Playing complex games

Wouldn’t it be nice if we could play a complex game just like a simple one?
Playing complex games

Wouldn't it be nice if we could play a complex game just like a simple one?

Can you do that?

John Nash
The Strategy Selection Metagame

- Yes, we can!
  - With the strategy selection metagame.

- Strategy:
  - A mapping from states to actions
  - A black-box policy to play the game
The Strategy Selection Metagame

Strategies

Really aggressive
Purely defensive
Something in the middle

Game

1) Identify strategies in a game
The Strategy Selection Metagame

1) Identify strategies in a game
2) Identify how strategies interact
The Strategy Selection Metagame

3) Solve the metagame
The Strategy Selection Metagame

I like the metagame!

<table>
<thead>
<tr>
<th>Strategies</th>
<th>Metagame</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>P</td>
</tr>
<tr>
<td>R</td>
<td>0</td>
</tr>
<tr>
<td>P</td>
<td>1</td>
</tr>
<tr>
<td>S</td>
<td>1</td>
</tr>
</tbody>
</table>

Expected payoff: 0

John Nash

3) Solve the metagame
Metagame in StarCraft

- Complex RTS game
- Vibrant developer community
- Lots of available bots
Metagame in StarCraft

1. Identify strategies:
   – AIIDE 2015 Protoss bots
   – Full game-playing agentes
   – They map states to actions

<table>
<thead>
<tr>
<th>Bot</th>
<th>Xelnaga</th>
<th>CruzBot</th>
<th>NUSBot</th>
<th>Aiur</th>
<th>Skynet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xelnaga</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CruzBot</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>NUSBot</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Aiur</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Skynet</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
2. Identify how strategies interact:

- 100 rounds in Fortress map:

<table>
<thead>
<tr>
<th>Bot</th>
<th>Xelnaga</th>
<th>CruzBot</th>
<th>NUSBot</th>
<th>Aiur</th>
<th>Skynet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xelnaga</td>
<td>-</td>
<td>26%</td>
<td>86%</td>
<td>73%</td>
<td>73%</td>
</tr>
<tr>
<td>CruzBot</td>
<td>74%</td>
<td>-</td>
<td>80%</td>
<td>67%</td>
<td>16%</td>
</tr>
<tr>
<td>NUSBot</td>
<td>14%</td>
<td>20%</td>
<td>-</td>
<td>74%</td>
<td>97%</td>
</tr>
<tr>
<td>Aiur</td>
<td>27%</td>
<td>33%</td>
<td>26%</td>
<td>-</td>
<td>79%</td>
</tr>
<tr>
<td>Skynet</td>
<td>27%</td>
<td>84%</td>
<td>3%</td>
<td>21%</td>
<td>-</td>
</tr>
</tbody>
</table>
3. Solve the metagame:

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xelnaga</td>
<td>41.97%</td>
</tr>
<tr>
<td>CruzBot</td>
<td>28.40%</td>
</tr>
<tr>
<td>NUSBot</td>
<td>0%</td>
</tr>
<tr>
<td>Aiur</td>
<td>0%</td>
</tr>
<tr>
<td>Skynet</td>
<td>29.63%</td>
</tr>
</tbody>
</table>

**Expected payoff:** 50% victories

Nash Equilibrium
Metagame in StarCraft

3. Solve the metagame:

I would even play StarCraft now!

John Nash
Metagame in StarCraft

• Let’s play the metagame!
Metagame in StarCraft

• Isn’t solving it enough?
  – You can do better against sub-optimal opponents

• Computer Rock, Paper, Scissors\(^1\):
  – Nash Equilibrium placed only 27\(^{th}\) out of 55 competitors

Playing the Metagame

- Strategy selection methods:
  - Frequentist
  - Reply-last
  - Nash
  - $\epsilon$-Nash
  - $\alpha$-greedy
  - Single choice
• Strategy selection methods:
  – Frequentist
  – Reply-last
  – Nash
  – $\varepsilon$-Nash
  – $\alpha$-greedy
  – Single choice

Respond to opponent’s most frequent choice
Playing the Metagame

• Strategy selection methods:
  – Frequentist
  – Reply-last
  – Nash
  – $\varepsilon$-Nash
  – $\alpha$-greedy
  – Single choice

Respond to opponent’s last choice
Playing the Metagame

- Strategy selection methods:
  - Frequentist
  - Reply-last
  - Nash
  - $\varepsilon$-Nash
  - $\alpha$-greedy
  - Single choice

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xelnaga</td>
<td>41.97%</td>
</tr>
<tr>
<td>CruzBot</td>
<td>28.40%</td>
</tr>
<tr>
<td>Skynet</td>
<td>29.63%</td>
</tr>
</tbody>
</table>
Playing the Metagame

• Strategy selection methods:
  – Frequentist
  – Reply-last
  – Nash
  – $\epsilon$-Nash
  – $\alpha$-greedy
  – Single choice

Safe opponent exploitation

$(1-\epsilon)$: Nash
$\epsilon$: Frequentist
Playing the Metagame

• Strategy selection methods:
  – Frequentist
  – Reply-last
  – Nash
  – $\varepsilon$-Nash
  – $\alpha$-greedy
  – Single choice

Multi-armed bandit approach

$(1 - \alpha)$: Best strategy
$\alpha$: random strategy
Playing the Metagame

• Strategy selection methods:
  – Frequentist
  – Reply-last
  – Nash
  – $\epsilon$-Nash
  – $\alpha$-greedy
  – Single choice

Dummy player
Always select the same strategy
Experiments

• Strategy selection tournament
  – Strategy selection methods face each other
  – Each match: methods choose a bot
  – Result: queried from a pool of matches
  – Repeat

![Diagram showing strategy selection tournament]

-1

Nash

VS

Reply-last

+1

Xelnaga

Xelnaga vs CruzBot

CruzBot

Match history
Experiments

• Setup
  – 1000-match round-robin tournament
  – 30 repetitions
### Experiments

- **Results**

<table>
<thead>
<tr>
<th></th>
<th>Reply-last</th>
<th>$\epsilon$-Nash</th>
<th>$\alpha$-greedy</th>
<th>Frequentist</th>
<th>Nash</th>
<th>Single choice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reply-last</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\epsilon$-Nash</td>
<td></td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\alpha$-greedy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequentist</td>
<td></td>
<td></td>
<td></td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nash</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Single choice</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-</td>
</tr>
</tbody>
</table>
Experiments

• Results
  – Reply-last is good against ‘repeaters’

<table>
<thead>
<tr>
<th></th>
<th>Reply-last</th>
<th>ε-Nash</th>
<th>α-greedy</th>
<th>Frequentist</th>
<th>Nash</th>
<th>Single choice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reply-last</td>
<td>-</td>
<td>50.2%</td>
<td>62.5%</td>
<td>63%</td>
<td>48.1%</td>
<td>80.8%</td>
</tr>
<tr>
<td>ε-Nash</td>
<td>49.8%</td>
<td>-</td>
<td>49.8%</td>
<td>53.6%</td>
<td>51.3%</td>
<td>69.1%</td>
</tr>
<tr>
<td>α-greedy</td>
<td>37.5%</td>
<td>50.2%</td>
<td>-</td>
<td>52.5%</td>
<td>51.3%</td>
<td>73.5%</td>
</tr>
<tr>
<td>Frequentist</td>
<td>37%</td>
<td>46.4%</td>
<td>47.5%</td>
<td>-</td>
<td>52.5%</td>
<td>80.8%</td>
</tr>
<tr>
<td>Nash</td>
<td>51.9%</td>
<td>48.7%</td>
<td>48.7%</td>
<td>47.5%</td>
<td>-</td>
<td>55.5%</td>
</tr>
<tr>
<td>Single choice</td>
<td>19.2%</td>
<td>30.9%</td>
<td>26.5%</td>
<td>19.2%</td>
<td>44.5%</td>
<td>-</td>
</tr>
</tbody>
</table>
Experiments

