Review: Computer Shogi Through 2000

Takenobu Takizawa[1] and Reijer Grimbergen[2]

[1] School of Political Science and Economics, Waseda University
1-6-1 Nishi-Waseda, Shinjuku-ku, Tokyo, Japan 169-8050
takizawa@mse.waseda.ac.jp
[2] Complex Games Lab, Electrotechnical Laboratory
1-1-4 Umezono, Tsukuba-shi, Ibaraki-ken, Japan 305-8568
grimberg@etl.go.jp

Abstract. Since the first computer shogi program was developed by the first author in 1974, more than a quarter century has passed. During that time, shogi programming has attracted both researchers and commercial programmers and playing strength has improved steadily. Currently, the best programs have a level that is comparable to that of a strong amateur player (about 4-dan), but the level of experts is still beyond the horizon. The basic structure of strong shogi programs is similar to chess programs. However, the differences between chess and shogi have led to the development of some shogi-specific methods. In this paper we will give an overview of the computer shogi history, summarise the most successful techniques and give some ideas for the future directions of research in computer shogi.

Keywords: shogi, computer shogi history, evaluation function, plausible move generation, SUPER SOMA, tsume shogi, tesuji search.

1 Introduction

Shogi, or Japanese chess, is a two-player complete information game similar to chess. As in chess, the goal of the game is to capture the opponent's king. However, there are a number of differences between chess and shogi: the shogi board is slightly bigger than the chess board (9x9 instead of 8x8), there are different pieces that are relatively weak compared to the pieces in chess (no queens, but gold generals, silver generals and lances) and the number of pieces in shogi is larger (40 instead of 32).

But the most important difference between chess and shogi is the possibility to re-use captured pieces. A piece captured from the opponent becomes a *piece in hand* and at any move a player can *drop* a piece that was captured earlier on a vacant square instead of moving a piece on the board. For a more detailed description of the rules of shogi, see [9].

There are only a few restrictions on where a piece can be dropped. Creating a double pawn by a drop is not allowed, but dropping a piece with check or mate is perfectly legal (with one exception: mate with a pawn drop is not allowed). As a result of these drop moves, the number of legal moves in shogi is on average much larger than for chess. In chess the average number of legal moves is estimated at 35, while for shogi the figure is about 80 [11]. In the endgame, the situation is even worse, as in most endgame positions there will be various pieces in hand and the number of legal moves can easily grow to over 200 [3].

Since shogi is similar to chess, the techniques that have proven effective in chess also have been the foundation of most shogi programs. However, to deal with the high number of legal moves in shogi, shogi-specific methods have to be developed because deep search is more difficult than in chess. Shogi could therefore be considered as an intermediate step between chess and Go [12].

The improvement of shogi programs over the last couple of years has been impressive. When Kasparov lost to DEEP BLUE in 1997, computer shogi programs could only compete with average amateur players (about 2-dan). After the latest computer shogi tournament, Hiroyuki Iida (a professional shogi player and an associate professor at Shizuoka University) estimated the strength of the top programs at about 4-dan. Even though on the Japanese grading scale this is only two grades difference, the actual difference in playing strength is quite large. Even for strong amateurs, losing against the computer (especially in quick games) is no longer an embarrassment.

In this review paper we will start with a brief overview of the history of computer shogi in Section 2. In Section 3, we will then give an overview of the techniques that have been most successful. In Section 4 we will explain about some of the recent developments in computer shogi. We will end with some conclusions and ideas about the future direction of computer shogi in Section 5.

2 A Brief History of Computer Shogi

The first shogi program was developed by the research group of the first author in November 1974. At that time, shogi seemed so complex that the prediction was that it would take about 50 years for shogi programs to reach the level of a 1-dan amateur [1]. However, this prediction was way off, as Iida estimated that the strength of the top programs in 1995 was already strong 1-dan.

One of the reasons for this has been the establishment of the *Computer Shogi Association* (CSA) in 1986 by Yoshiyuki Kotani and the first author. This organisation started organising computer shogi tournaments in 1990, tournaments that were also supported by the *Nihon Shogi Renmei*, the Japanese shogi organisation.

