AlphaGo and Artificial Intelligence

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GUEST LECTURE IN “THE GAME OF GO AND SOCIETY” AT OCCIDENTAL COLLEGE, 10/29/2018
The Game of Go

A game for aliens, presidents, and gods.

- “... if intelligent life forms exist elsewhere in the universe they almost certainly play Go.”
  – Chess master Edward Lasker.

- “I learned to play Go in college ... It's a very complicated game ... non-linear.”
  – President Barack Obama.

- “I'm making the universe. It's like I'm a God. I'm going to become a God! On this Go Board.”
  – Hikaru, in the Hikaru no Go anime.

A grand challenge for artificial intelligence to beat a top professional.

- No program came close before AlphaGo.
Alternate Views

Scientific achievement?

Master of Go?

Harbinger of automation?
Computer Go is hard

There are many possible games of Go:
- Number of Go games: $\approx 10^{511}$.
- Number of chess games: $\approx 10^{120}$.
- Number of atoms in the universe: $\approx 10^{80}$.

The *branch factor* is high:
- $\approx 200$ possible moves at each turn in Go.
- $\approx 20$ possible moves at each turn in chess.
- Hard for brute-force search!

Non-locality:
- The best move in a game of Go may be far away from the previous move.
Why now?

Why the explosive progress of (Go) AI in the last 10 years?

Lots of **computing power**.
- Huge networks of computers (i.e. server farms).
- Specialized hardware: GPUs, TPUs.

 Lots of **data**.
- User-generated content, social media.
- Ubiquitous sensors.

The main **algorithms** are not new.
- Neural networks [McCulloch and Pitts 1943, Rosenblatt 1957].
- (Stochastic) gradient descent [Cauchy 1847, Robbins and Munro 1951].
- Reinforcement learning [Sutton 1984].
- Backpropagation [Linnainmaa 1970].
- Monte Carlo Tree Search [Abramson 1987].
The Algorithms behind AlphaGo

   - A *policy network* – used to predict which moves are most likely to be played.
   - A *value network* – used to predict how likely a move is to result in a win.

2. Reinforcement learning.
   - AlphaGo Zero *only* uses reinforcement learning to train its networks.

3. Monte Carlo Tree Search (MCTS).
   - A different way to predict how likely a move is to result in a win.

Image source: Silver, David et al. “Mastering the game of Go with deep neural networks and tree search.”
The Perceptron: A 1-node Neural Network

**Inputs:** $x_1, x_2$ which are either 0 or 1.

The weights $w_0, w_1, w_2$ are numbers that are set while *training* the neural network, but which don’t change when *evaluating* it.

**Output:** A 1 if $w_1 x_1 + w_2 x_2 \geq w_0$ and 0 otherwise.

Example: AND($x_1, x_2$).
\[ w_1 = w_2 = 1, w_0 = 2. \]

Example: NOT($x_1$).
\[ w_1 = -1, w_2 = 0, w_0 = 0. \]
(Deep) Neural Networks

Figure 12.2 Deep network architecture with multiple layers.

Image source: https://twitter.com/gp_pulipaka/status/944590018957529088
Reinforcement Learning

“Reinforcement learning = learning by playing itself” for games.

Learn given only a state space, a set of actions and a reward function.

- State space: Possible Go board configurations.
- Actions: Legal Go moves.
- Reward: Does playing the move result in a win or a loss?

Reinforcement learning does not use human-generated data.

- The first version of AlphaGo trained on some human games and then used reinforcement learning.
- AlphaGo Zero and AlphaZero used only reinforcement learning, and no human games or knowledge.

Image source: https://skymind.ai/wiki/deep-reinforcement-learning
Monte Carlo Tree Search (MCTS)

The basic algorithm:
1. Play a candidate move.
2. For each candidate move from Step (1), play out 10000 games all the way to the end randomly, and record in how many of the games black won.
3. Select the move that resulted in the most wins in Step (2).

Improvements:
- Store win rates for variations considered in Step (2) deeper in the search tree.
- Use these to bias further playouts in terms of *exploitation* and *expansion*.
AlphaGo is strong

October 2015:
◦ Defeated Fan Hui 2P, European champion, 5-0.

March 2016:
◦ Defeated Lee Sedol 9P, 18-time world champion, 4-1.

December 2016 – January 2017:
◦ Defeated many top players in online games, 60-0.

May 2017:
◦ Defeated Ke Jie 9P, ranked #1 in the world at the time, 3-0.
Where does that leave us?

... signalled the birth of a “new age—an age of computers able to resolve specifically humanistic problems.” Lockhart told me that his “heart really sank” at the news of AlphaGo’s success. Go, he said, was supposed to be the “the one game computers can’t beat humans at. It’s the one.”

From The New Yorker.
“What’s bad about better AI?"

The title of a slide from a presentation by Stuart Russell.

**Ethical issues related to AI:**

1. Weaponization.
2. Accountability.
4. Automation of work.
Killer robots?
More likely

Study by Frey and Osbourne (≥ 2700 citations): 47% of American jobs will be **automated** in the near future:
- Most likely: Telemarketers (99% chance).
- Least likely: Recreational therapists (0.3% chance).
- In the middle: Computer programmers (48% chance).
- Go players?
A challenge for the 21\textsuperscript{st} century

How to handle the automation of work?

1. 
   - 
     - Retraining programs.
     - “Everyone should learn how to program.”

2. Universal income.

Editorial comment: These things aren’t enough.
All true at once

Scientific achievement

Master of Go

Harbinger of automation
This talk is based on my article “AlphaGo and Artificial Intelligence” from March 2016. Available at https://hdbennett.wordpress.com/2016/03/18/alphago-and-artificial-intelligence/.

The AlphaGo papers: