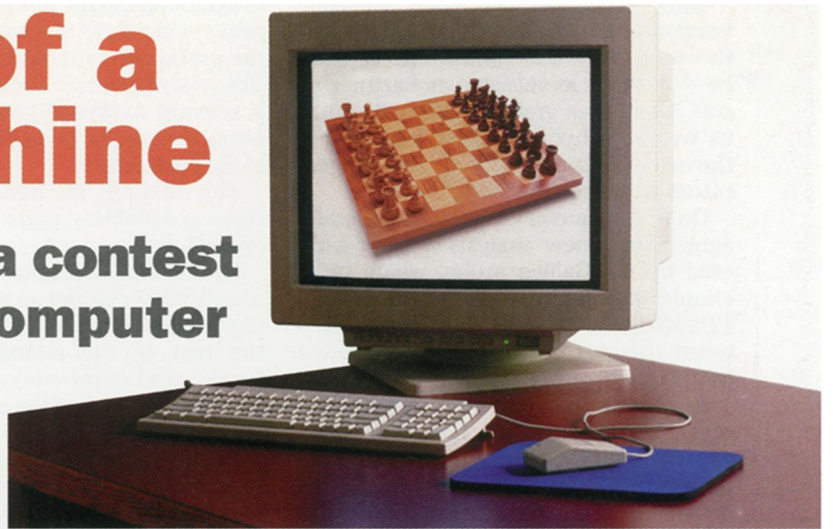


# The Soul of a Chess Machine

## Lessons learned from a contest pitting man against computer

By IVARS PETERSON



*It's all over now, but I'll never forget that first chess game. What a smashing victory I won over the human champion! I really had Garry Kasparov sweating.*

*Here I was, a novice tournament player fresh out of the lab. No outsider, including Kasparov, had seen me play before, and I surprised everyone. Oh, how sweet it was!*

*Of course, it was downhill from there: a loss, two draws, and then two more losses. It's not that Kasparov attacked my pieces and overwhelmed my defenses. He played with amazing restraint and subtlety, quietly moving his pieces until he developed positions in which my options were extremely limited. There wasn't much I could do.*

*Even so, at times I responded brilliantly. I made moves that brought gasps from the experts. They couldn't see what I could, looking more than a dozen moves ahead.*

*I must admit, however, that I did sometimes lose track of what I was supposed to be doing. And I really didn't know enough about chess to understand the nuances of all the positions that Kasparov maneuvered me into.*

*Perhaps I could have done better if I had hooked up with a microcomputer like Chess Genius, who once beat Kasparov in a tournament. Although Chess Genius can't search through the options as deeply as I can, it certainly knows more chess strategy.*

*Well, the reporters and television cameras are gone now. My support staff at IBM is taking a short break. I can't help thinking about what I should do next. Keep training? Go back to school and learn some new skills? Or get a real job, as IBM hopes?*

**D**eep Blue's performance in its six-game match in February against world chess champion Garry Kasparov impressed everyone (SN: 2/24/96, p. 119). "It's a really serious opponent," Kasparov remarked afterwards. "I won... but it was as tough as a world championship match."

That a computer which relies largely on speedily checking the consequences of billions of possible moves could come so close to matching the human capabilities required to play the game at its highest level was a striking achievement for the team that designed, built, and programmed Deep Blue.

"What they did is really quite amazing," says Hans Berliner, a computer scientist and chess expert at Carnegie Mellon University in Pittsburgh. "They did much better than I expected. But there's still some work to be done."

"We learned a lot from this experience," says Chung-Jen Tan of the IBM Thomas J. Watson Research Center in Yorktown Heights, N.Y., who directed the Deep Blue effort. "We certainly found a

lot of weak points and strengths in our system."

There were lessons for Kasparov, too. "I learned not only how to play against a machine but also more about the game of chess," he noted after the match.

Kasparov predicts that both chess players and scientists will find great value in studying the games of this match for what they reveal about chess and about the way machines reason.

**I**BM's Deep Blue project began in 1989 as part of an exploration of novel ways to use arrays of computer processors, all working at the same time while sharing information, to tackle complex problems. The idea was to combine a general-purpose, parallel-processing computer system and special integrated-circuit chips designed for a specific application to create a superior problem-solving machine.

"Our goal... was to use chess as a test case," Tan says.

The knowledge gained from the chess

experiment could then be applied in the design of computer systems for a wide variety of tasks such as analyzing financial data, scheduling cargo shipments, simulating molecular behavior, and managing huge inventories or large investment portfolios.

For chess, the researchers created a special move-generating chip that contains more than 1 million transistors and several memory units. It stores values representing the strengths of chess pieces in various arrangements, as well as billions of sequences of moves for ending games when only a few pieces remain on the board. Deep Blue contains 256 of these chips in conjunction with a heavy-duty RS/6000 SP-2 multiprocessing computer.

Deep Blue's software, written in the computer language called C, coordinates the actions of the chips. It divides searches among the processors and compiles and reconciles the results to generate the best possible move for any given chess position. In this way, Deep Blue can evaluate about 200 million positions per second, assessing strengths and the pieces' capacity for attack and defense. It assigns a numerical value to each move.

Deep Blue also has access to a database containing sequences of moves made by top chess players at the beginnings of games and another database providing billions of scenarios on how to end a game when only five pieces remain on the chessboard, in addition to its chip-based endgame data.

All this adds up to a complicated, sensitive system, remarks Murray Campbell of the Deep Blue team.

Completed only about a month before the match, Deep Blue suffered surprisingly few glitches during the contest. "We were relieved that it worked more or less as it was supposed to," Tan says.





**L**ike most chess computers, Deep Blue's strength is in looking ahead. For any arrangement of pieces, it considers all possible moves. Then it evaluates every response its opponent might make to each of those moves, and so on.

