COMPUTER CHESS: State of the Art

Lessons for computer Shogi and Go

Jos Uiterwijk[1]

University of Limburg
MATRIKS Research Institute

Abstract

In this paper an overview is given of the present state of the art of computer chess. After a short historic sketch of the field, stressing the key position of computer chess in the artificial-intelligence domain, the current position of computer chess will be contemplated. It will be argued that computer chess has reached a mature level, playing at the same level as (weak) grandmasters. Some key techniques enabling this status are indicated and some statements about the future of computer chess will be made. Finally, a short comparison of computer chess with computer Shogi and computer Go will be made.

Computer Chess and Artificial Intelligence

Ever since Shannon's (1950) seminal paper on computer chess this subject has had a large attraction to researchers in the field of artificial intelligence. But why is this field so tempting? At least three arguments for the popularity of computer chess can be given.

First, chess has always been viewed as an *intellectual* game par excellence, "a touchstone of the intellect", according to Goethe. Precisely for that reason there always has been a large interest for chess among psychologists. One of the most eminent Dutch psychologists, professor Adriaan de Groot, has spent many years of effort in investigating *how* chess-players play chess (De Groot, 1946). The hope was that such research would lend insight in the way people reason. This has found imitation among many psychologists. The American scientists Newell and Simon (1972) tried to build models of the human mind, based on the results of their computer-chess research (Newell *et al.*, 1958).

Besides this cognitive incentive a second reason for the popularity of computer chess stems from the interest of many researchers to create intelligent machines. Refraining from the

[1] Dr. J.W.H.M. Uiterwijk, University of Maastricht, Department of Computer Science, P.O. Box 616, 6200 MD Maastricht, The Netherlands.
Email: uiterwyk@cs.rulimburg.nl; WWW: http://www/cs.rulimburg.nl/~uiterwyk/

difficult philosophical questions concerning the nature of intelligence, it has been postulated that intelligence is a prerequisite for playing chess. Chess is such a complex game, with a long and standing tradition, that the design of an artificial chess-player was viewed as an intellectual challenge, from which much was to be learnt about the creation of machine intelligence. In particular Alan Turing, an English mathematician who played a leading role in breaking enemy codes at the British Foreign Office during World War II, seriously suggested to consider the question: "Can machines think?" (Turing, 1950) and mentioned the field of computer chess as an interesting domain of research for this purpose.

Thirdly, a reason underlying all research in game programming, is of a more practical nature. Many scientists are prone to use *games* as their primary test domain for the reason of being simple and well-defined (thus yielding a common test area), and simultaneously being so complex as to make the implementation and examination of interesting techniques worthwhile. Moreover, as a useful side-effect of using games, the quality and comparison of different programs can easily be determined by entering them in tournaments. The absolute level of programs can be established by pitting them against human or machine opponents of known strength, the ELO rating[2] being the well-known grade in the field of chess.

For this and other reasons, professor Donald Michie decorated computer chess as the *Drosophila melanogaster* [fruit fly] of machine intelligence (Michie, 1980). And although the reputation of computer chess at present is somewhat detoriating, the eminent psychologist professor Peter Frey has recently held an impressive plea for the resurrection of computer chess as a core research area for artificial intelligence (Frey, 1991).

Some History of Computer Chess

Even though since 1950 by Shannon's publication a rather thorough guide for a chess program was available, it lasted until 1958 before the first program, obeying the full set of chess rules, was a fact. The strength of this program (written by Alex Bernstein) did not surpass the level of a beginner and it lasted another ten years before the first program emerged capable of playing a decent game (MACHACK VI by Richard Greenblatt).

During this period and up to 1973 chess programmers held the opinion that the strongest chess programs would be obtained by incorporating in the programs as much chess knowledge as possible. It is therefore not strange that there were several chess experts among the chess programmers elite, including Hans Berliner (a former world correspondence-chess champion) and Michael Botvinnik (a former world chess champion). The disadvantage of implementing lots of chess knowledge of course is that the evaluation of chess positions is a time-consuming process, considerably diminishing the number of positions a program can investigate in the allotted period of time. This problem is not only recognized in the field of computer chess, but is a general problem in the application of practically every artificial-intelligence technique: there is a natural balance between much knowledge combined with little search and a lot of searching using only a few chunks of knowledge.

