What's New in Computers?

Will a Computer Become the World Chess Champion?

K S R Anjaneyulu

There has recently been significant interest in the area of computer chess. In February this year, Garry Kasparov, the world chess champion played a six match chess tournament with *Deep Blue*, the current computer chess champion. Garry Kasparov won the tournament, but lost one of the matches. This article describes the area of computer chess and the *Deep Blue* system.

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Why Computer Chess?

Computer chess has been an active area of interest since the beginning of the computer age. One may ask why chess has evoked so much interest. This is partly because of the complexity of the game. People who initially worked in Artificial Intelligence (AI) thought that chess was a good place to experiment with ideas in AI.

Claude Shannon, the founder of information theory, stated in 1950 that "the investigation of the chess-playing problem is intended to develop techniques that can be used for more practical applications." Shannon further argued that chess represents the ideal hurdle for computer analysis. "The problem is sharply defined, both in the allowed operations (the moves of chess) and in the ultimate goal (checkmate). It is neither so simple as to be trivial nor too difficult for satisfactory solution."

Since the board is small, the number of rules is few and chance does not play a role, so one would think that it should not be difficult to design a computer chess machine. The problem however is the very large number of possibilities which need to be explored. The number of moves is so large that no machine will

Definitions of AI

Artificial Intelligence is the study of how to make computers do things at which, at the moment, people are better. *Elaine Rich, 1983.*

Artificial Intelligence is that branch of computer science dealing with symbolic, non-algorithmic methods of problem solving. *Bruce Buchanan and Edward Shortliffe, 1984.*

be able to explore all of them.

History of Computer Chess

In 1957, Herbert Simon, one of the pioneers in the field of AI, predicted that we would be able to produce a computer chess machine which could beat any human being in 10 years. It turned out that this prediction was way off the mark, and even 40 years hence we have not achieved that. However, this is not to rob the AI community of credit. Computer chess performance has improved by about 50 points each year.

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The international chess association started a world-wide chess competition in 1974. In this competition computer chess machines clash with each other to determine 'who' is the best. In addition there are the Fredkin prizes which are awarded to chess machines for outstanding performance. The *Belle* program written by Ken Thompson (one of the developers of the UNIX operating system) won the Fredkin's prize of $5000 in 1983 for being the first machine to achieve a master's ratings. *Deep Thought* in 1989 won the $10,000 Fredkin's prize for being the first computer to attain a grandmaster's rating. The $100,000 prize for the first computer that becomes the world champion is still unclaimed.

How do Computers Play Chess?

The general procedure used by computers to play chess is given below. This procedure will play a perfect game of chess.

1. Every time a move has to be made, select the best move on the assumption that your opponent will also do the same.
2. How does one select the best move? For this one needs to generate the possible moves and select a move (The moves can be generated using the rules of chess). We can then examine the moves to see if they lead to a winning or a losing situation.
3. We then select one of the moves which leads to a winning situation. However, our move depends on the move our opponent makes. For this we select the best move which our opponent can

make and assume that he will make that move. (We can do this, by putting ourselves in our opponent's place and repeating the procedure we are using now).

4. The program thus keeps calling itself, continuing to expand possible moves and countermoves in an ever expanding tree of possibilities. So the game can be viewed as a tree, in which the nodes of the tree correspond to possible moves which can be made by the two players.

5. When does this end? It ends when we reach the end of the game.

If the procedure is simple, one would have thought that we would have had a world champion chess program long ago. The problem is the number of possibilities which need to be explored at each stage. If one needed to explore all possibilities before making one's first move, the amount of time required is estimated to be 40 billion years. How does one arrive at this figure? If you assume that a game lasts about 30 moves, we need to consider 8^{30} possible move sequences to fully expand the tree. If you assume that we can search 1 billion move sequences each second, we need 10^{18} seconds or about 40 billion years.

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How do computers overcome this problem? Since the whole tree cannot be searched, we place limits on the tree's depth and height. By reducing the number of moves we can do this in a reasonable amount of time. However, we then run into a problem. In our procedure, we had said that we will be selecting a move based on whether it leads to a winning situation or not. Since we are not able to search the whole tree, we can only guess whether something leads to a winning situation or not. This is done by using heuristics which give us some measure of the goodness of a move in the tree.

This is quite different from how humans play chess. The reason this approach was adopted was because attempts to develop computer systems which use a lot of human-like chess intelligence were not successful. Human beings typically consider a much smaller number of positions for each move. They use an extremely

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complicated strategy which includes intuition, experience, memory and pattern recognition. It has not been possible to decipher this strategy in a form in which a computer can use it.

The following table from Raymond Kurzweil's book (see Suggested Reading list) gives an estimate of the number of rules and board positions considered by computers and humans respectively. An interesting observation from this table is that computers make up for their relative lack of knowledge (represented by smaller number of rules) by being able to search much deeper in the tree (represented by the large number of board positions which are examined). Another confirmation of this fact is that the best computer chess systems invariably seem to be the most powerful. The advances in the area of computer hardware and parallel programming have allowed these machines to search many more moves than was possible earlier.

