Research Review

By David Venturi

AlphaGo by the DeepMind Team

Mastering the game of Go with deep neural networks and tree search[1]

Goals

The specific goal of the research is described in the title of the article: to master the game of Go with deep neural networks and tree search. The program created for this challenge was named AlphaGo.

Broadly, the DeepMind team's goals was to find and apply novel techniques that are successful in games that have massive search spaces. The degree of massiveness isn't explicitly defined, though the DeepMind team often refers to the search space of Go being massive in relation to the search space of chess. A game of Go using a 19x19 board has a branching factor of 250, a state-space complexity of 10^{170}, and a game-tree complexity of 10^{250}, while chess has much smaller values of 35, 10^{47}, 10^{123}.[2] The massiveness of Go was previously thought to make the game unconquerable by computers until decades in the future.

Even more broadly, the DeepMind team wished to progress the field of artificial intelligence to help solve other problems. These problems are often grander in scope, i.e., more life-changing than a computer beating a human at a board game. Using artificial intelligence in personalized medicine, for example.[3]

Several novel techniques (or combinations of techniques) were introduced:

- Using 'value networks' to evaluate board positions and 'policy networks' to select moves
- Training these deep neural networks using a combination of supervised learning from human expert games, and reinforcement learning from games of self-play
- A new search algorithm that combines Monte Carlo simulation with the 'value' and 'policy' networks

Results

A human professional Go player was defeated by a computer program (AlphaGo) for the first time in history and decades in advance of public expectation. Oft described as the last frontier for artificial intelligence in conquering full information games, a program was created that plays Go at the level of the strongest human players.

AlphaGo also had 99.8% winning rate against other computer Go programs, demonstrating its dominance. DeepMind's research also revealed the level of computational power required to conquer such a task. The final version of AlphaGo used 40 search threads, 48 CPUs, and 8 GPUs. Though a distributed version with 40 search threads, 1,202 CPUs, and 176 GPUs was also implemented, the program's competitiveness in terms of Elo rating exhibited diminishing returns.

This feat involved, as described at the end of the paper, *"a challenging decision-making task, an intractable search space, and an optimal solution so complex it appears infeasible to directly approximate using a policy or value function."* DeepMind's research has provided hope that, by similarly leveraging AlphaGo's novel techniques, human-level performance can be achieved in artificial intelligence domains that were also previously seen as currently unconquerable.

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[1] Mastering the game of Go with deep neural networks and tree search, Nature. https://storage.googleapis.com/deepmind-media/alphago/AlphaGoNaturePaper.pdf
[2] Game complexity, Wikipedia. https://en.wikipedia.org/wiki/Game_complexity#State-space_complexity
[3] AlphaGo Can Shape the Future of Healthcare, The Medical Futurist. http://medicalfuturist.com/alphago-artificial-intelligence-in-healthcare/