Applying Deep Reinforcement Learning to finite state single player games

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Task Definition

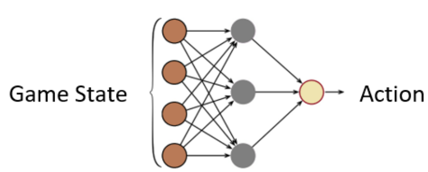
Design an engine capable of solving any valid constructed ***Solitaire Chess Puzzle***. The engine must be capable of performing better than a brute force approach by exploring less paths (sequence of states-actions).

Game Summary

Solitaire Chess is a single-player logic game utilizing the same rules of classical chess, but presented in a simplified form posed as mini Chess problems rather than full length opponent based strategy games.

Rules

- A single-player game.
- All of the Chess pieces are the same color.
- Pawns can be placed anywhere on the board.
- Pawns are not promoted and captured pieces cannot be restored.
- Kings cannot be placed into a state of check and should never be captured.
- Every move must result in a piece capture.



Considerations

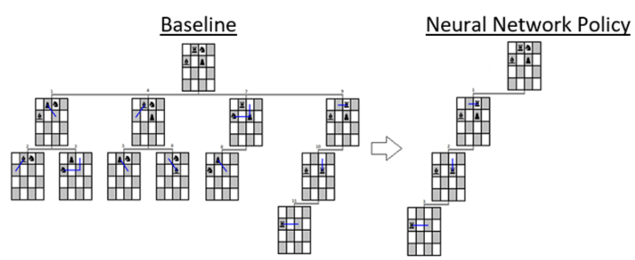
- All valid puzzles are designed to have a distinct winning piece. However, the sequence of actions need not be unique.
- A valid puzzle can contain multiple instances of any chess piece except for a King.

Evaluation Metrics

- The ***accuracy*** of identifying the intended final board piece and its final position. Must be 100% to be considered a viable model.
- The ***number of paths explored*** needed to identify a valid solution. Must be less than the average needed by baseline model.

Challenges

- Popular Chess solving strategies offer very little to no advantage to Solitaire Chess:
  - There are no opposing agents.
  - Every action must result in a capture.
- Increasing the number of Chess pieces of a puzzle increases the size of the solution search space.



Q-Learning + Exploration

$$Q(s,a) \leftarrow (1-\alpha)Q(s,a) + \alpha\left(r + \gamma \max_{a'}\{E\big(Q(s',a'), N(s',a')\big)\}\right)$$

Benchmark Models

- **Baseline**: Backtracking algorithm iterating through entire search space of all possible actions.
- **Oracle**: Human generated solutions created by The author of Solitaire Chess.

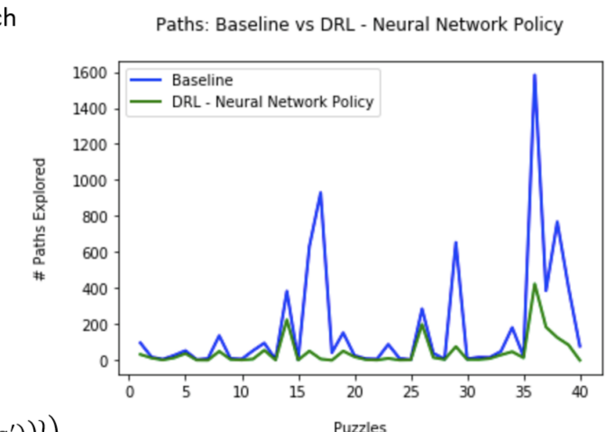
Our Model

Applied a ***Deep Reinforcement Learning (DRL)*** Model based on ***Deep Q-Learning (DQN)*** to choose the best action for a given state. The estimated Q-Value is updated using ***Experience Replay***. A multi-layer perceptron network was implemented using Google TensorFlow.

- Which action to take in a given state.
- Estimated value based on the current state.

Results

- Correctly identified **100%** of final pieces.
- On average, **explored less paths** than baseline.



Video

https://youtu.be/r9RTdeM09wM