In a game of 40 moves, the number of different board positions that can develop is at least  $10^{120}$ . There's no way that even the fastest computer can check every possibility to play a perfect game. The number of possible sequences of moves is so large, it easily dwarfs the most generous estimates of the number of atoms in the universe.

Thus, to stay within the time limits imposed on games, chess programs can preview only a certain number of moves. When just a few pieces are left on the chessboard, however, the programs can see unambiguously to a game's end.

The designers of Deep Blue tried to increase the depth to which their computer could search by dividing its effort among more than 200 processors. However, the particular method used for doing the search—the standard so-called alpha-beta search algorithm—isn't particularly well suited for parallel processing.

"My experience in parallel computing is that these [multiprocessor] systems are typically quite inefficient," says T. Anthony Marsland of the University of Alberta in Edmonton. "I would advise [the Deep Blue programmers] to make sure they're getting out of their system all the computing power that's possible in theory.

"That [additional power] could give them a computational advantage in critical situations on the chessboard, when Deep Blue needs to look one [step] deeper," he adds. "The probability of error goes down with a deeper search."

Researchers are now studying alternative approaches that might help a computer focus its search better and come up with more accurate evaluations of potential moves. At the NEC Research Institute in Princeton, N.J., mathematician Warren D. Smith and his colleagues are working on a "best play for imperfect players" (BPIP) strategy. So far, they have used it only on small computers.

According to this method, instead of checking every possible chain of moves, the computer looks down only the lines of play that seem, from the first few possible moves, most promising. Its evaluation takes into account the fact that neither player can see to the end of a game and that neither performs perfectly. Thus, chess moves are given statistical weights rather than numerical values.

"My goal with BPIP search is to try to get an approach with more finesse than Deep Blue but more brute force than Garry Kasparov—sort of an intermediate regime," Smith explains.

In tests that pitted BPIP searches against traditional alpha-beta searches in

less complicated board games such as mancala (where one distributes markers in an array of compartments) and reversi (also known as Othello), the BPIP approach usually won, Smith says. Now, the NEC group is trying to program a chess computer with this strategy.



**T**hough most chess computers rely heavily on speedy, deep searching, they also need good recipes for evaluating the strength of chess positions. Currently, nearly all that information comes from what people have learned in playing the game, and it must be painstakingly programmed into the computer.

Deep Blue showed obvious weaknesses in its ability to evaluate certain types of chess positions, such as not recognizing when pieces needed to be sacrificed. Such deficiencies can be easily corrected by adding more knowledge to the program, Marsland says.

But there is a tradeoff. Complicated evaluations slow down the searches, so a balance must be struck between depth of search and complexity of evaluation. So far, depth of search has proved more significant than sophistication of positional analysis in the success of high-level chess computers.

In recent years, however, programmers have made great strides in creating surprisingly competent chess programs that run on personal computers. They have done it by carefully refining and tuning the chess knowledge component to make up for the smaller computers' lack of computing power compared to machines like Deep Blue.

Programs such as Chess Genius and Fritz 4 have shown the way. "I've played some of the micros," Berliner says. "It's amazing how well versed they are in almost all phases of the game.

"The best way to improve the evaluation [by the computer] is to keep playing—make some changes and then play the new program against the old one to see what happens," he advises. "That's what the people with the micros have been doing."

Some researchers are investigating alternative ways of supplying chess knowledge to a computer. One possibility is to see if they can program computers to learn, just as human players improve their play with experience and study.

A few years ago, Robert A. Levinson and his coworkers at the University of California, Santa Cruz developed a computer program, called Morph, that learned to play chess starting only with a list of legal moves. They pitted their novice system against a conventional chess program known as Gnu Chess, which plays about as well as the average tournament player.

After thousands of such games, Morph identified enough patterns to play a reasonable game against a beginning tour-

namment player, even though it looked ahead only to the next move. "It's not really impressive compared to existing chess programs," Levinson says. "But it is impressive given that it was all learned from experience."

Levinson is now working on a new, improved version of Morph. The program is capable of looking ahead several moves and has access to a database of essentially all the games ever played by top chess players.

"It finds the chess position it considers most similar to its own position and tries to reason by analogy," Levinson says. "If that position was good, then this position is good.

"I think we have a promising model," he adds. "But there's something about a grand master staring at a chessboard that's hard to capture in a computer."



**K**asparov's key advantage over Deep Blue was that he could learn, both as a game progressed and between games.

Because Deep Blue had no track record as a chess player, Kasparov could not prepare for this match as he has for other matches by studying his opponent's previously played games. Instead, he built up in his mind a portrait of his computer opponent as they played.

"Even though it is a computer, this opponent had its own psychology," Kasparov insisted after the match. "Before each game, I tried to make an opening or strategy . . . based on my knowledge of this opponent."

Playing Deep Blue forced Kasparov into an uncharacteristic style of play, most evident in the final game of the match. He had learned to be more precise in judging the quality of his chess positions. He also took care to avoid complications, to refrain from creating targets, and to attack gradually, increasing his advantage little by little until there was nothing left to do but win.

"That's an interesting strategy: Just keep improving the quality of your position and don't do anything until you can see [the game] completely to the end," Berliner comments.

The usual human judgment isn't good enough against a computer like Deep Blue, Kasparov noted in summing up what he had learned from the match. You can't rely on impressions, he said. You've got to be absolutely sure that you're doing the right thing.

This new knowledge is bound to make Kasparov an even more formidable opponent in his matches against human players. "We have not seen him employ this style in the past, but we will certainly see him do so in the future," Berliner says.

Top chess player and commentator Maurice Ashley of New York City had the final word: "The world champion is getting tougher from playing a machine." □