An Application of Artificial General Intelligence in Board Games

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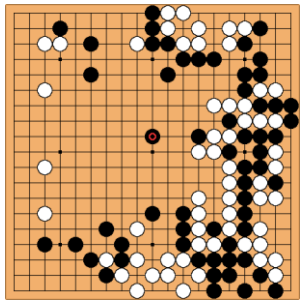
Go

- 19x19 Board Game (13x13 and 9x9 variants exist)
- Place pieces (black or white) on empty intersects of the board grid until filled
- Surrounding opponent's pieces captures the pieces within the territory
- Final game score for each player is calculated based on the total of empty spaces within a player's territory plus the number of pieces that player has captured



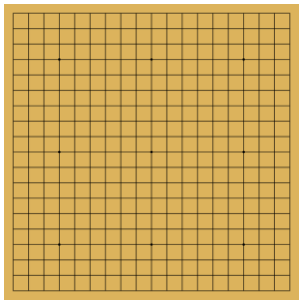
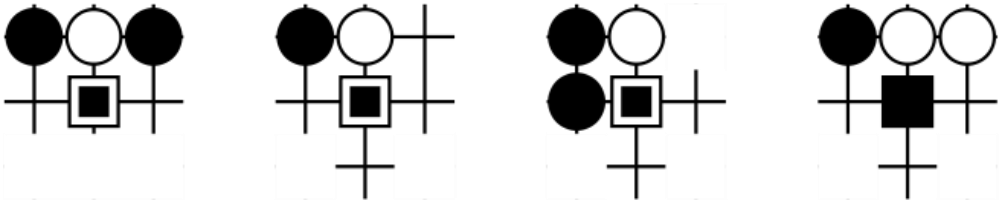


Image: Gringer. (19 February 2009). *Blank Go Board* [Digital]. Retrieved from https://commons.wikimedia.org/wiki/File:Blank_Go_board.svg.

Research - Monte-Carlo Tree Search (MCTS)

Pachi (2011) - MCTS with Rule-based Adaptive Policy Playouts

- MCTS with simulation-limited depth
- Common, high-level play patterns in local board analysis to calculate priority of playouts



Baudis, P., & Gailly, J. (2011). PACHI: State of the Art Open Source Go Program. *ACG*.
Browne, C. *et al.* A survey of Monte-Carlo tree search methods. *IEEE Trans. Comput. Intell. AI in Games* 4 (2012).

Implementation - MCTS

Development Work

- Implemented in Python 2.7
- MCTS with Adaptive Policy Playout
- Go-Text Protocol (GTP)
  - Text-based interface: command (genmove w) and response (= C5)
  - Allows for dependency inversion against other go engines

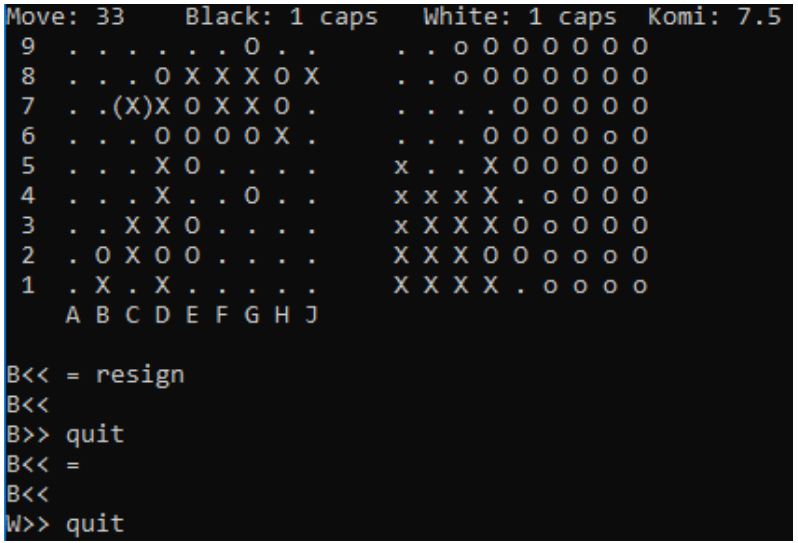
Elo Rating

- Arpad Elo, inventor
- A fair approximation of the outcome of a match between opponents
- Pachi Go-Engine pleads research comparisons via Elo, not win percentage
- Formula: $P(A \text{ wins}) = 1 / (1 + 10^{(\text{RatingB} - \text{RatingA}) / 400})$

Elo, Arpad E (2008). "8.4 Logistic Probability as a Rating Basis". *The Rating of Chessplayers, Past&Present*. Bronx NY 10453: ISHI Press International.

Evaluating Research Implementation vs Pachi

- GoGui-TwoGTP
- Research (Black:X) vs Pachi (White:O)
- Games Played: 25
- Research Win/Loss: 1-24



1400-1648

Estimated Elo Rating of research implementation based playing against Pachi

Research: Reinforcement Learning

AlphaGo (2016) by DeepMind

- **Supervised Learning** via replaying high ranked games provided by KGS

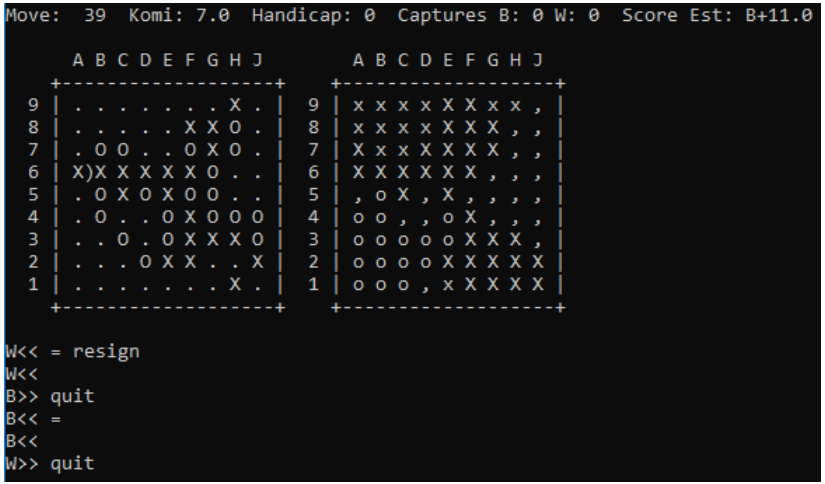
AlphaGo: Zero (2017) by DeepMind

- **Unsupervised Learning** via self-play
- minigo: a community implementation of the AlphaGo: Zero paper

Silver, D., Huang, A., Maddison, C. J., Guez, A., Sifre, L., Van Den Driessche, G., ... & Dieleman, S. (2016). Mastering the game of Go with deep neural networks and tree search. nature, 529(7587), 484.
Silver, D., Schrittwieser, J., Simonyan, K., Antonoglou, I., Huang, A., Guez, A., ... & Chen, Y. (2017). Mastering the game of Go without human knowledge. Nature, 550(7676), 354.

Evaluating minigo vs Pachi

- Minigo (Black:X) vs Pachi (White:O)
- Games Played: 25
- Research Win/Loss: 7-18



1750-2035

Estimated ELO Rank of minigo based on games played against Pachi

Future Work

- Focus on implementing reinforcement learning like AlphaGo:Zero's learning
- Steps so far:
  - GTP to Pachi interface
  - MCTS with Adaptive Policy Playout
  - Deployed 'minigo' program
  - Integrated system with Google Tensorflow GPU 1.13
- Ongoing Work:
  - Tensorflow-based reinforcement learning with GPU processing

Acknowledgments

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