• Results
  – Reply-last is good against ‘repeaters’
  – Nash is safe

<table>
<thead>
<tr>
<th></th>
<th>Reply-last</th>
<th>ε-Nash</th>
<th>α-greedy</th>
<th>Frequentist</th>
<th>Nash</th>
<th>Single choice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reply-last</td>
<td>-</td>
<td>50.2%</td>
<td>62.5%</td>
<td>63%</td>
<td>48.1%</td>
<td>80.8%</td>
</tr>
<tr>
<td>ε-Nash</td>
<td>49.8%</td>
<td>-</td>
<td>49.8%</td>
<td>53.6%</td>
<td>51.3%</td>
<td>69.1%</td>
</tr>
<tr>
<td>α-greedy</td>
<td>37.5%</td>
<td>50.2%</td>
<td>-</td>
<td>52.5%</td>
<td>51.3%</td>
<td>73.5%</td>
</tr>
<tr>
<td>Frequentist</td>
<td>37%</td>
<td>46.4%</td>
<td>47.5%</td>
<td>-</td>
<td>52.5%</td>
<td>80.8%</td>
</tr>
<tr>
<td>Nash</td>
<td>51.9%</td>
<td>48.7%</td>
<td>48.7%</td>
<td>47.5%</td>
<td>-</td>
<td>55.5%</td>
</tr>
<tr>
<td>Single choice</td>
<td>19.2%</td>
<td>30.9%</td>
<td>26.5%</td>
<td>19.2%</td>
<td>44.5%</td>
<td>-</td>
</tr>
</tbody>
</table>
Experiments

• Results
  – Reply-last is good against ‘repeaters’
  – Nash is safe
  – $\varepsilon$-Nash performs safe exploitation

<table>
<thead>
<tr>
<th></th>
<th>Reply-last</th>
<th>$\varepsilon$-Nash</th>
<th>$\alpha$-greedy</th>
<th>Frequentist</th>
<th>Nash</th>
<th>Single choice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reply-last</td>
<td>-</td>
<td>50.2%</td>
<td>62.5%</td>
<td>63%</td>
<td>48.1%</td>
<td>80.8%</td>
</tr>
<tr>
<td>$\varepsilon$-Nash</td>
<td>49.8%</td>
<td>-</td>
<td>49.8%</td>
<td>53.6%</td>
<td>51.3%</td>
<td>69.1%</td>
</tr>
<tr>
<td>$\alpha$-greedy</td>
<td>37.5%</td>
<td>50.2%</td>
<td>-</td>
<td>52.5%</td>
<td>51.3%</td>
<td>73.5%</td>
</tr>
<tr>
<td>Frequentist</td>
<td>37%</td>
<td>46.4%</td>
<td>47.5%</td>
<td>-</td>
<td>52.5%</td>
<td>80.8%</td>
</tr>
<tr>
<td>Nash</td>
<td>51.9%</td>
<td>48.7%</td>
<td>48.7%</td>
<td>47.5%</td>
<td>-</td>
<td>55.5%</td>
</tr>
<tr>
<td>Single choice</td>
<td>19.2%</td>
<td>30.9%</td>
<td>26.5%</td>
<td>19.2%</td>
<td>44.5%</td>
<td>-</td>
</tr>
</tbody>
</table>
Conclusion

• Contributions:
  – Simplified representation of complex games
  – Discussion of game theory concepts
  – Spin-off: look out for MegaBot!

• Limitation:
  – Works with a predefined set of strategies

“To Nash Equilibrium… and beyond!”
The end

- Resources:
  - Strategy selection tournament engine
    https://github.com/h3ct0r/StarcraftNash
  - MegaBot
    https://github.com/andertavares/MegaBot

Questions?