2.1 The Computer Shogi Championships (1990-1999)

The first computer shogi championship was held on December 2nd 1990. Table 1 gives an overview of all the computer shogi tournaments that have been held

[1] 1-dan is an interesting psychological barrier in shogi and most other Japanese sports. The Japanese ranking system in shogi starts at 15-kyu, going down to 1-kyu and then going up from 1-dan to 6-dan. Therefore, the difference between 1-kyu and 1-dan is only one grade, but the psychological difference is considerable. Unlike players with a kyu grade, players with a dan grade are considered strong players.

Table 1. Results of the computer shogi tournaments 1990-2000. CSA = CSA Tournament; SGP = Computer Shogi Grand Prix; MSO = Mind Sports Olympiad.

	Date	Entries	Winner	2nd	3rd
CSA1	Dec 2 1990	6	Eisei Meijin	Kakinoki	Morita
CSA2	Dec 1 1991	9	Morita	Kiwame	Eisei Meijin
CSA3	Dec 6 1992	10	Kiwame	Kakinoki	Morita
CSA4	Dec 5 1993	14	Kiwame	Kakinoki	Morita
CSA5	Dec 4 1994	22	Kiwame	Morita	YSS
CSA6	Jan 20-21 1996	25	Kanazawa	Kakinoki	Morita
CSA7	Feb 8-9 1997	33	YSS	Kanazawa	Kakinoki
CSA8	Feb 12-13 1998	35	IS	Kanazawa	Shotest
CSA9	Mar 18-19 1999	40	Kanazawa	YSS	Shotest
SGP1	Jun 19-20 1999	8	Kakinoki,YSS		IS, KCC
CSA10	Mar 8-10 2000	45	IS	YSS	Kawabata
MSO1	Aug 21-25 2000	3	YSS	Shotest	Tacos

since then. It is clear that computer shogi tournaments have become big events. The number of participants in the CSA tournaments has increased every year, from 6 participants in the first tournament (including 2 invited programs) to 45 entries in the last event. Since 1996, the finals of the tournament have been a round robin of eight programs. These eight programs are decided by taking the five strongest programs from the first day(s) of the tournament, and adding the three best programs from the previous year's contest.

The first CSA tournament was won by Eisei Meijin (made by Yoshimura), but even though this program is still strong and has participated in most tournaments since 1990, its only other top three finish was in the 1991 tournament. Since 1992, the CSA tournament has been dominated by Kiwame/Kanazawa, two programs written by Shinichiro Kanazawa. Kanazawa's programs have won the CSA tournament five times and have been runner-up three times.

Other past winners are Morita Shogi (written by Morita), YSS (Yamashita) and IS Shogi (Tanase, Goto, Kishimoto and Nagai), which is the reigning champion. In recent years, there have also been a number of foreign entries. The best results have been achieved by Jeff Rollason from England with his program Shotest, which entered for the first time in 1997 and finished third in both the 1998 and the 1999 tournaments. Other foreign entries have been KCC from Korea, Shocky by Pauli Misikangas from Finland, and SPEAR, a Dutch program by the second author. KCC managed to qualify for the finals of the 1999 CSA tournament and Shocky did the same in the 2000 CSA tournament.

Until recently, the CSA tournament was the only computer shogi tournament, but in 1999 the first *Computer Shogi Grand Prix* was organised as part of an international shogi festival called the *Shogi Forum*. The Computer Shogi Grand Prix was an invitation tournament for the best 8 programs of the previous CSA tournament and was won by Kakinoki Shogi (Kakinoki) and YSS. Unfortunately, Kanazawa Shogi had to pull out of this tournament because of problems with running the program on the single platform hardware that was used. Finally, there was also a (very small) computer shogi tournament held as part of the Computer Olympiad at the 2000 Mind Sports Olympiad. This tournament was won by YSS.

2.2 The Millennium CSA Computer Shogi Championship

Now let's look at the results of the latest CSA Computer Shogi Championship in a little more detail. The millennium tournament was held from March 8th to March 10th, 2000. This tournament had a record number of 45 participants and was also the first tournament that was played over three days: two days of qualification tournaments were played with the Swiss tournament system and the finals were then held on a single day.

