Chess, Shogi, Go, natural developments in game research

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Abstract

In game programming research there are four interesting and related domains: chess, xiang qi (Chinese chess), shogi (Japanese chess) and go. In this article we will compare chess with shogi, both comparing the rules and the computational aspects of both games. We will see that chess and shogi are very similar, but that there are some important differences that complicate game programming for shogi. Most important difference is the game tree complexity, which is considerably higher than the game tree complexity of chess.

We will then argue that these similarities and differences make shogi a good choice for further research in game programming. Chess will soon no longer be competitively interesting. Xiang qi has a game tree complexity similar to chess, suggesting that the same AI techniques will also be successful in this domain. Go is too risky as a next research target because little is known about the cognitive aspects of the game, which in our view hold the key to developing new techniques.

Also in this article, a short history of computer shogi with the results of the latest CSA computer shogi tournament is given. In the appendix a short introduction to the rules of the game is included.

1 Introduction

Considering the state of the art in game programming research, we feel that there are four interesting and related research domains: chess, xiang qi (Chinese chess), shogi (Japanese chess) and go. Interesting can be defined here as competitively challenging, i.e. not yet playing at world championship level. This excludes games like checkers, draughts and backgammon. The four games above are related in the sense that they are chess-type games. For go this point could be argued (and indeed we will), but we hope to make clear in this article why go was included in our list. The relation property excludes other interesting games like bridge, renju and mancala type games.

Chess, xiang qi, shogi and go are all complex games. In this article we will use two types of complexity:

Game tree complexity This is the search space that can be expected in a game, based on the average branching factor and average game length in plies. For our games the game tree complexity is:

- *Chess*: 10^{43} (Schaeffer et al., 1991) or 10^{123} according to a calculation by Allis (Allis, 1994), based on a branching factor of 35 and an average game length of 80 ply.
- *Xiang Qi*: 10^{150} (Tsao et al., 1991), based on a branching factor of 38 and an average game length of 95 ply.
- *Shogi*: 10^{226}, based on a branching factor of 80 (Matsubara & Handa, 1994) and an average game length of 115 ply (Yearbook, 1994).
- *Go*: 10^{360} (Allis, 1994), based on a branching factor of 250 and an average game length of 150 ply.

Decision complexity This is the complexity of the problem to find the optimal move in a given situation. It is easy to make an artificial example of a game with high game tree complexity, but low decision complexity. An example for go can be found in (Allis et al., 1991). It is of course difficult to quantitatively measure decision complexity. The fact that all four games are being played on a large scale and that only a small percentage of the player's population can be considered experts (i.e. professionals) is in our view sufficient evidence of a high decision complexity. For shogi, more evidence of decision complexity can be found in (Iida & Uiterwijk, 1992).

Our main interest is the game of shogi (Japanese chess). In section 2 we will describe the similarities and differences between chess and shogi in detail. In section 3 we will explain why shogi is a more natural target for game programming research than to continue research in chess, or put more effort in xiang qi or go. Finally, in section 4 we will give a short history of computer Shogi.

2 Chess and Shogi: Differences and similarities

In this section we will closely look at the similarities and differences between shogi and chess, both regarding rules and computational aspects. In Appendix A a short introduction to shogi and its rules is given. More elaborate introductions to shogi have been written by Leggett (1966) and Fairbarn (1984).

2.1 Similarities

1. Both chess and shogi are two-person perfect-information games. Therefore, in every position all possible moves can be considered and a game-theoretical value can be attached to each position (Allis, 1994).

2. Both games are sudden-death games. The game can end abruptly when the king of either player is captured (check-mate).

3. Most pieces in chess and shogi are either the same (king, rook, bishop) or similar (pawn, knight). Only three pieces are different: in shogi there are golden generals (short: gold), silver generals (short: silver) and lances.

4. In both games is it possible to draw by repetition of moves. Both in chess and shogi this way of drawing is not very common.

2.2 Differences

2.2.1 Rule differences

In this section we will only look at those differences that are important from the game programming point of view. We will therefore not discuss unimportant details about the shape of the pieces or that in shogi black plays up the board and is the first player to move instead of white.