Precisely this last approach was the one adopted by the programmers Slate and Atkin in 1973, be it more by necessity than by wisdom. They wanted to enter a new version of their chess program CHESS, dominating the chess programs already for many years, into a

---

[2] The ELO rating, named after the mathematician professor Arpad Elo, is an internationally used measure for the strength of a chess-player, varying from some 1400 ELO for a beginning club player till some 2800 ELO for the current world champion, Gary Kasparov. In the USA the USCF rating system is in use, USCF ratings roughly being some 100 points higher than their ELO equivalents.

forthcoming tournament, but lacked the time to re-implement all chess knowledge of the previous version. To their surprise the new version, having only a small part of the knowledge but being very fast, appeared to be much stronger than the previous version. They therefore decided to enter their new version as it was, winning the tournament convincingly and remaining one of the strongest chess programs for many years.

The emerging preference for fast programs with little knowledge even got stronger in the late seventies and begin eighties, due to the increasing use of supercomputers and special-purpose hardware. An example was the program BELLE, two times world computer-chess champion and the first program earning the official title of Master in chess, which was developed with special-purpose hardware by Ken Thompson (1982), whose boast it was that he knew nothing at all of chess. Other notorious names from the eighties are CRAY BLITZ, running on a powerful supercomputer, and the chess machines HITECH and CHIPTEST. The successor of the latter, DEEP THOUGHT, which was later renamed to DEEP BLUE, was and still is generally acknowledged as the strongest program. The program was however unable to defend the in 1989 (Edmonton) captured title of computer-chess champion in the championship of 1992 (Madrid), neither to recapture the title recently in Hong Kong.

Although the above is only a very rough sketch of the rise of computer chess programs, it should serve as an indication of the main developments occurred. For a much more detailed description of the history of computer chess the reader is referred to the book *How Computers Play Chess* by Levy and Newborn (1990).

After a systematic study of the history of computer chess Donskoy and Schaeffer (1989) and Simon and Schaeffer (1992) came to distinguish three eras. The *pioneering* era, for computer chess from the early 1950s to the mid 1970s, is the period when many different appoaches are being tried and particularly much domain knowledge is being used. The second era is the *technology* era, characterized by a strong correlation between machine speed and program performance. For chess this era began with the full exploitation of the α-β algorithm in the mid 1970s, after Knuth and Moore's (1975) extensive analysis of the method. This era is dominated by brute-force searching programs using few knowledge, relying on the speed of computers for a good performance. Also the design of special chess hardware and the parallellisation of chess programs is typical for this period. In the third era, called the *algorithm* era, which has just begun for computer chess, it is recognized that speed alone will reach its limits, resulting in a new appraisal for innovative search methods (e.g., singular extensions (Anantharaman *et al.*, 1989), conspiracy-number search (McAllester, 1988; Schaeffer, 1989) and proof-number search (Allis *et al.*, 1994) and for use of knowledge (e.g., Berliner and Ebeling, 1989). Moreover, there is renewed interest for methods deviating from the strict α-β framework, which try to optimize the outcome of games by anticipating the fallible nature of the opponent; methods like speculative play (Uiterwijk and Van den Herik, 1994) and opponent-model search (Iida *et al.*, 1993) come to mind.

The State of the Art of Computer Chess

So where does computer chess stand now on an absolute scale of chess qualities? According to Levy and Newborn (1990) there has been from 1967 to 1988 almost a linear increase in strength of computer chess programs as measured in their performances in rated human tournaments. The top of this was the 2745 USCF performance (ca. 2645 ELO) by DEEP THOUGHT sharing first place in the Software Toolworks Open Championship, defeating among others GM Bent Larsen. DEEP THOUGHT's established rating thereby raised to some 2445 ELO points, indicative of a weak grandmaster level. Shortly after that event, the present world champion Gary Kasparov demonstrated convincingly that the human race had not to fear deprival of its chess crown within a few years, by winning a 2-game match against DEEP THOUGHT easily (October 22, 1989).

