Reinforcement Learning

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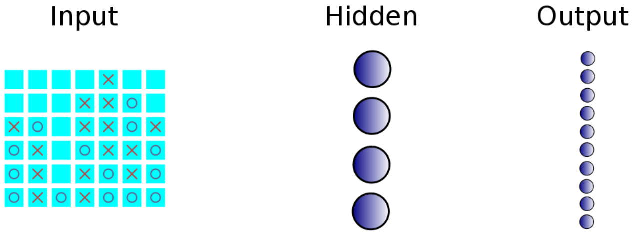
Outline

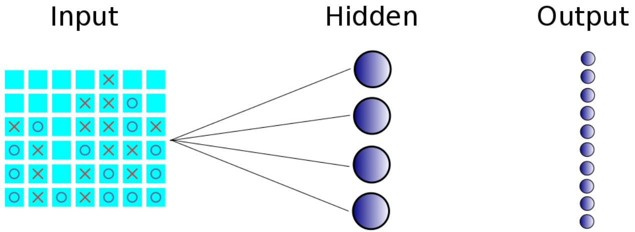
Supervised Learning vs Reinforcement Learning

- Supervised Learning
  - Have access to a large set of data with known desired results
  - Adjust model parameters to minimize an objective function
- Reinforcement Learning
  - Have access to an environment that can be modeled
  - Typically a reward function is used as a signal for how to adjust model parameters
  - Board games present a natural environment that is easily modeled and can provide a reward whenever a game finishes.

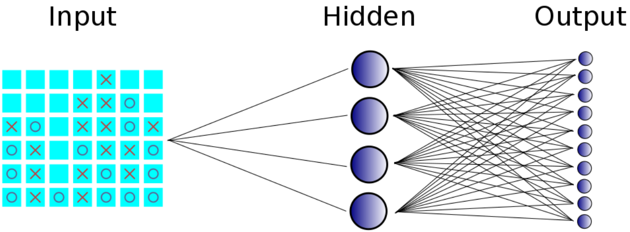
Simple Perceptron



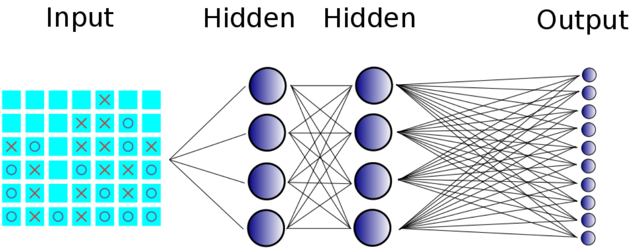
Simple Perceptron



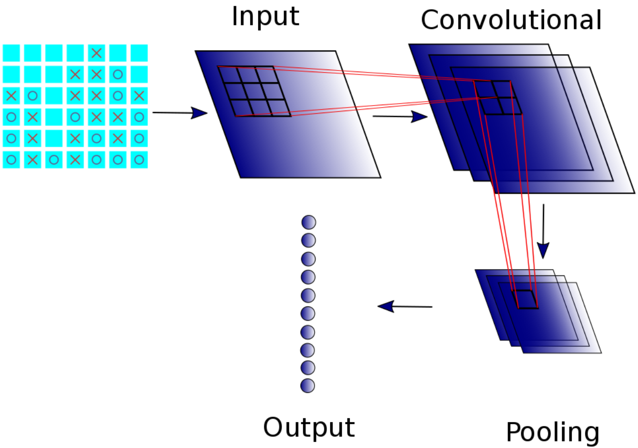
Simple Perceptron



Multilayer Perceptron

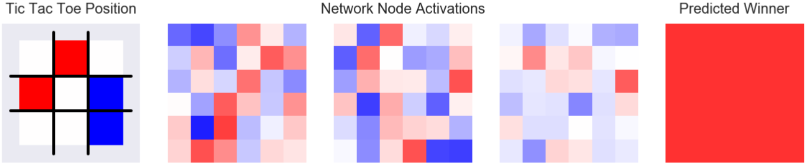


Convolutional Neural Network



Value Network

- A value network is a neural network that evaluates an environment and determines a value to associate to it
- In the case of board games, a value network can be used to determine the probability of winning from any given position
- Here is an example of a multi-layered neural network in action
- The network takes a Tic Tac Toe board as input, and through a succession of node activations the network outputs a prediction on who will win, in this case: the red player



Temporal Difference Learning

- TD(λ) Equation
  - When a terminal state occurs, the reward propagates to previous states and the targets are updated

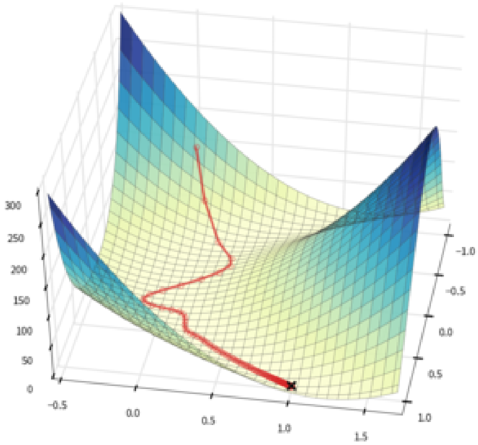
$$T_n = \quad (1-\lambda) \quad V_n + \lambda \quad r$$

