

Deep Blue - Summary of Techniques, Results, and Extensions

Patrick Yoho

The intention of this brief paper is to summarize the techniques and advances made during the development of IBM's Deep Blue II, the chess machine that beat World Chess Champion Garry Kasparov in 1997. It was the first such game agent to achieve this level of superhuman performance in chess. We will try to prepare the reader with the context and basic intuitions that are helpful for engaging directly with the primary source paper¹.

Game Context

The basics of chess are potentially well-known so we will skip any description of the basics besides stating that the goal is capture the opponent's king and that different pieces can move different numbers and patterns of spaces on the game board. The one concept worth noting as context for this paper is the idea of "forcing moves". Here is a summary²:

A forcing move is one which requires the opponent to reply in a certain way, or which greatly limits the ways in which he can respond. Essentially, a forcing move is either a check, a capture, or a threat. In the case of a check, it is the rules which force the opponent to respond – he must get out of check. Capturing moves and threats are also usually forcing, because while the opponent may legally be allowed to make any move, most of the moves will be bad.

Chess has an average branching factor b of about 35 and average depth d of about 80.

System Description

Vastly simplifying this system, it essentially is a large search program that uses now traditional game-playing methodologies like quiescent search, iterative deepening, an evaluation function, and opening and closing move databases to find the optimal move to play on each turn. There are three things that make the architecture of Deep Blue II (the version that beat Kasparov in 1997 after losing to him in 1996) interesting. Firstly, it was a massively parallel system that implemented the top levels of search in software executed across 30 processors and the bottom levels of search in hardware using specially-developed chess chips that executed a hard-programmed evaluation function with tunable parameters. Secondly, it used a modified alpha-beta search that allowed the search to be extended when certain conditions are met and there is a succession of forcing moves. Thirdly, it effectively used an extended book mechanism that allowed a 700,000 game Grandmaster database to influence and direct the system's play by assigning bonuses or deficits (based off of factors like the number of times a move has been played) during the search for a move if the board were in a position that had been played in the database.

Results and Extensions

Deep Blue II was able to beat then-reigning World Chess Champion Garry Kasparov in a six-game match in 1997. The Deep Blue II team credit their large searching capability, non-uniform search, and complex evaluation function as being the most critical factors to their success. However, they say that they could have improved their methodology by improving the parallel search efficiency, adding an external FPGA to the chess chips to help with the hardware search and evaluation, adding pruning mechanisms, and further improving evaluation function tuning in both automated and manual fashions.

References

- [1] Campbell, M., Horne, A., Jr., & Hsu, F. (2002). Deep Blue. *Artificial Intelligence*, 57-83. Retrieved from <https://pdfs.semanticscholar.org/ad2c/1effcd7c3b7106e507396bdaa5fe00fa597.pdf>.
- [2] Smith, B. (2012, August 16). Forcing Moves, Part 1. Retrieved from <https://www.chess.com/article/view/forcing-moves-part-1>