

## Research Review on Deep Blue

The paper has categorized the search strategy for Deep Blue into three groups: software, hardware, and parallel search.

For software search, it has implemented the forced pairs of moves (ffp). Ffps are sets of moves that force the other player to choose for countering when it is near the endgame or there's a checkmate. When there are multiple Ffps, the one with more "accumulated" credit wins. There are a few ways to accumulate credit. First, if a move is significantly better than the other moves. Second, if it detects a potential threat, or a checkmate situation. Third, it gives credit to a move if this response is not available last time the opponent moved. The idea is to assume that the opponent is developing a combination of moves. Lastly, it also credits traditional tactics such as check evasion and passed pawn push.

For hardware search, Deep Blue uses chess chip to do fixed-depth null-window search, which includes a quiescence search. Some of the interesting tactics include number of "mating" checks allowed and number of singular checking moved allowed in the quiescence search, flag to ignore stalemate at one ply above quiescence, and flag to allow one-ply extension in the quiescence search after a pawn moves to 7th rank. In general, hardware search tactics are faster than software search, but they are simple checks only.

In order to utilize all resources at once, Deep Blue implements parallel search. First, it does load balancing to mitigate complex quiescence search. For example, it aborts hardware searches (more than 8,000 nodes) and delegate these to the software search. Second, the bottleneck is at the master node since it controls all the other nodes. Therefore, slave nodes have a pending job once they finish the active job, so that the slave nodes don't have to stay idle when the master is not responding. Third, the child nodes share information, such as the transposition table, via the master node.

There are also tactics used in DeepBlue that are not categorized since they are used in both software and hardware. For example, there's a pruning mechanism called "no progress." If the current position could have been reached by playing an alternative move at some earlier position on the search path, there is essentially no progress in the game. DeepBlue can terminate this search since it is better to perform the same action earlier rather than later. (Opponent player could react differently if the move is played later.) While this tactic has limited effect on most moves, the team observes noticeable benefits when there are few pieces left on the board.