Meanwhile the main programmers from DEEP THOUGHT were hired by IBM to transform their brainchild into a much more powerful successor, to be named DEEP BLUE in order to express the company's favourite colour. After several years of silence this program emerged recently, trying to regain the computer-chess title at the Eighth World Computer-Chess Championship in Hong Kong (see the *ICCA Journal*, Vol. 18, No. 2 for a full account). Although not succeeding in this purpose (after drawing a game against WCHESS and loosing in the last round against the Dutch program FRITZ, leaving the title to the latter), most people feel that this was an unlucky incident and that DEEP BLUE really is the strongest program today. Whether the level of play, however, indeed is that much stronger, that the human world champion has to fear to be dethroned, still has to be seen. The chance to demonstrate this will be very soon already, since Kasparov has accepted to play a 6-game match, the ACM Chess Challenge, against DEEP BLUE from February 10-17, 1996 in Philadelphia, Penn., USA. It then will be seen whether Kasparov will fulfil his hope and expectation, uttered after his previous match against DEEP THOUGHT: "I want to be the man who will save our pride, human pride" and "... right now the only chance [to use my ful strength] is to face a computer with one billion positions per second. Within five years I will show my real chess, what I really can do at the chess-board".[3]

Not anticipating this match' result it is nevertheless evident that computer chess (and not only DEEP BLUE) has reached a level at which they are able to play strong games against the best humans. Some facts to underline this statement. At the INTEL World Chess Express Challenge, a blitz-chess tournament (5-minute games) held in Munich, May 19-20, 1994, the program FRITZ3 tied for first place with Kasparov in a field of seventeen Grandmasters. The program won the mutual encounter with Kasparov, although the latter outscored FRITZ with 4-1 in the playoff match. For more details, see the report by Friedel and Morsch (1994), the latter being FRITZ' programmer. Shortly after, Kasparov was again beaten, this time in a rapid-chess (25-minute games) encounter, when PENTIUM GENIUS won a 2-game match with 1½-½, London, August 31, 1994. In the second round two days later the computer also defeated Grandmaster Pedrag Nikolic with 2-0, only to be stopped in the third round the day after by GM Vishy Anand with 0-2 (see Friedel's (1994) report for more details). Again a few months later, the program WCHESS achieved the best tournament performance (2895 USCF) in the Fifth Harvard Cup. This is a rapid-chess encounter between eight computers each against six top American grandmasters (Benjamin, Gulko, Yermolinsky, Wolff, Rohde and Shabalov), where WCHESS only drew against the first two and won the other four games (see the report by Chabris and Kopec (1994) for more details on the tournament). Finally, in the last edition of the largest human-computer encounter in the world, the AEGON Man-Machine Tournament (using standard time controls), the computers clearly were superior (for the first time!) to the humans by 155 points against 132. And maybe even more important, for the first time the computers did not only dominated the *weaker* humans, but also were superior in the >2400 ELO region, even though this region was strengthened at the human side by no less than eight IGMs. The final score saw then not less than 7 machines among the first ten finishers, four of which had tournament performance ratings of 2600 ELO or more!

[3] From the television documentary The Chip vs the Chess Master, written and produced by Irv Drasnin, 1990.

Other Achievements of Computer Chess

A large part of the research on computer chess is not directed at creating stronger computer-chess programs, but at finding new (hitherto unknown) data regarding chess. One of the most obvious fields in this respect is the endgame theory. Due to the technique known as retrograde analysis (Van den Herik and Herschberg, 1985) complete knowledge of many endgames has been obtained, leading to extension of endgame theory with a huge set of new facts and the necessity of correcting many old-day facts, proven to be false or incomplete.

As an extreme example, we now know that the KRBKNN endgame, most instances of which were formerly regarded as draws, mostly is a win for White, with a max-to-win distance of 223 as in the example position depicted in Diagram 1 (Stiller, 1991).

k							
		N	N				
	b		K				
	r						

Diagram 1: A max-to-win KRBKNN position.

