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AIND: Advanced Game Playing

On Deep Blue

Deep Blue is the first chess machine that defeated the world's Chess champion Kasparov. It achieved what many have thought as inconceivable by using a single chess search engine, a parallel system, search extensions, a complex evaluation function, and the use of a Grandmaster's games database.

The efforts to build this machine started with building machines that used single chip chess move generator which were capable of between 500, 000 and 700,000 moves. The ending result being Deep Blue 2 that could put forth between 2,000,000 and 2,250,000 moves per chip. Even though Deep Blue 2 used the same type of chip, it had approximately 24 processors as compared to Deep Blue's 2, used larger RAM, had an improved search software, and used an extended book that was capable of the same caliber of opening moves even without a Grandmaster's games database.

Deep Blue uses 3 SP processors, with one designated as the master and the other two as workers. The master processor searches the top level of the game tree and then distributes nodes to the workers which execute searches a few level deep and then hand those over to the chess chips that search for the remaining tree levels. In the match against Kasparov, Deep Blue averaged between 126,000,000 to 300,000,000 position searches.

The software was built on top of what was already used by other chess engines such as quiescence search and iterative deepening. Knowing that human players achieve higher depth than uniform searching, researchers decided on looking at non-uniform searches. This was achieved by extend forcing pair of moves, forcing moves based on expectation levels, using

forced moves only after evaluating alternatives, delayed extensions, dual credit and avoiding an oscillating search.

However, the researchers decided to implement the evaluation function in hardware. This helped with simplifying the programming part of the task. Programmers constantly tweak the evaluation function for what they perceive to be better, only to have the software run slower, not achieve the same depth, and inevitably leading to inferior performance. The evaluation function has programmable weights and it is comprised of a fast and a slow evaluation; which is a standard technique that when used it skips computing an expensive evaluation in favor of a quick approximation one. It recognizes around 8000 patterns with each being assigned a value.

The search is hybrid by nature, using both compiled C code and hardware search. The chip's move generator generates one move at a time, and is implemented as an 8x8 combinatorial logic array. It first generates captures. Captures are ordered from low valued pieces capturing high valued ones and high valued pieces capturing low vales one. After generating captured moves it generates non captured moves. Deep Blue uses the hardware search for shallow searches only, which results in 4 or 5-ply searches, quiescence in middlegame positions, and deep searches in endgames.

For its parallel system, Deep Blue uses a static processor tree, in which the SP node controls the other 29 nodes that in turn control 16 chess chips each. The chess chips are not general-purpose processors, they can only act as slaves and they can only communicate with the SP. Parallelism is only possible after the first move has been examined at a PV node, nodes where the first move either fails or exceeds expectations, nodes where the fail high move is not searched first and nodes were all the nodes fail low. The parallel search is first carried out on the master node, and

as the search goes deeper it gets allocated throughout the other nodes. The parallel's search efficiency seems to between 8% and 12%.

To make Deep Blue successful, the researchers also added both an opening book and an ending game book. The opening book was created by several Grandmasters and it consists of 4000. Each move having been consistently tested by the system through nightly runs. An extended book was added on top of it, that consists of a Grandmaster's game played database of approximately 700,000 moves. Each move was given a either a bonus or penalty depending on how the games faired in each of them.

Deep Blue's famous 1997 win came as the result of a number of contributing factors. These were, in no particular order, a highly efficient search, a parallel system, a complex evaluating function, and the use of opening/endgame databases.