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AI in chess games

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1-Introduction:

Chess is a recreational and competitive board game played between two players.

It is played on a square chessboard with 64 squares arranged in an eight-by-eight grid. At the start, each player (one controlling the white pieces, the other controlling the black pieces) controls sixteen pieces: one king, one queen, two rooks, two knights, two bishops, and eight pawns. The object of the game is to checkmate the opponent's king, whereby the king is under immediate attack (in "check") and there is no way for it to escape. There are also several ways a game can end in a draw.

One of the goals of early computer scientists was to create a chess-playing machine. In 1997, Deep Blue became the first computer to beat the reigning World Champion in a match when it defeated Garry Kasparov. Though not flawless, today's chess engines are significantly stronger than even the best human players, and have deeply influenced the development of chess theory.

2-Chess Complexity

Programming a computer to play chess is not an easy task. You can't hard code the perfect move for every position since the size of the complete Search Tree of chess is 10^{123}.

To compare to other board games we can see it in this list:

- Tic Tac Toe: 10^{5}
- Connect Four: 10^{21}
- Chess: 10^{123}
- Backgammon: 10^{144}
- Go: 10^{360}

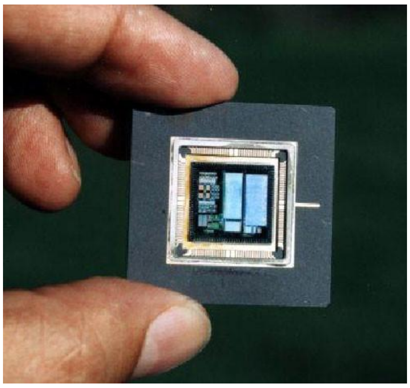
So chess doesn't have a Search Tree as big as Backmoon or Go, but still is very huge. To compare:

- Number of Atoms in Human Body: 10^{27}
- Atoms in Earth: 10^{49}
- Atoms in Milky Way: 10^{68}
- Atoms in Universe: 10^{78}

So if the question is, can we not just store all the perfect moves? The answer obviously is no. We need to use heuristic algorithms, tree search, evaluation functions and a lot of techniques to make an AI to play chess. This way it won't play perfectly but almost, like Deep Blue did.

3-Deep Blue:

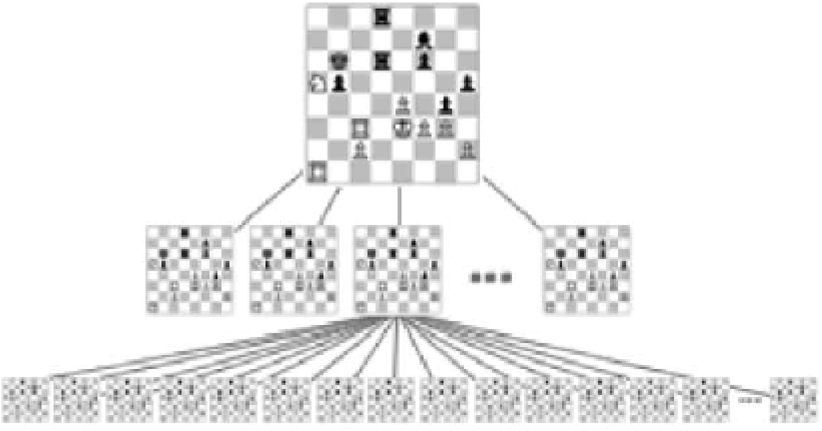
Deep Blue was a very important supercomputer made by IBM in the 90’s. It was formed by 30 IBM Power2 processors of 120 MHz with another 480 coprocessors specially made for this machine. It could calculate 100 million plays per second.



