

Part 2: Research Review - Deep Blue

This paper describes the technology behind Deep Blue, a computer chess system known for being the first in history to beat a world champion. The authors highlight the following as particularly important factors that contributed to their success:

- *a single-chip chess search engine*: The three main components of the chess chip are: the move generator, which is essentially a silicon chessboard implemented as an 8x8 array of combinatorial logic with a hardwired finite state machine to control move generation; the evaluation function, which has a “fast evaluation” (computes a score for a chess position in a single clock cycle) and a “slow evaluation” (scans the board column by column evaluating chess concepts like king safety or trapped pieces); and the search control, which uses state machines to implement a fixed-depth null-window alpha-beta search, with quiescence search and various types of search extension heuristics.
- *a massively parallel system with multiple levels of parallelism*: Deep Blue is a massively parallel 30-processor IBM RS/6000 SP-based computer system with 480 single-chip chess search engines, capable of searching 100M-200M nodes (chess positions)/second. In terms of systems design, Deep Blue is organized in three layers: one composed by one SP processor that searches the top levels of the chess game tree and distributes the remaining work to the second layer. The second layer is composed of the remaining SP processors (workers), and is responsible for searching “leaf” positions and distributing the remaining work to the last layer, which is composed by the chess chips and carry out the search in the last levels of the tree.
- *a strong emphasis on search extensions*: They developed a software based selective search named “dual credit with delayed extensions” which applies a number of specific principles to a modified version of alpha-beta. In addition, they developed a set of mechanisms to determine which nodes should receive credit, and a pruning mechanism named “no progress,” which “is based on the assumption that if a move is good for a given side, it is best to play it earlier rather than later.” The hardware search is the one handled by the chess chip.
- *a complex evaluation function*: the approximately 8000 different “patterns” recognized by the chess chip as assigned a value, and the evaluation function is “essentially a sum of feature values.” Most of the features and weights were manually created/tuned, but there were also a couple of automated analysis tools.
- *effective use of a Grandmaster game database*: with the help of chess Grandmasters, they manually created an “opening book” with about 4000 positions and an emphasis on positions that Deep Blue played well. They also manually created an “override book” to accommodate last minute changes or corrections. Further, they created a mechanism called “extended book” that gathered information from a 700,000 game database and influenced the game through an ad hoc function that assigned bonuses or penalties. Finally, they added “endgame databases covering “all chess positions with five or fewer pieces on the board, as well as selected positions with six pieces that included a pair of blocked pawns.”