Apart from this, maybe bizarre, result the construction of almost all 5-piece endgames (mostly due to the work by Ken Thompson (1986), who later made this knowledge easily accessible on three CD-ROMs) and many 6-piece endgames (e.g., Stiller, 1989) led to the amelioration and extension of much chess-endgame theory. The most difficult part of using this increased knowledge is not generating it, but *understanding* it, preferably by discovering general rules and patterns emerging from the newly discovered data. One of the pioneers in this respect is Grandmaster John Nunn, who devoted much time to explore the mysteries of this fascinating realm (Nunn, 1994a) and to offer his findings to a broad audience (Nunn, 1992, 1994b).

As an example of the influence of newly-discovered endgame knowledge on the practise of chess games we mention a game between IGMs Jan Timman and Jonathan Speelman, during a tournament in Linares, March 1992. Timman knew that his game, adjourned after 60 moves, would result quickly in the KBBKN position of Diagram 2. Although the main literature on such positions learns that such positions mostly are draws, when Black reaches a so-called Kling-Horwitz conformation, Timman was eager to know if recent computer-chess reesearch maybe learns otherwise. After consulting professor Van den Herik, expert on the field of endgame databases, Timman was relieved to know that the position indeed was a win, though the winning path was so complex that Timman still felt he did not understand exactly how to win. However, using all information available, Timman was sufficiently knowledgeable about this endgame that he indeed was able to convert the adjourned position into a win (see Breuker *et al.*, 1992, for a detailed account of this).

							b
	b		k				
					K	N	

Diagram 2: The adjourned position of Timman-Speelman, Linares, 1992.

The Future of Computer Chess

One of the questions posed most often to chess programmers is whether they believe computer chess has a future. Since it is commonly believed that the human supremacy in chess over machines will last no longer than some years, it is argued that interest in computer chess will largely vanish when the machines become stronger than their human opponents. I do not adhere to such a point of view. Even when the chess computer will soon be too strong for human opponents, computer chess still will be a good testing ground for the investigation of artificial-intelligence techniques. It still will be possible to test different techniques by investigating the results in the chess arena of a program in which the techniques are incorporated, be it that the beauty of moves may not be understood by its audience. And there is no reason why the ELO scale would not give relevant comparisons above, say, 3000 ELO.

A second argument disfavouring a great future for computer chess runs that computer chess is killing the game of chess. And when chess is dead, interest in computer chess of course also will diminish. I do not agree with this argument either. The complexity of chess is such that even in our fanciest dreams we should not think about *solving* the game of chess (which, according to many discussions on the Internet, many people confuse with surpassing the human world champion's level). On the contrary, the computer still has us a lot to learn. Notwithstanding the thorough analyses and investigations chess theory still has many mysteries and uncomprehended facts. I feel that, after the digestion of the shock caused by the loss of the human supremacy at the chess-board, humans will quickly realize that the chess machine is no longer an enemy, to be contended, but in stead a teacher and tutor, from which much can be learnt.

The future of computer chess as the *Drosophila melanogaster* of artificial intelligence is also heavily disputed these days. All artificial-intelligence researchers agree that in the early years of computer chess there has been a lot of innovative work, of which many other disciplines have profited. However, many argue that computer chess has abandonned this leading role ever since the brute-force approach became common. Donskoy and Schaeffer (1989) even argue that the early rise of computer chess maybe has been more a serious hindrance than an advantage for computer chess as a scientific domain. The emphasis of research shifted to a typically engineering view. However, the same authors also argue that with the beginning of a third phase of computer chess with a renewed interest for innovative search methods and knowledge-acquisition and -representation issues computer chess may start to regain its lost status in the artificial-intelligence domain.

Comparison of Chess with Shogi and Go

Several researchers thus claim that computer chess has to or will in the near future refrain its leading role in artificial intelligence. Some feel this role can be reserved for other game domains, like computer Shogi (Matsubara, 1993) and even more people see this prospect for the field of computer Go.

As a first base for discussion, let us compare the respective games' complexities. As a measure we use the notion of *game-tree complexity*, defined as the number of leaf nodes in the solution tree of the initial position(s) of the game (Allis, 1994). As a crude approximation for game-tree complexity we calculate the number of leaf nodes of the search tree with as depth the average game length (in ply), and as branching factor the average branching factor (per depth). The game-tree complexity of chess then is estimated to be 10^{123}, based on an average branching factor of 35 and an average game length of 80 ply. The game-tree complexity of Shogi is considerably higher, being 10^{230}, based on an average branching factor of 100 and an average game length of 115 ply (Iida and Kotani, 1991). The game-tree complexity of Go even exceeds the latter number by far, estimated to be 10^{360}, based on an average branching factor of 250 and an average game length of 150 ply. So the complexities of Shogi and Go are indeed of a different magnitude than chess. Therefore, as has been experienced already, the brute-force depth-first iterative-deepening approach so successful for chess is unsuited for obtaining high-level Shogi or Go programs. The need for highly selective-search programs or even programs that do without searching at all therefore clearly is inorder.

