M. Campbell et al. “Deep Blue”. Research review

The goal of this paper is to describe the Deep Blue system, and give some of the rationale that went into the design decisions behind Deep Blue. Deep Blue is the chess machine that defeated then-reigning World Chess Champion Garry Kasparov in a six-game match in 1997. The main factors that contributed to this success, were:

Single-chip chess search engine

- Use of **move generator** which computes all the possible moves simultaneously in a reasonable order and selects one. The chess chip uses an ordering that has worked well in practice, first generating captures followed by non-capture moves
- The **evaluation function** is composed of a “fast evaluation” and a “slow evaluation”. The fast evaluation computes a score for a chess position contains all the easily computed major evaluation terms with high values: “piece placement” value (the sum of the basic piece values with square-based location adjustments), some positional features (e.g “pawn can run”). The slow evaluation scans additional features (e.g. square control, pins, X-rays, king safety, pawn structure etc)
- Usage of **null-window alpha-beta search** technique to simplify hardware design

Massively parallel system

- Deep Blue is composed of a 30-node RS/6000 SP computer and 480 chess chips, with 16 chips per node. The SP nodes communicate with each other using the MPI (Message Passing Interface) standard. Communication is via a high-speed switch. The chess chips communicate with their host node via a Micro Channel® bus.
- There was invented **some tricks to deal with challenges of this heterogeneous architecture**: push more of the search into software to enhance parallelism., trying to reduce master processor overload. Due to static processor tree sharing between the nodes was only through master processor
- In general, indirect evidence suggests an overall observed efficiency of about 8% in tactical positions and about 12% in quiet positions. It is clear that there is room for improvement here. However it was a conscious design decision of the Deep Blue team to focus on improving the evaluation function.

Strong emphasis on search extensions

- A new selective search was built called in the newspaper “**dual credit with delayed extensions**”. Algorithm try to extend forcing/forced pairs (ffp) of moves (moves which have a backed up score significantly better than the backed up score of all the available alternatives).
- It is more productive to identify a series of ffp’s. One response to this observation is to allow ffp’s to accumulate “credit” and only when sufficient credit is available can it be “cashed in” for an extension. As a result **extensions are delayed** until multiple ffp’s occur in a given path
- To avoid exploding of search alternatives for the best move for both side, algorithm separate and accumulate the credit for the two sides separately (**dual credit**)
- To identify nodes that should receive credit, multiple techniques are used (e.g. “singular, binary”, “Threat, mate threat”, “Influence” etc)

Complex evaluation function

- **Evaluation function** is essentially a sum of feature values (**recognized about 8000 different patterns** and for each the value is assigned). Values could be static (set once at the beginning of a search) or dynamic (additionally scaled during the search as are sensitive to the amount of material on the board)
- The initialization of the feature values is done by the “**evaluation function generator**” which is run only at the root of the search tree. This sub-program is also dictating relationships between groups of related feature values rather than setting them independently.
- **Developing tools for automated** evaluation function **analysis.** First tool let automatically identify the features insensitive to the weights of evaluation function for further modification. Second tool was developed with the goal of tuning evaluation function weights (increase hand-tunes weights related to pawn shelter)

Efficient use Grandmaster game database

- **Opening book** containing about 4000 positions. Includes tactically complex openings, but also included more positional openings that Deep Blue handled well in practice
- **Extended book** summarize the information available at each position of a 700,000 game database, and use the summary information to nudge Deep Blue in the consensus direction of chess opening theory
- **Endgame databases** includes all chess positions with five or fewer pieces 20 on the board, as well as selected positions with six pieces that included a pair of blocked pawns