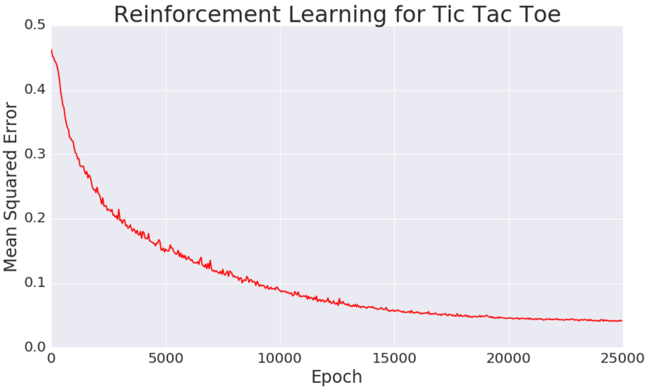
Temporal Difference Learning

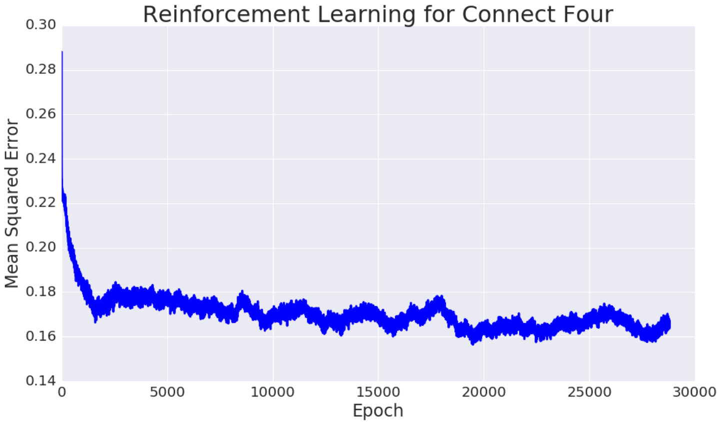
- TD(λ) Equation
  - When a terminal state occurs, the reward propagates to previous states and the targets are updated

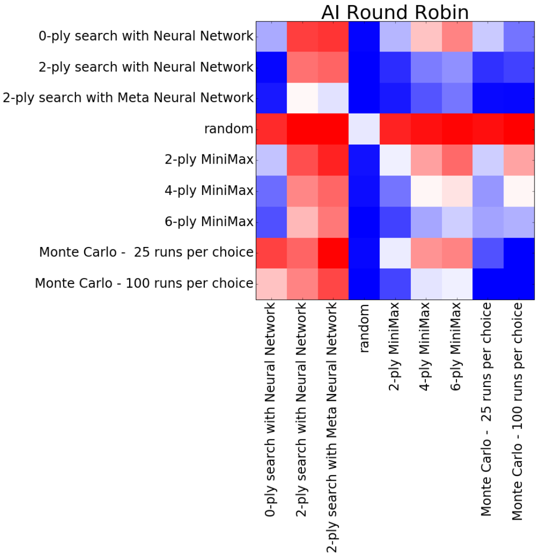
$$T_n = \sum_{n=0}^{N_0} (1-\lambda)\lambda^n V_n + \lambda^{N_0} r$$

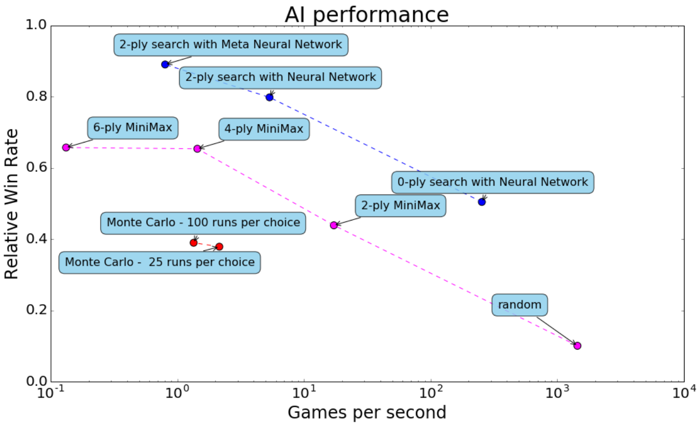
Stochastic Gradient Descent




Reinforcement Learning for Tic Tac Toe
Mean Squared Error
0.0
0.1
0.2
0.3
0.4
0.5
Epoch
0
5000
10000
15000
20000
25000


Reinforcement Learning for Connect Four
Mean Squared Error
Epoch
0.30
0.28
0.26
0.24
0.22
0.20
0.18
0.16
0.14
0
5000
10000
15000
20000
25000
30000


AI Round Robin
0-ply search with Neural Network
2-ply search with Neural Network
2-ply search with Meta Neural Network
random
2-ply MiniMax
4-ply MiniMax
6-ply MiniMax
Monte Carlo - 25 runs per choice
Monte Carlo - 100 runs per choice


AI performance
2-ply search with Meta Neural Network
2-ply search with Neural Network
6-ply MiniMax
4-ply MiniMax
0-ply search with Neural Network
2-ply MiniMax
Monte Carlo - 100 runs per choice
Monte Carlo - 25 runs per choice
random
Relative Win Rate
1.0
0.8
0.6
0.4
0.2
0.0
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
Games per second

Future Directions

- Apply to more games
  - chess, hex, backgammon, go, video games, etc.
- Route finding app
- Traffic prediction analysis
- Control (robots, self-driving cars, etc.)
- Prediction (stock prices, sports betting, etc.)
- Acquire large data sets and compare with supervised learning