Whether computer Shogi and computer Go will show a similar three-phase development as sketched for computer chess still is unclear. For the moment it only can be said that both still are in their first phase. The strongest Go programs are claimed to play at some 10 Kyu, i.e., at a weak club player's level. For Shogi programs the situation even is worse, most programs still being at a beginner's level. It still has to be investigated which methods will be valuable for building stronger Shogi and Go programs. Methods presently under consideration include such diverse techniques as pattern recognition, neural networks, and even genetic algorithms.

The innovative research now going on in computer Shogi and computer Go surely may provide a strong and profitable stimulus for artificial-intelligence research. So, whether or not computer chess will regain its status as the *Drosophila melanogaster* of artificial intelligence, it surely would be good if computer Shogi and computer Go would at least experience as much attention in the near future as computer chess did in the previous few decades.

Literature

Allis, L.V. (1994). *Searching for Solutions in Games and Artificial Intelligence*. Ph.D. thesis. University of Maastricht.

Allis, L.V., Meulen, M. van der, and Herik, H.J. van den (1994). Proof-Number Search. *Artificial Intelligence*, Vol. 66, pp. 91-124.

Anantharaman, T.S., Campbell, M.S. and Hsu, F.-h. (1988). Singular Extensions: Adding Selectivity to Brute Force Searching. *ICCA Journal*, Vol. 11, No. 4, pp. 135-143. Republished (1990) in *Artificial Intelligence*, Vol. 43, No. 1, pp. 99-110.

Berliner, H.J. and Ebeling, C. (1989). Pattern Knowledge and Search: The SUPREM Architecture. *Artificial Intelligence*, Vol. 38, No. 2, pp. 161-198. Revised as Berliner, H.J. and Ebeling, C. (1990). Hitech. *Computers, Chess, and Cognition* (eds. T.A. Marsland and J. Schaeffer), pp. 79-109. Springer-Verlag, New York.

Breuker, D.M., Allis, L.V., Herik, H.J. van den and Herschberg, I.S. (1992). A Database as a Second. *ICCA Journal*, Vol. 15, No. 1, pp. 28-39.

Chabris, C. and Kopec, D. (1994). Report on the Fifth Harvard Cup Human versus Computer INTEL Chess Challenge. *ICCA Journal*, Vol. 17, No. 4, pp. 224-232.

Donskoy, M. and Schaeffer, J. (1989). Perspectives on Falling from Grace. *Proceedings Workshop on New Directions in Game-tree Search*, pp. 85-93. Edmonton, Canada. Also published in *ICCA Journal*, Vol. 12, No. 3, pp. 155-163.

Frey, P.W. (1991). Memory-Based Expertise:Computer Chess vs. AI. *ICCA Journal*, Vol. 14, No. 4, pp. 192-197.

Friedel, F. and Morsch, F. (1994) The INTEL World Chess Express Challenge. *ICCA Journal*, Vol. 17, No. 2, pp. 98-104.

Friedel, F. (1994). Pentium Genius Beats Kasparov: A Report on the INTEL Speed-Chess Grand Prix. *ICCA Journal*, Vol. 17, No. 3, pp. 153-158.

Groot, A.D. de (1946). *Het denken van den Schaker, een experimenteel-psychologische studie*. Ph.D. thesis, University of Amsterdam; N.V. Noord-Hollandse Uitgevers Maatschappij, Amsterdam. Translated, with additions, (in 1965) as *Thought and Choice in Chess*. Mouton Publishers, The Hague.

Herik, H.J. van den and Herschberg, I.S. (1985). The Construction of an Omniscient Endgame Data Base. *ICCA Journal*, Vol. 8, No. 2, pp. 66-87.

