Adversarial Search

Toolbox so far

- Uninformed search
  - BFS, DFS, iterative deepening DFS, uniform cost search
- Heuristic search
  - A*
- Local search
  - Hill climbing, simulated annealing, genetic algorithms
- Constraint satisfaction problems

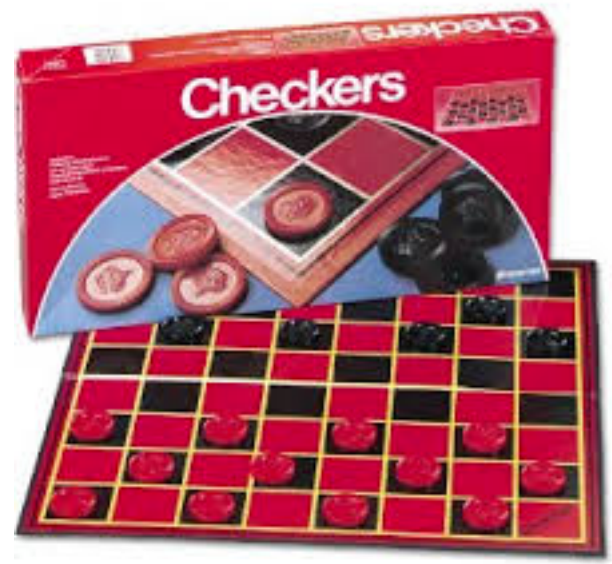
Common environmental factors: static, discrete, fully observable, deterministic actions.
Also: single agent, non-episodic.

Kick it up a notch!

- Add a second agent, but not controlled by us.
- Assume this agent is our adversary.
- Environment (for now)
  - Still static
  - Still discrete
  - Still fully observable (for now)
  - Still deterministic (for now)

Games!

- Deterministic, turn-taking, two-player, zero-sum games of perfect information.



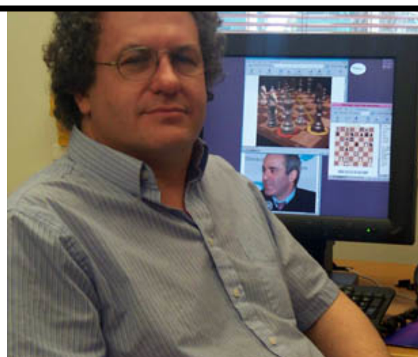
Checkers Is Solved

Jonathan Schaeffer,* Neil Burch, Yngvi Björnsson,† Akihiro Kishimoto,‡
Martin Müller, Robert Lake, Paul Lu, Steve Sutphen

The game of checkers has roughly 500 billion billion possible positions (5×10^{20}). The task of solving the game, determining the final result in a game with no mistakes made by either player, is daunting. Since 1989, almost continuously, dozens of computers have been working on solving

best known is the four-color theorem (*9*). This deceptively simple conjecture—that given an arbitrary map with countries, you need at most four different colors to guarantee that no two adjoining countries have the same color—has been extremely difficult to prove analytically. In 1976, a computational proof was demonstrated. Despite the convincing result, some mathematicians were skeptical, distrusting proofs that had not been verified using human-derived theorems. Although important components of the checkers

The game of checkers has roughly 500 billion billion possible positions (5×10^{20}). The task of solving the game, determining the final result in a game with no mistakes made by either player, is daunting. Since 1989, almost continuously, dozens of computers have been working on solving checkers, applying state-of-the-art artificial intelligence techniques to the proving process. This paper announces that checkers is now solved: Perfect play by both sides leads to a draw. This is the most challenging popular game to be solved to date, roughly one million times as complex as Connect Four. Artificial intelligence technology has been used to generate strong heuristic-based game-playing programs, such as Deep Blue for chess. Solving a game takes this to the next level by replacing the heuristics with perfection.



