

Research Report – Deep Blue

Background:

Deep Blue is a computer chess system developed at IBM during mid 1990s. It has been hailed as the first breakthrough in chess engine development to beat a human chess grandmaster. Deep Blue is a massively parallel system designed to carry out chess game tree searches¹.

New techniques introduced:

- Non-uniform search to select subtrees that are more likely to reach a win
- Search should provide insure against simple errors
- Evaluation function implemented at hardware level. Therefore, the time to execute a function is a fixed constant. However, the hardware evaluation function can't changed unless the hardware itself isn't changed.
- Massively parallel search – over 500 processors performing game tree search.

Deep Blue has two evaluation functions on-chip: fast and slow evaluation. Fast evaluation computes a score for a chess position in a single clock cycle. While the slow evaluation scans the chess board one column at a time to compute for chess concepts, such as square control, majority, blockade, restraint (mainly chess heuristics). Also, each feature recognized by both the slow and fast evaluation has adjustable weights that controls the relative impact of each feature on the final decision on a move. The large majority of the weights were tuned by hand, but were supplemented with automated analysis tools, which also led to improved play. Deep Blue also has an opening book consisting of 4000 positions to be used early in the game. It also used an extended book consisting of positions for 700,000 game database and endgame database to guide Deep Blue to make heuristics and make better moves during the game.

Deep Blue also performs alpha-beta pruning to reduce the search space. It also has a special pruning policy called “no progress”, where if a move is good for a given side, that move is played since it's best to play it earlier rather than later. In situations where chess pieces are somewhat blocked, it can present noticeable benefits.

Key results:

Deep Blue had a time control mechanism, which sets a normal time target and panic time target. Deep Blue will return the best known move if a timeout expires during its search. Deep Blue has lost to Kasparov in 1996, but the updated version 2 won in 1997 with a score of 3.5 – 2.5 and it was awarded the Fredkin prize for defeating the human world champion in a regulation match. For its victory, the large searching capability, non-uniform search and complex evaluation functions were all critical. Other factors have also played a role: chess game position databases, evaluation function tuning and so on. The single chip chess move generator achieved search speeds of 2-2.5 positions per second. Overall search speed of the system was 50-100 million chess positions per speed. Although there were avenues in terms of search pruning to reduce the complexity of the search, the IBM development team decided to focus more on hardware optimization and increasing computational power of the Deep Blue system.

[1] Campbell, Murray, A. Joseph Hoane, and Feng-hsiung Hsu. "Deep Blue." *Artificial Intelligence* 134, no. 1 (January 1, 2002): 57–83. doi:10.1016/S0004-3702(01)00129-1.