The detailed results of the finals are given in Table 2. The finalists are an interesting mix between programs that have participated for a long time (IS Shogi: 4 years, YSS: 9 years, Kanazawa Shogi: 9 years, Kakinoki Shogi: 10 years), some relatively new entries (Kawabata Shogi (Kawabata) and KFEnd (Arioka)) and non-Japanese entries (Shotest and Shocky).

A second observation is that the tournament was very close. Before the start of the final round there were four programs that could still win the tournament. IS Shogi in the end was the lucky one, as it won in the final round and two other games ended in its favour. The fourth place of Kanazawa Shogi can be called a surprise, but if the program would have won in the final round against YSS, it would have won the tournament: another illustration of how close the tournament was.

This year the foreign entries did not do very well, as Shotest and Shocky ended at the bottom of the table. Still, it was only Shocky's second appearance in this tournament and Shotest has proven its strength in the two previous CSA tournaments. Furthermore, the Korean program KCC just missed the final eight, even though it beat IS Shogi in the qualification tournament. Although computer contests are still dominated by the Japanese programs, this is an indication that computer shogi is becoming more and more international. More details about the 10th CSA tournament can be found in [4].

Table 2. Results of the finals of the CSA tournament 2000.

No	Program Name	1	2	3	4	5	6	7	Pt	SB
1	IS Shogi	6+	8+	3-	2+	5+	4-	7+	5	15
2	YSS 10	8+	5+	6+	1-	3-	7+	4+	5	14
3	Kawabata Shogi	4-	7-	1+	5+	2+	8+	6-	4	16
4	Kanazawa Shogi	3+	6-	5-	8+	7+	1+	2-	4	13
5	Kakinoki Shogi	7+	2-	4+	3-	1-	6+	8+	4	10
6	KFEnd	1-	4+	2-	7-	8-	5-	3+	2	8
7	Shotest 4.0	5-	3+	8-	6+	4-	2-	1-	2	6
8	Shocky 3	2-	1-	7+	4-	6+	3-	5-	2	4

3 Techniques used in Computer Shogi Programs

As pointed out earlier, shogi is similar to chess, and strong shogi programs have a structure that is similar to that of chess programs. Typically, mini-max game trees are built that are explored by an iterative alpha-beta search. Shogi programs also make use of common refinements of this scheme such as PVS-search, quiescence search, aspiration search, null-move pruning, history heuristic and killer moves.

Despite these similarities, however, the specific features of shogi have made it necessary to explore other methods. In this section we will look at the following elements that need to be handled differently in shogi, or are shogi specific: *data structures*, *the evaluation function*, *hash tables*, *plausible move generation* and *tsume shogi*.

3.1 Data Structures

Probably the best English overview of the data structures used in shogi is given by Yamashita on his webpage [19]. The most important extra data structure that is used in shogi seems to be the *kiki table* (or piece attack table). In the kiki table, information about which piece attacks which square is stored. The table distinguishes between pieces that can move to a square directly and pieces that can only move there indirectly (for example, a rook behind another rook). In shogi the kiki table is very important as it is accessed by a number of other modules in the program such as the evaluation function, plausible move generation and mating search.

3.2 The Evaluation Function

The evaluation function of chess contains many different features, but material is the dominant component. For example, it is almost impossible to have enough positional compensation for the loss of a queen. On the other hand, in shogi the balance between material and king safety is the most important part of the evaluation function [7, 18].

As pointed out, in shogi captured pieces do not disappear from the game, so a game of shogi almost always ends with one of the kings being mated (there are some possibilities of a draw in shogi, but less than 1% of the professional games end in a draw). Therefore, the endgame in shogi is usually a mating race where the speed of the attack has the highest priority. Losing a strong piece such as a rook often leads to disaster in the opening and middle game, but can be completely insignificant in the endgame.