As well as the hardware is important, the software designed by IBM is important too. These are some of the most important AI Techniques used by Deep Blue:

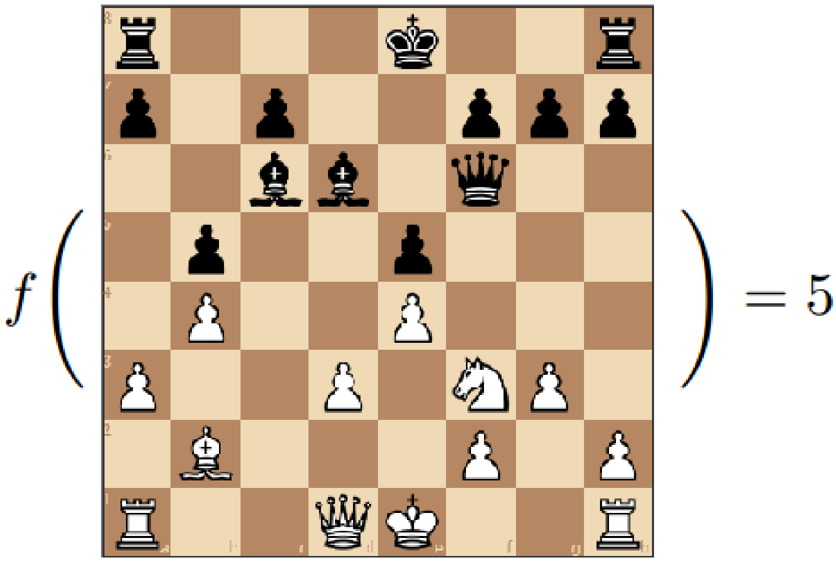
Tree Search

The basic model of chess is that of a Tree Search problem, where each state is a particular arrangement of the pieces on the board and the available actions correspond to the legal chess moves for the current player in that arrangement.



The Evaluation Function

Since we can't look forward all the way to the end of the game and see if a particular move will win (especially since we don't know what the other player will do during their turns!), we must create a function which takes in a state of the game (in our case, a board arrangement) and boils it down to a real-number evaluation of the state.

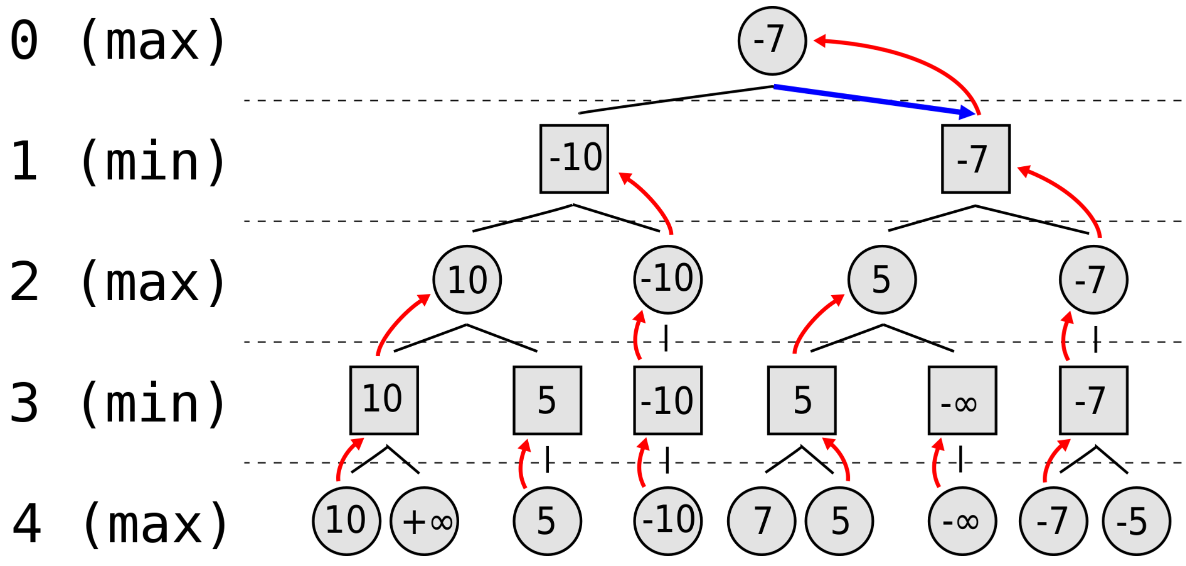


The function could give higher scores to board states in which the player of interest has more of their pieces on the board than the opponent. In particular, we would probably want the function to assign an extremely high score (perhaps even infinity) to the board arrangement in which the opponent's king is in checkmate, meaning that the player of interest is guaranteed to win the game.

