

Candidate: Miodrag Vujkovic

Research review: Deep Blue Paper

The paper describes the Deep Blue chess machine developed by IBM in the nineties. It starts with the history of IBMs research on chess machines which would, through several iterations (Chip Test, Deep Thought, Deep Thought 2, Deep Blue), lead to Deep Blue II. In 1997, Deep Blue II beat reigning chess champion of the time, Gary Kasparov, by 3.5-2.5.

Before that, in February 1996, Deep Blue played against Gary Kasparov but lost by 4-2. Deep Blue II was improved based on the feedback from that match.

Deep Blue I had 216 chess move generator chips which had move generation logic encoded in the hardware. Each chip searched 1.6 to 2 million chess positions per second totalling to 50-100 million searches per second. Besides Gary Kasparov, Deep Blue played against three Grandmasters and had one win (1.5-0.5 Ilya Gurevich), one draw (1-1 Patrick Wolff) and one defeat (0-2 Joel Benjamin). Feedback from these games was also used for improving chess move generation chips.

For rematch with Gary Kasparov, which was scheduled for May 1997, IBM made a lot of changes in the chess machine. Chess chips were redesigned and evaluation function was improved, features number has increased from 6400 to 8000. Speed per chip was increased to 2-2.5 million positions per second and number of chips more than doubled to 480 chips. System (IBM RS/6000 SP) was composed of 30 nodes/processors and 480 chess chips (16 chess chips per node/processor). Each node had 1GB of RAM and 4GB of disc space. Nodes were connected via high speed switch.

Deep Blue is organised in three layers. One of the SP processors is a master and others are workers. Master searches the top levels of the game and delegates "leaf" positions to the workers to search. Workers do few levels of the search and then distribute "leaf" positions to the chess chips for the last few levels of the tree. Depending on the game position, Deep Blue would search 100 to 200 million positions per second. Average search speed was 126 million positions per second and maximum sustained speed obtained was 330 million searches per second.

Deep Blue II algorithm used many ideas developed before like: quiescence search, iterative deepening, transposition tables but performed on a much more powerful architecture. Evaluation function is implemented on a hardware chip and search is a hybrid software/hardware solution. Search is performed in parallel on almost 500 processors.

Evaluation function is composed of "fast evaluation" and "slow evaluation". Fast evaluation is computed in a single cycle by computing easily computed major evaluation terms with high values like piece placement values. Slow evaluation scans the board one column at a time and computes values for some more complicated concepts such as king safety, X-rays, square control, pawn structure, trapped pieces, etc. Final evaluation is a sum of feature values with roughly 8000 features (chess patterns). Most of the features and weights used were created/tuned by hand by 4 Grandmasters.

Hardware search is performed on a tree using fixed-depth null-window algorithm with quiescence search. It is very fast and uses various types of search extensions. Search is performed in parallel with one master node and 29 worker nodes controlling 16 chess chips. Chess chips are not general purpose chips and can only work as slaves. Search is controlled on the nodes, since hardware chess chips do not have this functionality.

Deep Blue had an opening book with over 4000 positions in order to emphasise positions that Deep Blue plays well. Beyond that, extended book was used with over 700,000 Grandmaster games to help with generating moves in the absence of opening book information. Deep Blue algorithm assigned bonuses or penalties to moves that were played in the same position in the Grandmaster game database. The final part of the system was an endgame database which contained all chess positions with five or less pieces and selected games with six pieces that contained blocked pawns.

Since chess is a time restricted game, algorithm contained time control. It had two parts. One was a normal time target which was calculated as remaining time divided by remaining time restricted moves. Second one is panic time limit which is triggered when there is only one third of time remaining.

Deep Blues success was not a result of a single technique or feature but a well executed sum of the pieces.