Strong shogi programs therefore need an understanding of the stage of the game (opening, middle game or endgame). The weights of the features of the evaluation function can change dramatically based on this game stage. A game of shogi usually has a slow build-up, so in the opening there is almost no weight given to the king safety. The most important features are material balance, castle formations, the mobility of major pieces (in shogi the rook and bishop are the strongest pieces) and the control of squares near the centre. In the middle game increasing weight is given to king safety, even though material still is the most important feature. In the endgame the king safety takes priority over material considerations. The best shogi programs can handle these transitions quite well and are able to accurately adjust their evaluation function during the game [20].

3.3 Hash Tables

The possibility of having pieces in hand also changes the way in which hash tables are used in shogi. In chess, only the pieces on the board matter, so hash tables are only used for transpositions. Transpositions are the same for chess and shogi: if two board positions are identical and the same player is to move, then there is a transposition if the pieces in hand for both players are identical. However, in shogi it is also possible to have *domination* of positions:

Definition 1 *A position P is* dominating *a position Q if the pieces on the board in P and Q are identical, the same player is to move in P and Q and the pieces in hand for the player to move in P are a superset of the pieces in hand of the player to move in Q.*

Search can be stopped in these types of positions as this is a cycle with a material advantage (or disadvantage) for the player to move.

Hash tables can be used to handle domination as well. In shogi, hashing of positions is only done on the pieces on the board and an extra hashcode is stored in the hash table for the pieces in hand [17].

3.4 Plausible Move Generation

To deal with the large number of legal moves in shogi, most shogi programs use plausible move generation to reduce the number of candidate moves that need to be searched. Some of the cuts are very safe. For example, promotion of shogi pieces is almost always optional. It is possible to construct positions where not promoting a rook, bishop or a pawn is the only way to win, even though the moves of these pieces in their promoted state are a superset of the moves of the non-promoted ones. However, in practice the non-promotion moves for these pieces are so rare that they can be safely removed from the list of legal moves.

These almost safe cuts are only a small percentage of the total number of legal moves, so most shogi programs also perform a number of more speculative, unsafe cuts (for more details, see [3]). The general approach is to have a set of categories with tactical moves, ordered by urgency. Common categories are *Capture material*, *Attack material*, *Move attacked piece*, *Defend attacked piece*, *Attack king*, *Defend king*, *Discovered attack*, *Promote piece*, *Threaten promotion* and *Defend against promotion threat.* For example, IS SHOGI has 10 different categories [18]; KAKINOKI SHOGI uses 8 general move categories [6] and YSS uses a very detailed move categorisation with no less than 30 move categories [20]. In YSS the move categories also depend on the search depth. For example, moves that attack a piece are not generated if the remaining search depth is 1, since the position evaluation will not change much if the attacked piece moves to a safe square.

3.5 Tsume Shogi

Tsume shogi, or checkmating problems in shogi, has been an independent research domain for many years. Unlike the mating problems in chess, each move by the attacker in a tsume shogi problem must be a check, finally leading to mate in all variations. The aim of the defender in a tsume shogi problem is to prolong the mate as long as possible and the solution of a tsume shogi problem is the longest variation that leads to mate.

The best tsume shogi solver has been developed by Seo [16]. While previous tsume shogi solvers used iterative alpha-beta search, Seo's solver used conspiracy number search [13] and this worked much better than previous approaches. After further improvements of his program (for example using proof number search [1] instead of conspiracy number search), Seo was able to solve the longest tsume shogi problem to date called *Microcosmos*. This problem was composed by Koji Hashimoto in 1986 and has a solution of 1525 ply. Seo's tsume shogi solver solved Microcosmos in about 30 hours in April 1997. Currently, tsume shogi is the only area in shogi where computer programs outperform world class shogi players. More details about the history and design of tsume shogi solvers can be found in [2].

Most strong shogi programs use a tsume shogi solver to find mate in the final stages of the game. However, because of the rule that each move by the attacker must be a check, the use of the tsume shogi solver is limited. Seo showed that the branching factor of an average search tree in tsume shogi is only about 5 [16], which is very different from the branching factor of the search tree in general endgame positions.

4 Recent Developments in Computer Shogi

Of course, all methods currently used in computer shogi are still being revised and improved. However, there are also some new ideas that have been developed recently, which we summarise here.