The Minimax Algorithm

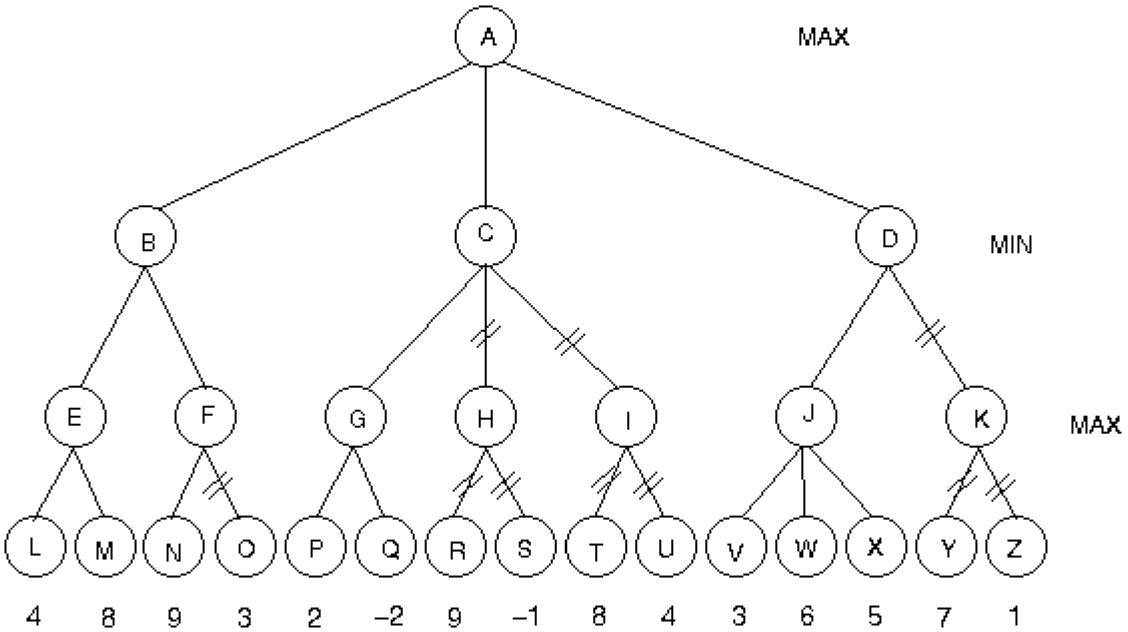
Given an evaluation, all that's left is a way of actually choosing which move to take. Although looking ahead one step and simply choosing the move which leads to the board arrangement with the highest evaluation score would be a good baseline, we can be even smarter and take into account the actions our opponent could take once we've moved.

This intuition leads to the "Minimax algorithm", so-called because we choose the action which minimizes our maximum possible "loss" from making a particular move.



Heuristics/Optimizations

A popular optimization of minimax is known as Alpha-beta pruning, wherein any move for which another move has already been discovered that is guaranteed to do better than it is eliminated. For example, in the following tree we do not need to explore any of the paths whose edges are crossed-out, since we've already found moves we know will perform better:



Along with this technique of increasing the amount of wins and decreasing the amount of losses there were some techniques of machine learning. Machine learning is the study of computer algorithms that can improve automatically through experience and by the use of data. Those techniques were used to improve the algorithm. So this machine used the games it played to improve and be better.

4-Stockfish:

Stockfish is a free open-source chess engine created in 2008 and is still being improved year by year. Stockfish can use up to 512 CPU threads in multiprocessor systems and has a maximum size of 32 TB cache of previously seen positions. The software had been developed in C++ and implements an advanced alpha-beta which was highlighted for its depth and a neural network is used as the validation function. This chess engine could examine 70 million positions per second.

