REVIEW

THE IMPORTANCE OF BEING SCALABLE

Scalable Search in Computer Chess
Algorithmic Enhancements and Experiments at High Search Depths
by Ernst A. Heinz
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Reviewed by Dap Hartmann[1]

"One of the nice things about computer chess is the fact that the to-do list of interesting ideas seems to grow steadily despite all the improvements made since the last time you checked."

Appendix A.6: Future Work

Ernst Heinz is one of the most productive computer-chess researchers of the past several years. After earning his Ph.D. (summa cumma laude) from the University of Karlsruhe in July 1999, he joined the MIT Laboratory for Computer Science as a Postdoctoral Fellow. The results of his extensive experiments on the scalability and performance of game-tree searching have been laid down in this excellent book. Most of the material has already been published in the *ICCA Journal*, or presented at the *ACC* 9 conference. But the text has been expanded, and two chapters and several appendices have been added. Heinz's master-strength chess program DARKTHOUGHT (shared 2nd place in the 1999 WMCC) served as the guinea pig for the implementation and testing of a wide variety of ideas, yielding empirical evidence for the practical usefulness of the various techniques.

The book consists of three parts, preceded by a 'Computer-Chess Primer' (Chapter 0), and supplemented by four appendices. Part I 'Forward Pruning without Tears' describes various techniques to (forwardly) prune the game tree with no concessions to the tactical strength of the program. In Chapter 1 (Adaptive Null-Move Pruning), the depth reduction used in the application of the null-move algorithm is made variable instead of fixed, combining the safety of the more traditional 2-ply depth reduction with the advantages of the reduced search effort resulting from a 3-ply depth reduction. Extensive experiments using a large suite (2180 positions) of widely-used test positions yielded a reduction in the search effort of 10 to 30%, while remaining tactically sound. Chapter 2 (Extended Futility Pruning) describes a (static) domain-dependent forward-pruning technique which (in combination with limited razoring) reduces DARKTHOUGHT's search trees by 10 to 30% as compared with normal futility pruning, while maintaining the tactical strength of the program. Again, the aforementioned test suite provided the empirical evidence for this conclusion. One of the strong points of the book, is the emphasis on the scalability of the various techniques. The results of experiments carried out at increasing search depths provide the basis for the analysis of the behaviour of each technique with search depth (or size of the game tree). It is found that Extended Futility Pruning scales almost linearly with search depth. The combination of Adaptive Null-Move Pruning, Extended Futility Pruning, and Limited Razoring (referred to as AEL Pruning) is the subject of Chapter 3. The superiority of this combined pruning technique is empirically verified by the test suite experiment, as well as by 580 self-play games and games played under tournament time-control conditions against strong commercial chess programs. The results indicate a 20% (at depth 8 ply) to 50% (at 12 ply) overall reduction of the search effort while maintaining the tactical strength of the program.

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Part II (Integration of Perfect Knowledge) deals with game-tree nodes in which the exact game-theoretical value is known. Chapter 4 (Efficient Interior-Node Recognition) addresses the all-important issue of how such nodes can be recognized and evaluated. Using an efficient so-called Material Signature, the program is able to quickly classify positions and recognize material distributions for which the game-theoretical value is known. Not only is the program capable of evaluating drawn and won/lost interior nodes, it can also deal with 'at least/most drawn' positions. In Chapter 5 (Index Schemes of Endgame Databases) and Chapter 6 (Knowledgeable Endgame Databases), an efficient endgame database encoding is developed to enable the recognition of game-theoretical values in real-time. Using this encoding, all endgames up to 4 pieces can be squeezed into less than 15 Mb of memory space, allowing DARKTHOUGHT to utilize this knowledge in the game tree without any loss of speed.

Part III (Search Behaviour at Increasing Depths), focuses on the scalability of the techniques developed and discussed earlier in the book. Chapter 7 (DARKTHOUGHT Goes Deep) repeats an experiment by Hyatt and Newborn in which 347 positions from real games are searched to fixed depths. Heinz reaches the same surprising observation that the aforementioned authors made, namely that even at high search depths (11 to 14 ply), new best moves occur in one out of every six searches. Even more astonishingly, it was found that up to half of all new best moves had never been deemed 'best move' earlier in the iterative search. Chapter 8 (Modeling the "Go Deep" Behaviour) elaborates on the results of the previous chapter, and develops a model to predict the behaviour at even higher search depths. One final data point is added by the results from 16-ply searches in the test suite positions. It confirms the earlier conclusion (based on searches up to 14 ply deep) that the 'Best Change Rate' at high search depths remains fairly constant (at about 15%). Chapter 9 (Self-Play Experiments Revisited) explores the treacherous territory of self-play experiments for various computer games (Chess, Checkers, Othello). Heinz carefully analyzed past self-play experiments, including the famous fixed-depth-searching Belle experiments. His conclusion is that there is no empirical evidence that increased search depth (in computer self-play) leads to diminishing returns. He conjectures that *at least 1000 games per program version* are necessary to quantify this widely expected, although yet unproven phenomenon. The appendices contain information on Heinz's chess program DARKTHOUGHT: How DARKTHOUGHT Plays Chess; Tournament History of DARKTHOUGHT; DARKTHOUGHT and Test Suites; DARKTHOUGHT at Test Games.

I warmly recommend this book to any serious computer-chess enthusiast. The style of writing is very clear, and hardly any programming experience is required to enjoy most of this work. Reminiscent of Jonathan Schaeffer's seminal Ph.D. thesis, this book is one of the very few thorough in-depth accounts of quantifying the effectiveness of new ideas and innovations in game-tree searching in computer chess. Even a casual reading will convince anyone of the tremendous amount of work that Heinz put into the experiments described in this monograph. I applaud Heinz's initiative to rework his ICCA articles and ACC conference contributions into this highly enjoyable book, which turned out to be much more than the sum of the individual components. There is absolutely no need for the 'apology' he offers on his homepage (http://supertech.lcs.mit.edu/~heinz/): "I know that this [book] is not cheap. :-(But although I sincerely intended the book to cost much less, there was no chance to hit a lower price point for a printed volume in a specialty area such as computer chess (even if I renounced all royalties)". Heinz absolutely deserves the little money he earns in royalties from this excellent book. Even though I can think of two places where he might have cut the size of the manuscript ('Figure 0.1: Empty Chess Board', which occupies half a page, and, more notably, 'Appendix D.1 Test Games vs. Strong PC Chess Programs', which takes up 40 pages of this 268-page book) I doubt whether this would have brought the price down. As it is, the book offers good value for the money. Had the field not been so frightfully small, my closing remark would have carried a wee bit more weight: *Scalable Search in Computer Chess* is one of the three best computer-chess books of the decade!