Deep Blue

Deep blue is the chess machine that defeated Gary Kasparov in 1977 using a mix of hardware and software search mechanisms like massive parallelism, single chip search engine, complex evaluation functions a exhaustive database of opening moves, search extensions. Deep blue-1 which played with Kasparov in 1977 ran on a 36-node IBM RS/6000 SP computer and used and use 216 chess chips. Overall search speed was 50-100 million chess positions per sec. Deep Blue-2 came into existence due to a number of deficiencies in the deep blue-1 machine which Kasparov won against. The new chess chip had a redesigned evaluation function. The new chip also added hardware repetition detection i.e. generate all moves that would attack the opponents pieces and some efficiency improvements that increased the per chip search speed to 2-2.5 million chess positions per sec. The second major change was to more than double the chess chips in the system to support higher processing demands, also debugging tools, visualisation tools to aid match preparation were created. Deep Blue -2 defeated Kasparov 3.5-2.5 in 1997.

Deep Blue - 2 is a **massively parallel system** designed for carrying out chess game tree searches. Deep-blue is organized into 3 layers. One SP processor is designed as the master and the others as workers. The master searches the top levels of the chess search game tree and then distributes the leaf nodes to the workers for further examination. The workers carry out a few levels of additional search and distributes their leaf positions to the chess chips which search the last few levels. Deep blue relies heavily on chess search techniques like iterative deepening, quiescence search, trans position tables. The success of deep blue was 1. **Large and non-uniform searching capacity** 2. **Search should provide insurance against simple errors** (even without pruning - using highly selective search). Example - a 3 minute search will reach a depth of 12.2 on an average.3. **Hardware evaluation,** these functions were complex and a software evaluation function might take too long to execute hence slowing down the entire system and software patches are painful.4. **Hybrid Sw/Hw search** in compiled C code and hardware search encoded in silicon on a chess chip, this can lead to horizon effects since these 2 searches are different.

The **deep-blue chess chip** divides into 3 parts 1. **Move Generation:** the chip has various attacking, checking and check evasion moves, its implemented as an 8X8 array of combinatorial logic. Hardwired finite state machine controls the move generation, the chess chip uses an ordering where low valued pieces capture high valued pieces and then high valued pieces captures low valued. 2. **Evaluation function:** slow and fast evaluation functions, do not go to the depths when approximation is good enough 3. **Search Control:** Implements a null window alpha beta search. Limitation of a h/w search is a lack of transposition tables - this limitation is lessened by the fact that levels where s/w searches are prominent there can be transposition table. The search also maintains a move stack having a repetition detector - maintaining the last 32 ply circular buffer.

Software Search - a search mechanism “dual credit with delayed extensions” was designed The credit generation mechanism were

1. **Singular, Binary, Trinary** - Singular move that is significantly better than all alternatives. Like thought of grand masters

2. **Absolute Singular** - there is only one legal move
3. **Threat, Mate threat** - null move search to detect if there is a threat in the current position. If a large threat exists a higher credit can be awarded
4. **Influence** - credit for moves which are enabled by previous moves
5. **Domain Dependent** - traditional search extension schemes can be incorporated.

All these mechanisms use the tremendous raw power of deep blue

Hardware Search - takes place in the chess chip, it carries out a null window search which includes a quiescence search. Hardware searches are relatively simple and carries out only shallow searches. The hardware search has various parameters like 1. Depth of the search 2. Depth of offset searches. 3. Endgame rules assertion off and on 4. End game ROM assertions off and on both end game rules are for debugging purposes 5. Number of mating checks 6. Number of singular checking moves 7. Various flags to ignore stalemates, allow one ply extension depending on moves by pawns, when pieces are hung (one or multiple)

Parallel Search - Communicatio with chips is via a micro channel which enables parallelism and has a strong influence on the parallel search algorithm used in deep blue.After the first move has been examined all the other moves can be evaluated in parallel. Null move searches to generate threat information can also happen in parallel. Early iterations of the parallel search are carried out in the master nodes - as the search gets deeper major issues needs to be addressed like load balancing - abort long running hardware search and push the search to the software, master overload - workers have a job on deck ready to execute when it completes its active job , sharing between notes - worker nodes will communicate through the master. For a full 30 node deep blue, idirect evidence suggested that there was a overall efficiency of 8% in tactical positions and 12% in quiet positions. The focus was more on evaluation functions rather than on the parallelism code between 1996 and 1997

Evaluation Function - The complex evaluation function allows the chess chip to recognize approximately 8000 patterns and each is assigned a value. These are either static or dynamic values. Static values are assigned at the beginning of the search, but dynamic values are assigned at the beginning but constantly evaluated and scaled during the search. Initialization function is done by the evaluation function generator a program that is run on the root node of the search tree. It would be of great benefit to run it at nodes closer to the root node after a large positional change has occurred. There are 54 registeres, 8096 table entries - total of 8150 parameters that can be set in deep blue evaluation functions

Opening Book Extended Book and Ending book databases

Deep blue has 4000 opening book positions - positions where deep blue played relatively well. Extended book positions in absence of an opening move. A 700000 game database a mechanism was used to either reward or penalize if deep blue played one of the moves from the grand master database. Endgame database included all chess positions with five or fewer pieces. Endgame databases were both online and offline, offline was during design of the chess chip (hardware level). Software searches uses the database in online mode

Conclusion

Success of deep blue was not due to a single factor, deep blue used raw power and brute force searches with complex evaluation functions and combination of intelligent hardware and software search mechanism to achieve success against Gary Kasparov in 1997. Improvements could be made in areas like parallel search efficiency which are difficult to test. Lot of areas were explored but there were other areas where further research can be made. But overall Deep blue was a powerful chess system that defeated the Grand Master at that time and proved and tested the various AI hypothesis and algorithms in the process