artificial intelligence, game theory, multiagent systems, multiagent learning, large-scale optimization, large-scale data analysis and analytics, knowledge representation
Scope and applicability of game theory

- Strategic multiagent interactions occur in all fields
  - Economics and business: bidding in auctions, offers in negotiations
  - Political science/law: fair division of resources, e.g., divorce settlements
  - Biology/medicine: robust diabetes management (robustness against “adversarial” selection of parameters in MDP)
  - Computer science: theory, AI, PL, systems; national security (e.g., deploying officers to protect ports), cybersecurity (e.g., determining optimal thresholds against phishing attacks), internet phenomena (e.g., ad auctions)
Game theory background

<table>
<thead>
<tr>
<th></th>
<th>rock</th>
<th>paper</th>
<th>scissors</th>
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</thead>
<tbody>
<tr>
<td>Rock</td>
<td>0,0</td>
<td>-1, 1</td>
<td>1, -1</td>
</tr>
<tr>
<td>Paper</td>
<td>1,-1</td>
<td>0, 0</td>
<td>-1,1</td>
</tr>
<tr>
<td>Scissors</td>
<td>-1,1</td>
<td>1,-1</td>
<td>0,0</td>
</tr>
</tbody>
</table>

- Players
- Actions (aka pure strategies)
- Strategy profile: e.g., (R,p)
- Utility function: e.g., $u_1(R,p) = -1$, $u_2(R,p) = 1$
Imperfect information

• In many important games, there is information that is private to only some agents and not available to other agents
  – In auctions, each bidder may know his own valuation and only know the distribution from which other agents’ valuations are drawn
  – In poker, players may not know private cards held by other players
Extensive-form representation
Extensive-form games

- Two-player zero-sum EFGs can be solved in polynomial time by linear programming
  - Scales to games with up to $10^8$ states

- Iterative algorithms (CFR and EGT) have been developed for computing an $\varepsilon$-equilibrium that scale to games with $10^{17}$ states
  - CFR also applies to multiplayer and general sum games, though no significant guarantees in those classes
  - (MC)CFR is self-play algorithm that samples actions down tree and updates regrets and average strategies stored at every information set
Standard paradigm for solving large imperfect-information games

Original game

Nash equilibrium

Abstracted game

Automated abstraction

Custom equilibrium-finding algorithm

Reverse mapping

Nash equilibrium
Texas hold ‘em poker

• Huge game of imperfect information
  – Most studied imp-info game in AI community since 2006 due to AAAI computer poker competition
  – Multi-billion dollar industry (not “frivolous”)

• Limit Texas hold ‘em – fixed betting size
  – $\sim 10^{17}$ nodes in game tree

• No Limit Texas hold ‘em – unlimited bet size
  – $\sim 10^{165}$ nodes in game tree
  – Most active domain in last several years
  – Most popular variant for humans
Brains vs. Artificial Intelligence

- April 24-May 8, 2015 at Rivers Casino in Pittsburgh, PA
- 20,000 hands of two-player no-limit Texas hold ‘em between “Claudico” and four of the strongest human players in the world
  - Dong Kim, Jason Les, Bjorn Li, Doug Polk
  - 80,000 hands in total
- Humans won by 732,713 chips, which corresponds to 9.16 big blinds per 100 hands
  - Statistically significant at 90% confidence level, but not 95% level
Endgame solving

Strategies for entire game computed offline

Endgame strategies computed in real time to greater degree of accuracy
Exploitation-exploitability tradeoff

Exploitation

Exploitability

Exploitability

Nash equilibrium

Full opponent exploitation

?????
Big picture questions

- Solution concepts, theory, and algorithms for games with more than two agents
- Improved algorithms and theoretical analysis of endgame solving and abstraction
- Interplay between opponent exploitation/learning and game-theoretic solution concepts
- Fundamental theory and applications to other domains
  - medicine, national security
- Fundamental problems in AI and big data analytics
  - New manuscript “Optimal Number of Choices in Rating Contexts,” applications to grading, paper reviewing, dating
• www.ganzfriedresearch.com
• Strategic Adversarial Multiagent Artificial Intelligence Lab (http://www.sam-ai.com/)
• https://www.youtube.com/watch?v=phRAyF1rq0I