1. Chess has an 8×8 board, while shogi has an 9×9 board.
2. In chess there are 6 different pieces, in shogi there are 8 different kinds of pieces. In chess each player has 32 pieces in total (16 pieces each) while in shogi each player has a total of 40 pieces (20 pieces each).
3. Most pieces in shogi are short range pieces. Each side has only one rook and one bishop. Among the other pieces, only lance and knight can move more than one square from their starting square. In chess, only the king, knight and pawn are limited in their movement.
4. In chess only the pawn is allowed to promote. In shogi promotion is allowed for 6 different kinds of pieces. Also, in chess promotion is only allowed on the 8th rank (for white) or the 1st rank (for black). In shogi promotion is possible in the camp of the enemy, being the top three ranks or the bottom three ranks of the board. Another interesting difference as far as promotion is concerned is the fact that in shogi promotion is not obligatory (except in a few minor cases).
5. The most important difference between shogi and chess is the possibility of reusing pieces in shogi. When a piece is captured, this piece does not disappear from the game (like in chess), but is put next to the board. If it is a player's turn, he can either choose to play a move with a piece on the board or take one of the pieces previously captured and put it on a vacant square on the board[1]. There are almost no limitations to where a piece can be "dropped", even giving mate by putting a captured piece back on the board is allowed.
6. A draw by agreement or a draw because of the fifty move rule is not possible in shogi. Stalemate is theoretically possible, but because of the possibility of drops this has never happened in a normal game. However, there is the possibility of impasse, where both kings enter into the enemy camp and can no longer be mated (*jishogi*). On average, only 2 out of every 1000 professional games end in jishogi (Yearbook, 1994). At amateur level, this is even rarer. As a result of these differences in the rules concerning draws, a draw is quite rare in shogi. Less than 1% of all professional shogi games end in a draw. Again, this figure is even less for amateur players.

[1]As a result, all pieces in shogi have the same colour. The difference between one's own pieces and those of one's opponent is only determined by the shape of the piece, which is not symmetrical.

2.2.2 Game programming differences

The rule differences between chess and shogi lead to differences in various aspects of game programming:

1. Chess is a converging game (number of possible moves decreases in the later stages of the game), while shogi is diverging (in the endgame the number of possible moves increases). This is mainly caused by the possibility of drops. However, since chess is slowly converging, the use of endgame databases is not so important as it is for example for mankala games and go-moku (Allis, 1994). In shogi, no endgame database is of any use, even though a special Tsume Shogi[2] solver is part of almost every shogi computer program.

2. As stated in the introduction, there is a considerable difference in game tree complexity due to the dropping possibility, the extra promotion possibilities and the virtual impossibility of draws. As said, the study by Matsubara and Handa (1994) shows that shogi has an average branching factor of about 80. In chess this is estimated at 35. It is also known that the maximum branching factor in shogi is 593. The following diagram[3] is taken from Nozaki (1990):

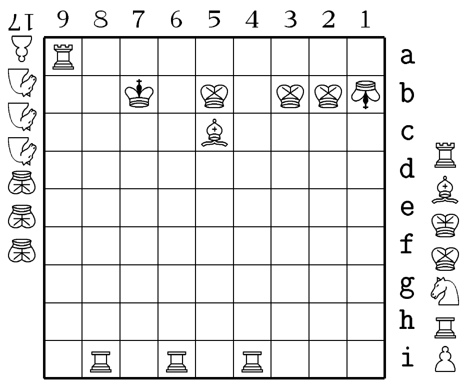

Diagram 1: An example of a maximum branching factor of 593

We do not know if such an upperbound is known for chess, but we believe that it is considerably smaller than 248, which is the maximum branching factor if all pieces are on the board and have their maximum moving ability[4]. We expect that the maximum branching factor of chess will be about 150.

It is also interesting to look at normal branching factors in the endgame (in shogi usually the stage of the game where the result is decided). In diagram 2, an example of a position that occured in an actual game between top players M. Nakahara and K. Yonenaga.

This position occured in the first game of the match for the most prestigious professional title, called *Meijin title*. Here, black (playing up the board) resigned. In this position,

[2]Tsume shogi is a shogi problem position where the king has to be mated by giving check with each move. The idea is to mate before the opponent has a chance to counterattack, since check is a forcing move. In Japan, composing and solving Tsume shogi is very popular. There are more than 100.000 different problems

[3]Diagrams, as well as the game score in appendix B were produced by a special tool called OhTeXfor LaTeX.

[4]It is possible to create a position with multiple queens, but as the 8 queen problem shows, it is not easy to align multiple queens in such a way that their interference is minimized.

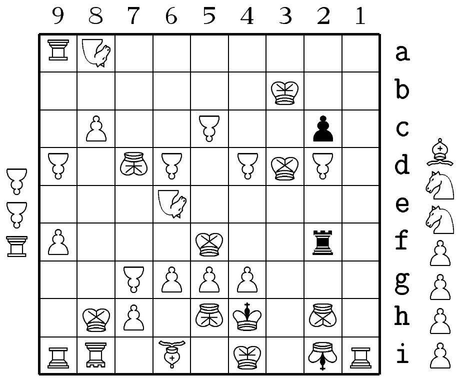

Diagram 2: An example of a position in an actual game played by two top players.

black has 159 possible moves, while white (in the previous position) had 158. These are common values in the endgame of shogi.

3. On average, a game of shogi takes about 115 ply. The maximum game length (in actual games) is more than 500 ply. In chess, the average is about 80 ply, while the record game length is currently 382 ply.

4. As said, many pieces in shogi have limited movement. This leads to a slow build-up and influences the average game length. It also influences the opening database that is so important in chess. There is a large number of books written on opening theory in shogi, but in general only patterns instead of strict move orders are being discussed. Also, new and interesting opening patterns are being developed until this day. Therefore, building a good opening database is more difficult in shogi.

