Creating Agents for Large Domains

Large multiagent domains, like Texas Hold'em Poker, are too big to calculate an optimal strategy. Instead, we derive a smaller abstract domain, calculate an abstract strategy, and use it to choose actions in the real domain.

Real Game \(10^{14}\) decisions

Game Solving (Intractable)

Real Game Strategy

Abstraction

Abstract Game \(10^9\) decisions

Game Solving (Tractable)

Abstract Game Strategy

How can we evaluate an abstraction?

| In-game performance against a Nash equilibrium | Can't compute an optimal policy in large games! |
| In-game performance against other strategies | Many suboptimal strategies tie, intransitivities are possible |
| Exploitability (or suboptimality) in the real game | Abstract equilibria are rarely the abstract strategies with the lowest real-game exploitability |
| Does not correspond well with in-game performance |

### Game Solving Algorithms: CFR and CFR-BR

**CFR** is a state-of-the-art algorithm for approximating Nash equilibria. **CFR-BR** is a new variant that works well with abstraction: it finds the abstract strategy with the lowest real-game exploitability. This gives a new, fourth way to evaluate an abstraction: its ability to represent a real game Nash equilibrium.

### Three Objectives of This Paper:

- **Demonstrate the use of CFR-BR for evaluating abstractions.**
- **Evaluate state-of-the-art poker abstraction techniques.**
  - Expectation-Based versus Potential Aware
  - New state features used by a world-class poker agent.
- **Evaluate the use of Imperfect Recall abstractions.**
  - Popular technique in the Annual Computer Poker Tournament
  - No proof of convergence, but effective in practice.

### New Poker Distance Metrics

**Earthmover's Distance** over Hand Strength Distributions

In the first three rounds, we can compare two poker hands' distribution over future strength.

**Opponent Cluster Hand Strength (OCHS)**

In any round, measure a hand's probability of winning against clusters of opponent hands. Compare vectors with \(L^2\).

### Forming Abstractions with \(k\)-Means Clustering

After choosing a distance metric (Earthmover or OCHS), we use \(k\)-Means clustering to group poker hands into buckets to form an abstraction for each round. Either Perfect Recall (PR) or Imperfect Recall (IR) can be used. This choice determines \(k\), the number of buckets, as listed in the table.

Combining a recall type (PR or IR), an early-game abstraction (PHS, KE or KO) and an end-game abstraction (PHS or KO) gives a full game abstraction, which can be solved with CFR or CFR-BR to generate strategies.

Evaluating the strategies allows us to evaluate the abstraction technique.

### In-game Performance (CFR)

<table>
<thead>
<tr>
<th>Perfect Recall</th>
<th>Imperfect Recall</th>
</tr>
</thead>
<tbody>
<tr>
<td>PR-PHS</td>
<td>308.188</td>
</tr>
<tr>
<td>PR-KO</td>
<td>288.157</td>
</tr>
<tr>
<td>KE-PHS</td>
<td>295.881</td>
</tr>
<tr>
<td>KE-KO</td>
<td>300.319</td>
</tr>
<tr>
<td>KE-PHS</td>
<td>281.645</td>
</tr>
<tr>
<td>KE-KO</td>
<td>295.881</td>
</tr>
</tbody>
</table>

Results are in milli-big-blinds/game and are accurate to 1.1 mbig.