4.1 Extended Use of the Tsume Shogi Solver

As pointed out above, tsume shogi solvers outperform human experts, so a logical step is to use the tsume shogi solver during normal tree search. IS SHOGI seems to be the program that is most advanced in this respect [18]. First of all, if the opponent is threatening mate, the moves in the mating sequence are added to the list of killer moves. A more sophisticated use of the tsume shogi solver is to store the mating sequence that was found for future use. A problem in shogi is that by dropping pieces it is possible to play long checking sequences that push the winning variation over the search horizon. IS Shogi uses the tsume shogi solver to find mating threats in the endgame. The sequences that lead to mate are then stored and the tree node is marked as being a mating threat. If the opponent then starts a sequence of checks that continue until the search horizon is reached, the stored mating sequences are retrieved and it is tested if these also work in the position at the end of the variation that was searched.

4.2 Artistic Evaluation of Tsume Shogi

An interesting related research domain is the artistic evaluation of tsume shogi problems. As with mating problems in chess, there are big differences between the artistic impression that a tsume shogi problem makes to a human solver. Koyama et al. have done some interesting work in this area [8]. Their ideas were pursued by Noshita [14] and Hirose et al. [5], who developed programs that could automatically generate tsume shogi problems using retrograde analysis. With Koyama's rules for artistic evaluation it was possible to distinguish good tsume shogi problems from bad ones. Some of the problems made by Hirose's program were sent under a pseudonym to monthly magazines that publish tsume shogi problems and were accepted for publication.

4.3 Tesuji Search

Another interesting idea used in IS Shogi is *tesuji search* [18]. In the middle game in shogi there are often sequences of moves that are played in a particular order to reach a certain goal. In shogi these standard move sequences are called *tesuji*. For a search algorithm it is hard to recognise tesuji, as their goal can be beyond the search horizon. In IS Shogi a small number of 3-ply move sequences are implemented. If such a sequence is found in the search tree, then the search is extended by two ply. At this point, IS Shogi implements only 6 different move sequences to deal with certain blind spots of the program, but this method seems more generally applicable. Even though we do not know of any other published methods, we have observed that most programs have some way to implement standard move sequences, especially in the opening.

4.4 SUPER SOMA

In Jeff Rollason's Shotest, the horizon effect is dealt with in a way that is very different from other programs. In Shotest a static tactical move analysis called *SUPER SOMA* is used to guide the search [15]. SUPER SOMA is an extension of the SOMA algorithm for static analysis of capture sequences [10]. SUPER SOMA can not only statically analyse captures, but also pins, ties to material as well as ties to mate and promotion (if a defending piece moves, material will be lost or mate will be possible), discovered attacks, forks and defensive moves. Shotest uses the results of this static tactical evaluation to guide the search.

Shotest's static tactical evaluator slows down the program considerably (it is the program that has the lowest node per second search rate among the top programs). Also, the tactical evaluator just returns one line of play, generating only the top move according to the tactical evaluator at each depth. However, SHOTEST's tournament performance show that this approach is a good alternative to the fast evaluation used in most other programs.

5 Conclusions and Expectations for the Future

Shogi programs have improved significantly in the past few years and are a good match for most strong amateur players. Unfortunately, there is no tradition of playing shogi programs against human players under tournament conditions, so it is not completely clear how strong shogi programs actually are.

We feel that the near future will be very important for computer shogi as the latest CSA tournament was the closest ever and the differences in strength between the programs seem to be getting smaller. It will therefore be interesting to see if there is some kind of limit to the methods that are now being used in computer shogi, or if this is the start of a combined effort of a large number of programs towards the ultimate goal of beating the best players in the world.

As for this ultimate goal, the best human player Yoshiharu Habu is one of the few professionals who recognises how much shogi programs have improved. When asked in 1996 when he thought a computer would beat him, his clear answer was: "2015". This sounds like a reasonable estimate, but there is still a lot of work to do, as Habu (already a living legend) will be only 45 years old by then and very much at the peak of his abilities.

To beat Habu, we might need the help of special purpose hardware like the chess chip that was used in DEEP BLUE. Feng-hsiung Hsu of the DEEP BLUE team has shown interest in designing such a chip for shogi, but so far there have been no concrete steps taken to design one.

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