	Human chess master	**Computer chess master**
Number of rules or memorized situations	30,000–100,000	200–400
Number of board positions considered for each move	50–200	10^6–10^{11}

Software Techniques used in Computer Chess

Computer chess programs primarily use variations of look ahead search. The improvements over the years have largely been in being able to look farther and wider. This is basically a function of raw processing power as mentioned earlier, but there have also been advances in software technology.

In order to produce better chess machines, researchers use a number of interesting techniques. Some of these techniques have general applicability and are also used in other areas of AI. The

procedure described earlier is called the *Minimax algorithm* and is well documented in books on AI.

There are other techniques such as forward pruning, move reordering, etc. which are used in a number of chess machines. In forward pruning, at each node in the tree, a subset of the possible children is considered for further exploration. This subset is normally based on some heuristic which indicates the goodness of a node. Move reordering tries to reorder nodes in a tree so that more plausible moves are explored before less plausible moves. There are many more techniques like these.

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Deep Blue Computer Chess System

Deep Blue's predecessor was a system named *Deep Thought* which was developed at the Carnegie Mellon University, Pittsburgh in 1988. This was created by a group of researchers including Feng-Hsuing Hsu and Murray Campbell.

The basic version of *Deep Thought's* chess engine contained 250 chips and two processors on a single circuit board and was capable of analysing 750,000 positions per second (a more powerful version was reported to be searching 1.6 million positions), for an international performance rating of 2450, which placed it in the lower ranks of the world's grandmasters. Kasparov played *Deep Thought* in 1989 and won quite easily.

IBM's *Deep Blue* project began in 1989 to explore the use of parallel processing to solve complex problems. The *Deep Blue* team at IBM, Feng-Hsuing Hsu, Murray Campbell (both from the *Deep Thought* project), A Joseph Hoane, Jr. Gershon Brody, and Chung-Jen Tan, saw this complex problem as a classical research dilemma to develop a chess-playing computer to test the best chess players in the world.

Deep Blue was designed to overcome many of the system limitations of *Deep Thought*, specifically in the areas of calculation

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speed and processing power. The research team aimed to build a machine which was a 1000 times more powerful than *Deep Thought* and which could examine close to a billion moves a second.

The *Deep Blue* computer is a 32-node IBM Power Parallel SP2 high-performance computer. Each node has 8 dedicated VLSI chess processors. So there are a total of 256 processors working in tandem. The system has been developed in the C programming language. This high degree of parallelism allows *Deep Blue* to check 50 to 100 billion moves within 3 minutes.

In addition to this, *Deep Blue* has a very large opening game database which has been built from grandmaster games played over the last 100 years. It also has an end game database which is activated when there are only five chess pieces remaining on the board.

Deep Blue played a 6 match tournament against Kasparov in February this year. It lost the tournament, but won one of the matches. This is significant since this is the first time a computer has beaten the world champion in a match played under normal tournament rules.

Moves of Game which Kasparov lost against Deep Blue.
Deep Blue plays White, Kasparov plays Black

1. e4 c5	9. Be3 cxd4	17. Bg6 Bb6	25. b3 Kh8	33. Nd6 Re1
2. c3 d5	10. cxd4 Bb4	18. Bxf6 gxf6	26. Qxb6 Rg8	34. Kh2 Nxf2
3.exd5 Qxd5	11. a3 Ba5	19. Nc4 Rfd8	27. Qc5 d4	35. Nxf7 Kg7
4. d4 Nf6	12. Nc3 Qd6	20. Nxb6 axb6	28. Nd6 f4	36. Ng5 Kh6
5. Nf3 Bg4	13. Nb5 Qe7	21. Rfd1 f5	29. Nxb7 Ne5	37. Rxh7
6. Be2 e6	14. Ne5 Bxe2	22. Qe3 Qf6	30. Qd5 f3	
7. h3 Bh5	15. Qxe2 O-O	23. d5 Rxd5	31. g3 Nd3	
8. o-o Nc6	16. Rac1 Rac8	24. Rxd5 exd5	32. Rc7 Re8	

When will a Computer be the World Chess Champion?

IBM claims that the design they have used for the *Deep Blue* system will allow them to construct chess computers with improved performance measured in orders of magnitude. Would Kasparov still be able to defeat the enhanced system? Maybe not.

Hans Berliner who has been involved in the development of chess machines at Carnegie Mellon University estimates that by 1998 the computer will be a world chess champion. Kurzweil estimates that it will be by the year 2000.

Kasparov believes that the very best players in the world should be able to exploit the special weaknesses presented by machines. Kasparov has long maintained that human creativity and imagination, especially his own, will always triumph over silicon. He says "Chess gives us a chance to compare brute force with our abilities. In serious, classical chess, computers do not have a chance in this century. I will personally take any challenge."

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Some questions are difficult to answer. Will there be learning in the chess machines? Will they model their opponents in any manner to exploit their weaknesses and be aware of their strategies?

One thing is however definite. This is one arena where humans are pitted against AI in a dramatic manner. With the turn of the century inching closer, the battle gains increasing significance. If nothing else, an AI chess machine beating the world chess champion in a tournament will have a profound psychological impact.

Suggested Reading

- **T A Marsland. Computer Chess Methods. Stuart C Shapiro (ed), *Encyclopedia of Artificial Intelligence*, Vol. 1. Wiley-Interscience,1987.**
- **Raymond Kurzweil. *The Age of Intelligent Machines*. The MIT Press, 1990.**

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