Nowadays Stockfish is a chess engine with a higher elo than the current chess world champion Magnus Carlsen.

5-Alpha Zero:

In the last years all popular chess playing algorithms were based on the min-max algorithm with an alpha-beta pruning, used a tree structure for calculating all the different possibilities and complex evaluation functions.

In 2017 DeepMind developed AlphaZero, it specializes in playing turn-based 2 player games (like chess, shogi and go). For this purpose it uses reinforced learning techniques and deep neural networks.

AlphaZero uses the Monte Carlo search tree that evaluates a position by generating a series of sequences of random moves and, averaging the final results it generates (win / draw / loss), modifies the evaluation function when random moves lead to good positions.

AlphaZero only makes 80.000 position searches per second in comparison with the 70 millions Stockfish do. This is compensated by the use of it’s deep neural network that focuses more on the best possibility.

The current position on the board is entered into the input layer of the neural network. Then it is processed by the first layer of neurons. The neurons of this layer send the result to the neurons of the next layer until reaching the output layer that obtains the final result.

AlphaZero's neural network has 80 layers and hundreds of thousands of neurons. The weights are very important, because training the network is a matter of giving values to the weights so that the network learns to play chess well.

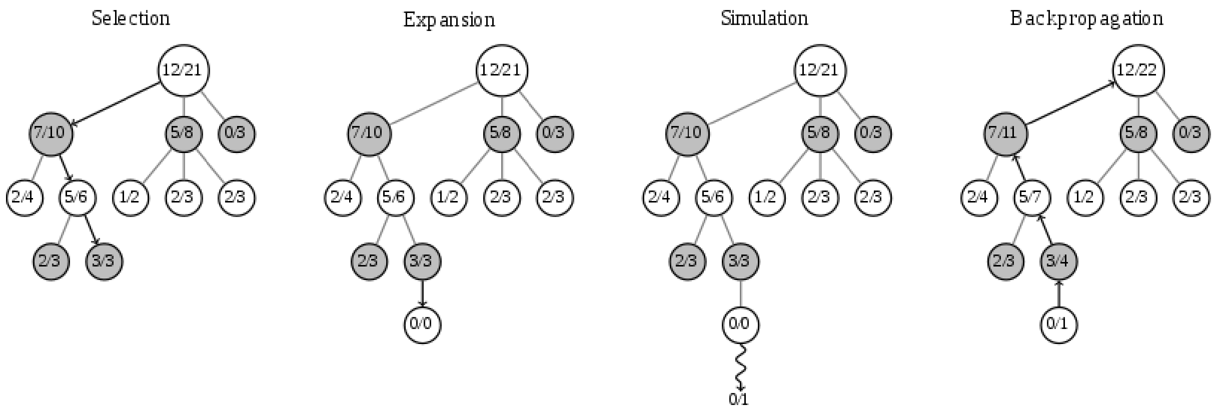
As well as the software is important, it is important to have good hardware too. This Alpha Zero engine uses 5,000 first generation TPUs to generate autonomous games and 64 second generation TPUs to perform the training. Nevertheless, it only uses 4 TPUs for playing.

6-Monte Carlo:

Is a Best-First algorithm based on randomized explorations of the search area. This algorithm uses the results of previous explorations to grow a game tree in memory, and becomes more accurate at estimating values for next moves.

The algorithm consist of four phases:

1. **Selection:** This phase is applied recursively starting from the root node until a leaf node that isn't added to the tree is reached.
2. **Expansion:** For each action a child node is added to the tree.
3. **Simulation:** plays moves in self-play until the end of the game.
4. **Backpropagation:** The result is propagated up the tree.



7-Conclusions:

A human can't win against a machine in terms of computational power. In games like chess it is clearly shown that as the time passes the AI algorithms and hardware capacity makes it even harder to play against a machine. Even though machines and robots can't win against humans in fields like emotions and mobility, there are things that a machine does much better than a human.

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