for details…
Michigan TAC Team, 99–04

• Faculty
  – Michael Wellman, Satinder Singh
• Staff: Kevin O’Malley
• Graduate Students
  – Shih-Fen Cheng, Joshua Estelle, Christopher Kiekintveld, Kevin Lochner, Thede Loder, Daniel Reeves, Jason Roselander, Matthew Rudary, Julian Schwartzman, Vishal Soni, Yevgeniy Vorobeychik, William Walsh, Peter Wurman
• Undergraduates
  – Anju Khetan, Evan Leung, Jason Powell, Rahul Suri