Deep Blue was the first chess computer to defeat a reigning human world chess champion in a regulation match. A number of factors contributed to the system’s success, including its ability to extract useful knowledge from a database of 700,000 Grandmaster chess games—a process that has implications for any non-chess knowledge-discovery application involving a vast database of human experience.
ing large databases of expert decisions. A tremen-
dous amount of information is contained in Deep
Blue’s database, which the system used in its
matches against Garry Kasparov in 1996 and 1997,
as well as in earlier games. The games in the data-
brase represent a rough consensus, developed over
decades of play, of the best opening moves known.

It is a tribute to the richness of chess that this con-
sensus, known to chess players as “opening theory,” is
surprisingly dynamic. Openings that may have been
considered bad are frequently revived with a new idea
in mind; blind faith in opening theory can be as haz-
ardous as not knowing it at all. Grandmasters devote
a great deal of time and study to opening theory, por-
ing over the games of their chess-playing peers from
around the world, subjecting a small subset of the
resulting positions to very deep analysis.

Deep Blue takes a different approach to using the
opening information in its database. Instead of sub-
jecting a few selected positions to detailed analysis,
it creates an additional database we call the “extended book.” The extended book allows the sys-
tem to quickly summarize previous Grandmaster
experience in any of the several million opening
positions in its game database. This summary is used
to nudge Deep Blue in the consensus direction of
opening theory. The system can combine its massive
searching ability (200 million chess positions per
second) with the summary information in the
extended book to select opening moves. But Deep
Blue does not blindly follow opening theory, using
it instead to guide its search for the most promising
move. This process gives Deep Blue the opportunity
to not only find errors in opening theory, but to fol-
low the branch of the theory that best fits its own
chess-playing style.

Extended Book
Most chess-playing computers, including Deep Blue,
have their own “opening book,” a set of positions,
along with associated recommended moves. While
using the opening book to navigate the early stages of
a chess game in which one of the included positions
arises, the computer selects one of the recommended
moves by way of some possibly random mechanism,
then plays without further computation.

Creating a high-quality opening book is time- and
labor-intensive, requiring a degree of chess skill.
Because this task was not our primary focus, the
opening book in Deep Blue and in its predecessor
machines has contained only a few thousand posi-
tions. In order to compensate for this relatively small
book, we introduced (in 1991) the idea of an
extended book derived automatically from a Grand-
master game database. For each of the (several mil-
on) positions arising in the first 30 or so moves in
these Grandmaster games, the system computes an
evaluation for each move that has been played.
Moves that appear to be good are given positive val-
ues; moves that look weak are assigned negative val-
ues. Our aim was to bias the search, preferring the
strong-looking moves while avoiding the weak ones.

Prior to conducting a search, Deep Blue first
checks whether a move is available from the opening
book. Finding a move, it plays it immediately. Oth-
erwise, it consults the extended book; if it finds the
position there, it uses the evaluation information to
award bonuses and penalties to a subset of the avail-
able moves. Finally, Deep Blue carries out a search,
with some preference for following successful
Grandmaster moves. However, because there is
always the possibility that opening theory has over-
looked the strongest move in the position, Deep

Figure 1. Position after White’s move 19 in the
second game of the 1997 match between Deep Blue
(White) and Kasparov (Black), ultimately won by
Deep Blue in 45 moves.
Blue still has the opportunity to discover it. In some situations, where the bonus for a move is unusually large, Deep Blue can make a move without computation; such automatic extended-book moves allow the system to save time for use later in the game. A number of factors goes into the evaluation function for the extended book, including:

- The number of times a move has been played. A move frequently played by Grandmasters is likely to be good.
- Relative number of times a move has been played. If move A has been played many more times than move B, then A is likely to be better.
- Strength of the players that play the moves. A move played by Kasparov is more likely to be good than a move played by a low-ranked master.
- Recency of the move. A recently played move (usually played knowing prior games) is likely to be good, an effect that can in some cases dominate the second factor.
- Results of the move. Successful moves are likely to be good.
- Commentary on the move. Chess games are frequently annotated, with the annotator marking strong moves (with “!”) and weak moves (with “?”). Moves marked as strong are likely to be good; moves marked as weak are likely to be bad.
- Game moves vs. commentary moves. Annotators of chess games frequently suggest alternative moves. In general, game moves are considered more reliable than commentary moves, and are thus likely to be better.

Deep Blue's designers combined these factors in a nonlinear function that produces bonuses as high as half the value of a pawn (50 points, where a pawn is worth 100 points) in situations in which a particular move has been played thousands of times with reasonable success.

The extended book idea has proved remarkably successful in the games Deep Blue and its predecessors have played. The system is often able to follow opening theory without any opening book at all, relying only on the extended book combined with its own search. An interesting example of the value of the extended book was demonstrated in the second game of Deep Blue's 1996 match with Kasparov. In that game, a configuration error caused Deep Blue to play the entire game without an opening book. Despite that limitation, the extended book allowed Deep Blue to follow opening theory up to move 13, after which Kasparov introduced a new move. Although this game, and the 1996 match, were ultimately won by Kasparov, the extended book allowed Deep Blue to obtain a respectable opening position.

More noteworthy was Deep Blue's victory over Kasparov in the second game of their 1997 match (see Figure 1). In that game, the first nine moves of a Ruy Lopez opening were taken directly from the opening book. The next eight moves (10–17) were all automatic extended-book moves. Two moves were given extended-book bonuses: 18.Qd2 was given a 17-point bonus, and 19.a4 was given a nine-point bonus. On move 19, Kasparov played a new move that led to a position not found in Deep Blue's extended book. From this point on, Deep Blue played without any extended-book bonuses, having established a very comfortable position from the opening.

Useful in Non-Chess Domains

Deep Blue uses knowledge extracted from a Grandmaster game database to improve its performance in actual play. The extended book technique, involving summarized human decisions to bias a search, also appears to be of general value in non-chess domains with access to large databases of expert decisions, such as other games, medical diagnosis, and stock trading, especially when there is a useful similarity measure between differing situations for a given domain.

For playing chess, one could extract knowledge from a Grandmaster game database in ways other than the Deep Blue extended book. For example, we have experimented with methods for tuning Deep Blue's position-evaluation function by, say, trying to maximize the number of Grandmaster moves that can be predicted through a shallow search. Though this optimization problem is very difficult, due to the size of the parameter space that has to be explored, the automated turning method has yielded insight and guidance to the Deep Blue team in the design and programming of the Deep Blue system.

References


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Deep Blue was an IBM created Supercomputer designed to defeat world champion Garry Kasparov. On 11 May 1997, the machine won a six-game match by two wins to one with three draws against world champion Garry Kasparov. Kasparov accused IBM of cheating and demanded a rematch, but IBM declined and retired Deep Blue. Deep Blue succeeded in its goal of winning against a reigning world champion in 1997. Kasparov had won an earlier match against a previous version of Deep Blue in 1996. In 1997, Deep Blue, a Chess computer developed by IBM as the next stage of Carnegie Mellon University’s Deep Thought project, defeated then-reigning World Chess champion Garry Kasparov with a score of 3.5–2.5. With this feat, Deep Blue became the first ever computer to defeat the reigning World Chess champion under standard time controls. It may seem unfair to compare Deep Blue and AlphaZero because of the difference in time periods in which they were invented.