Research Review

"Safe and Nested Subgame Solving for Imperfect-Information Games"

Problem

In perfect-information games, determining the optimal strategy at a decision point only requires knowledge of the game tree's current node and remaining game tree beyond that node, i.e. the subgames. This is leveraged to build AIs that can beat humans in chess and Go.
However, in imperfect-information games, the optimal strategy in a subgame may depend on the strategy in other, unreached subgames. Therefore, a subgame cannot be solved in isolation and must instead consider the strategy for the entire game as a whole, unlike perfect-information games.

Solutions

This paper proposes to first approximate a solution for the whole game and then improve it by solving individual subgames. It introduces subgame-solving techniques that outperform prior methods both in theory and practice.

It first describes techniques such as Unsafe, Resolve, and Maximargin that consider the target game in isolation which could lead to suboptimal solutions. It then shows how to adapt them to respond to opponent actions that are outside the original action abstraction by introducing Reach subgame-solving and using estimates for alternative payoffs. In addition, it is shown that subgame solving can be repeated as the game progresses down the game tree, leading to far lower exploitability.

Results

Heads-up no-limit Texas hold'em poker is an imperfection-information game that the authors chose to conduct their experiments on. They compared the exploitability of a player's strategy (how much worse does such a strategy perform against an opponent's best response than a Nash-Equilibrium would do) to the prior state of the art technique – action translation. In the three experiments, the results show that all subgame-solving techniques dramatically reduced exploitability, by almost a factor of 10. In particular, Reach-Maximargin performs the best.

This is the first time that exploitability of subgame-solving techniques was measured in large games. These techniques were a key component of Libratus, the first AI to defeat top human poker head-up specialists at a very respectable margin of 147mbb/hand.

The future applications of imperfect-information games include negotiation, auctions, and cybersecurity.