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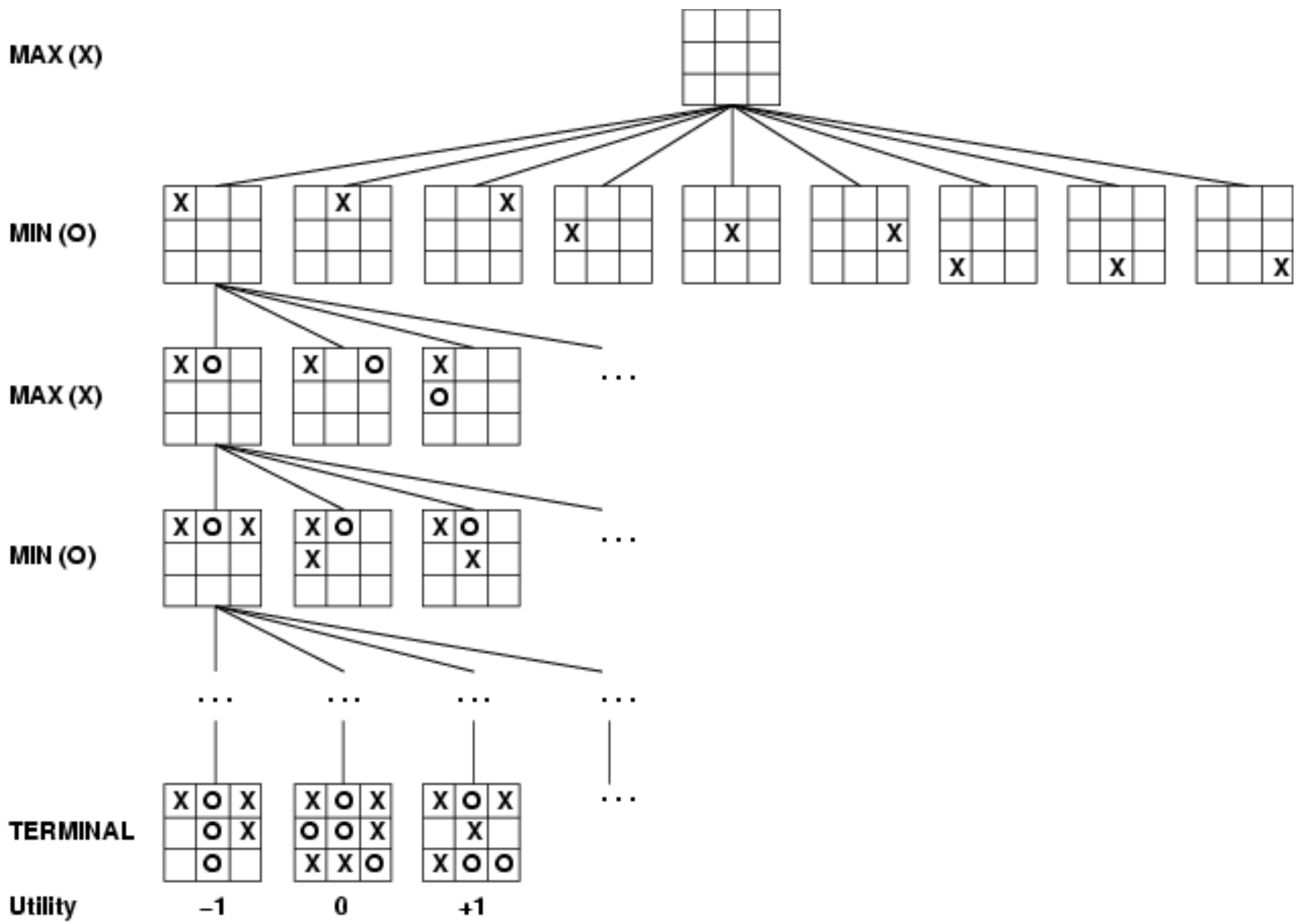
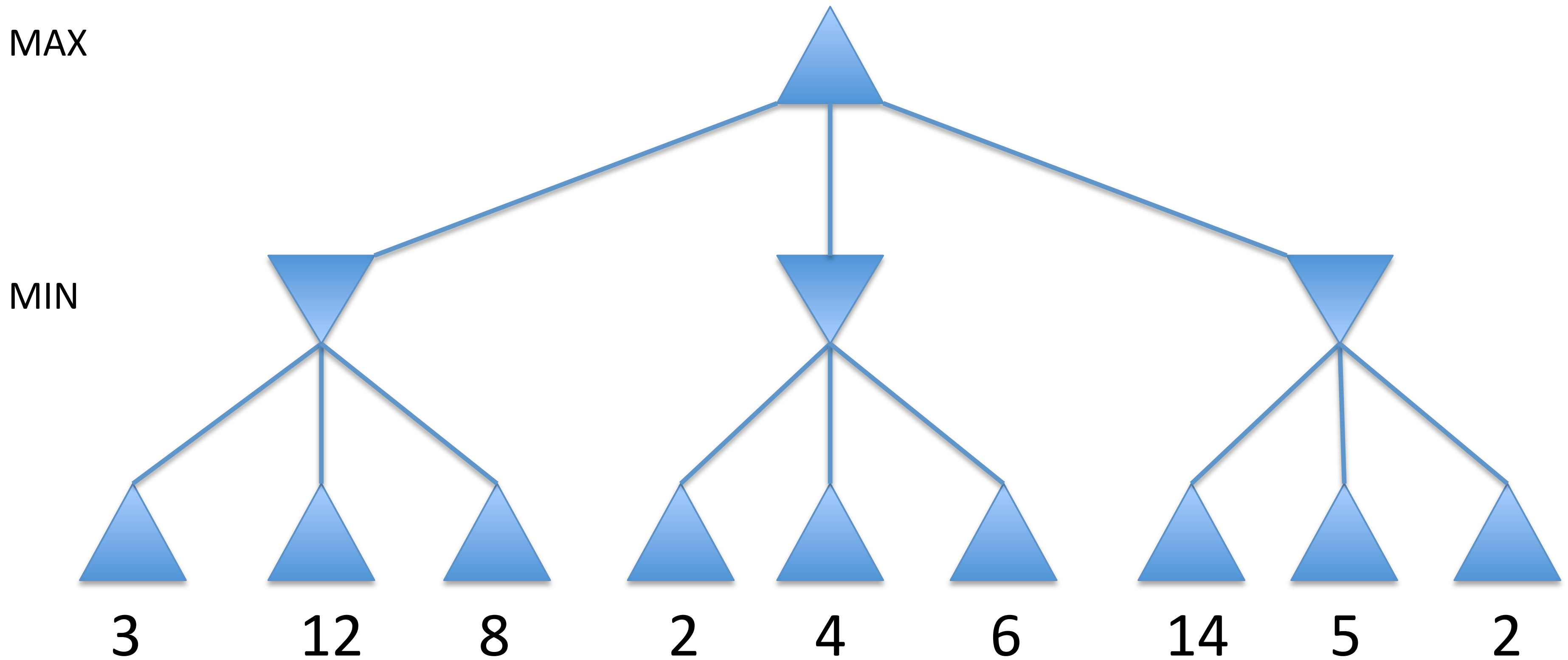
Adversarial search

- Still search!
  - But another agent will alternate actions with us.
- Concepts:
  - Two players are called MAX and MIN.
  - Instead of goal states, we have terminal states.
  - Utility function: tells how good a state is for a certain player.
  - Every state has a set of actions that can be taken.
  - Given a state and an action, you get another state.

Game Tree




MAX
MIN
3
12
8
2
4
6
14
5
2

Minimax algorithm

- Select the best move for you, assuming your opponent is selecting the best move for themselves.
- Works like DFS.

Properties of minimax

- Complete?
  - Yes (assuming tree is finite)
- Optimal?
  - Yes (assuming opponent is also optimal)
- Time complexity: $O(b^m)$
- Space complexity: $O(bm)$ (like DFS)
- But for chess, $b \approx 35$, $m \approx 100$, so this time is completely infeasible!