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Deep Blue[1]

A Summary

The authors report in some detail on Deep Blue, which was the chess machine built by IBM that defeated Garry Kasparov, who was the World Chess Champion at the time of the match in 1997.

Deep Blue was the culmination of research and development on computer chess systems, beginning with ChipTest, developed at Carnegie Mellon University in the 1980s, and proceeding to Deep Thought in 1988. These systems achieved search speeds around 500k-700k chess positions per second. Development subsequently moved to the IBM T.J. Watson Research Center with the Deep Thought 2 system, which served as the prototype for Deep Blue and won matches against human chess grandmasters. The first version of Deep Blue played Garry Kasparov in 1996, losing 4 games to 2. Based on that experience, improvements were made, and a second version of Deep Blue was made ready prior to the 1997 tournament. This version achieved search speeds in the hundreds of millions of positions per second, varying depending on the complexity of the state of the board.

No one primary system characteristic or search strategy entirely explains the success of Deep Blue. On the hardware side, the system consisted of 30 CPUs and 480 special purpose chess search engines-on-a-chip (16 per CPU). Most of the CPUs ran at 120 MHz. Each CPU had access to 1GB of RAM and 4GB of hard disk space, and ran the AIX 4.2 operating system. Thus Deep Blue employed massive parallelism to divide and conquer the problem. One CPU, designated the master, would search the top levels of the game tree, and then distribute the mid-tree positions to the remainder of the CPUs. Those CPUs would each subsequently distribute the leaf positions to the 16 special purpose chess chips connected to it.

Deep Blue made use of many ideas developed for previous chess systems, like quiescence search, iterative deepening and transposition tables. Other such ideas include an opening book of about 4000 moves, a 700,000 game grandmaster database, and a database for endgames including up to 5-6 pieces. But Deep Blue also pioneered some new strategies. One of these was to host part of the search, and the complex evaluation function (which is where one typically considers the “intelligence” to be located) on the special purpose chip, and not in software. And the evaluation function *is* complex, with about 8000 different features taken into account! Putting it in hardware yields the advantage of simplifying the software programming, since tweaking the evaluation function could otherwise affect total execution time, but with the subsequent disadvantage of making changes to the evaluation function more difficult.

Another of these strategies was to allow asymmetric, non-uniform search, as a way of selectively searching a small portion of the game tree in certain situations, which mimics the behavior of human chess grandmasters. In two such situations, the selective search was demonstrated to extend the depth of the search in software over 12 iterations from 8 plies to 23-24 plies, for a total combined software/hardware search depth of around 40 plies! By comparison, Deep Blue was shown to perform full-width game tree searches to 12.2 plies over 3 minutes, on average.

All of these features are explained in more detail in the paper, but this summary captures the highlights.

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[1] “Deep Blue” Murray Campbell, A. Joseph Hoane Jr., Feng-hsiung Hsu, Artificial intelligence 134 (2002) 57-83, https://pdfs.semanticscholar.org/ad2c/1efffcd7c3b7106e507396bdaa5fe00fa597.pdf