Deep Blue

Deep Blue is the chess machine that defeated then-reigning World Chess Champion Garry Kasparov in 1997. It's a sophistically designed computer that combining the power of Artificial Intelligence, Parallel computing, through a elegant collaboration between the software and the specifically designed hardware.

At high level, Deep Blue's job is to search for the best move in the search tree. To achieve that efficiently, Deep Blue is organized in three layers. One master processor searches for the top level of the game tree and then distributed "leaf" positions to the worker processors for further examination. At last, the near-end of the tree is send to the chess chips for further evaluation.

The first two layers of search are software searches. Software searches are very flexible and easy to change/update which enables developers to program complex logic to better control the initial fan-out of the search tree. Also, because it runs on general purpose processors, transposition table is available and can be used to speed up the search of the game tree. To leverage these opportunities, the team came up "dual credit with delayed extensions" algorithm to effectively search for the best move while limit the depth of the tree to avoid search explosion. The core concept of the algorithm is to give each branch a weight (credit) and only go deep and expand the branch when the weight is over a threshold.

The last layer of search of performed on the hardware. The chess chip is divided in three parts: the move generator, the evaluation function, and the search control. Move generator is essentially a hardwired finite state machine which is able to compute all moves simultaneously to reduce latency and in the meanwhile preserve reasonable ordering. The latter is achieved by tiered move generation where it generates captures first, followed by non-capture moves. Evaluation function is implemented to support "fast evaluation" and "slow evaluation" to improve evaluation efficiency. It's a standard technique to skip computing an expensive full evaluation when an approximation is good enough. Search control portion of the chip uses a number of state machines to implement null-window alpha-beta search. Null-window search eliminates the need for a value stack, which simplifies the hardware design, but it is necessary to do multiple searches when an exact score is needed.

In addition, Deep Blue is a highly parallelled system where searches are performed simultaneously when possible. It uses a static processor tree, with one SP node controlling the other 29 nodes, which in turn control 16 chess chips each. A well-designed parallel algorithm controls the whole process to make sure searches are run efficiently and correctly. The team did a analysis for the performance improvement against single chip system on a variety of positions. The result varies widely depending on the tactical complexity of the position searched, but overall it has about 8% improvement in tactical positions and about 12% in quiet positions.

Finally, Deep Blue keeps an opening book and extended book to further improve the search performance. Opening book consisted of about 4000 positions to emphasized the moves that

Deep Blue played well. Extended book allows a large Grandmaster game database to influence and direct Deep Blue's play in the absence of opening book information. The book assign bonuses(or penalties) to those moves in a given position that had been played in the database. I used the same tactic in my own assignment (custom score #2) as well and it achieved the best performance of all 3 heuristic functions.