Hsu, F.-h., Anantharaman, T.S., Campbell, M.S. and Nowatzyk, A. (1990). A Grandmaster Chess Machine. *Scientific American*, Vol. 263, No. 4, pp. 18-24.

Iida, H. and Kotani, Y. (1991). Computer Shogi. *Proceedings of the Game Playing System Workshop*, pp. 42-48. Tokyo.

Iida, H., Uiterwijk, J.W.H.M. and Herik, H.J. van den (1993). Opponent-Model Search. *Technical Reports in Computer Science*, Report CS 93-03. Dept. of Computer Science, University of Limburg, Maastricht.

Knuth, D.E. and Moore, R.W. (1975). An Analysis of Alpha-Beta Pruning. *Artificial Intelligence*, Vol. 6, No. 4, pp. 293-326.

Levy, D. and Newborn, M. (1990). *How Computers Play Chess.* W.H. Freeman and Company, New York.

Matsubara, H. (1993). Shogi (Japanese Chess) as the AI research target next to chess. *ETL Technical Report ETL-TR-93-23*. Tsukuba.

McAllester, D.A. (1988). Conspiracy Numbers for Min-Max Search. *Artificial Intelligence*, Vol. 35, pp. 287-310.

Michie, D. (1980). Chess with Computers. *Interdisc. Sci. Rev., Vol. 5, No. 3*, pp. 215-227.

Newell, A., Shaw, J.C. and Simon, H.A. (1958). Chess-Playing Programs and the Problem of Complexity. *IBM Journal of Research and Development*, October, Vol. 2, pp. 320-335. Reprinted (1963) in *Computers and Thought* (eds. E.A. Feigenbaum and J. Feldman), pp. 39-70. McGraw-Hill, New York.

Newell, A. and Simon, H.A. (1972). *Human Problem Solving.* Englewood Cliffs, N.J.: Prentice Hall.

Nunn, J. (1992). *Secrets of Rook Endings*. B.T. Batsford, London.

Nunn, J. (1994a). Extracting Information from Endgame Databases. *Advances in Computer Chess 7* (eds. H.J. van den Herik, I.S. Herschberg, and J.W.H.M. Uiterwijk), pp. 19-34. University of Limburg, Maastricht, The Netherlands.

Nunn, J. (1994b). *Secrets of Pawnless Endings*. B.T. Batsford, London.

Schaeffer, J. (1989). Conspiracy Numbers. *Advances in Computer Chess 5* (ed. D.F. Beal), pp. 199-217, North-Holland, Amsterdam.

Shannon, C.E. (1950). Programming a Computer for Playing Chess. *Philosophical Magazine*, Vol. 41, No. 7, pp. 256-275. Reprinted (1988) in *Computer Games I* (ed. D.N.L. Levy), pp. 81-88. Springer Verlag, New York.

Simon, H.A. and Schaeffer, J. (1992). The Game of Chess. *Handbook of Game Theory with Economic Applications, Vol. 1* (eds. R.J. Aumann and S. Hart), pp. 1-17. Elsevier Science Publishers, Amsterdam.

Stiller, L. (1989). Parallel Analysis of Certain Endgames. *ICCA Journal*, Vol. 12, No. 2, pp. 55-64.

Stiller, L. (1991). Some Results from a Massively Parallel Retrograde Analysis. *ICCA Journal*, Vol. 14, No. 3, pp. 129-134.

Thompson, K.L. (1982). Belle Chess Hardware. *Advances in Computer Chess 3* (ed. M.R.B. Clarke), pp. 45-54. Pergamon Press, Oxford.

Thompson, K. (1986). Retrograde Analysis of Certain Endgames. *ICCA Journal*, Vol. 9, No. 3, pp. 131-139.

Turing, A.M. (1950). Computing Machinery and Intelligence. *Mind*, Vol. 59, pp. 430-460.

Uiterwijk, J.W.H.M. and Herik, H.J. van den (1994). Speculative Play in Computer Chess. *Advances in Computer Chess 7* (eds. H.J. van den Herik, I.S. Herschberg and J.W.H.M. Uiterwijk), pp. 79-90. University of Limburg, Maastricht, The Netherlands.