We can see that shogi and chess are very similar. However, from a programming point of view there are some important differences. A slow build-up and the diverging nature of shogi makes it more difficult to aid the program in the opening and in the endgame. The most important difference, however, is the large game tree complexity of shogi compared to chess.

3 Why shogi instead of chess, xiang qi or go?

Chess, shogi, xiang qi and go are all complex games, both in game tree complexity and in decision complexity. Why is shogi better suited as a new target for game programming research than continue to research chess or put more effort in the research of xiang qi or go? First, let us look at chess. We belief that soon chess will no longer be of interest to AI research for the following reasons:

- Most programs use the same AI techniques: α–β search, a fine-tuned evaluation function, move-generator that is embedded in hardware and an opening and endgame database. The difference seems to be only in the speed of the hardware and the fine-tuning of the evaluation function. Therefore, chess is only of interest to those researchers developing new hardware and chess players interested in the evaluation function.

- The competitive element, which in our view has been an important motivation for improving chess programs, will soon no longer be there. The developers of Deep Blue (formerly Deep Thought, Hsu et al., 1990), which is considered the strongest chess-machine at present, already claim their new version will defeat the human world champion. If that happens the strongest chess programs will be stronger than the best human player.

We think that it is time to choose a new game as the next target domain. Such a domain should be competitively interesting and current AI techniques should be expected to fail, thus creating the need for new research efforts. Xiang qi, go and shogi are all competitively interesting. In all three domains the level of the best computer program is still far away from the level of the top players. What about the applicability of old and new AI techniques?

Xiang qi: The game tree complexity of xiang qi is similar to that of chess. We feel that in the near future current AI techniques can also be successful for xiang qi, i.e. play at expert level. This would render xiang qi no longer competitively interesting. It should be noted that fine-tuning the evaluation function for xiang qi is still difficult and interesting. Our interests are the development of new AI techniques, though.

Go: Go is even more complex than shogi and it is almost certain that current AI techniques will not be successful in the near future, if ever. It is our belief that new AI techniques should be more cognitively based, leading to special techniques for forward pruning. We are aware of the fact that these techniques have not lead to promising results in chess. We think that the main reason for this was that this type of research was overshadowed by the competitive success of less cognitively based techniques in chess research. It is our beleif that AI techniques based on cognition are still the key to many interesting problems in AI in general and game programming research in particular. If this is true, there are two problems in go:

1. There is very little cognitive research done in go. Furthermore, there is no game similar to go from where cognitive results can be expected to expand to this domain.
2. The cognitive research that has been done in go is sometimes inconclusive. For example: Reitman (1976) was not able to reproduce the study by Chase and Simon (1973) where it was shown that in chess positions are viewed in chunks (familiar subpatterns of information).

We think that it is risky to start a major research effort in go without knowing more about the game from a cognitive point of view.

Shogi: The game tree complexity of shogi is high enough to expect that current AI techniques will not be successful in the near future. We have also explained in this paper that shogi is very similar to chess and therefore we believe that most of the results in chess research will expand to shogi.

4 History of computer shogi

In the early 70s the first working computer shogi programs were written. These program could not cope with the game tree complexity very well, so they could only play at the level of a beginner. However, important break-throughs in hardware development, that have increased the strength of chess programs enormously, have also influenced computer shogi. Currently, the ability of computer shogi programs roughly correspond to that of Machack in computer chess. At the moment there are many commercial shogi programs on the (Japanese) market, the strongest of which act at the level of an average amateur. In the Japanese grading system this roughly corresponds to a level of 2 or 3 kyu, being the second and third grade of the weak amateur class. A complicating factor is that in shogi (as in other Japanese sports like judo and karate), there is no ELO like system to establish current playing strength. Grades are based on optimal performances and a grade once gained can not be lost. We estimate that an active 2 or 3 kyu player roughly corresponds to a player with an ELO of 1700 in chess.

A society for the study of computer shogi called the Computer Shogi Association (CSA for short), was established in 1988 in Japan[5]. The CSA has motivated the leading researchers in computer shogi to describe their programming techniques in a book (Kotani et al., 1990). After that, many shogi programs have been written. A annual shogi tournament for computer programs has been organised by CSA since 1990. At the moment, Kiwame and Morita-shogi are the names of the strongest programs. These programs run on NEC personal computers, and are commercially available on the Japanese market. The results of the 1994 tournament are shown in Tabel 1. A game score of the match between Kiwame and Morita-shogi in this tournament is given in Appendix B.

Table 1: The result of the 5th CSA tournament in 1994.

#	Name	1st	2nd	3rd	4th	5th	6th	7th	total	SP	rank
1	Kiwame 2.1	12+	15+	2+	8+	5+	3-	+17	6.0	28.0	1
2	Morita-shogi 5	13+	17+	1-	15+	19+	8+	3+	6.0	27.0	2
3	Kakinoki-shogi	14+	18+	8-	20-	12+	1+	2-	4.0	32.0	6
4	AI-shogi	15-	10+	20+	18+	1-	12+	8+	5.0	26.0	3
5	Super Hashimoto-shogi	16+	20-	10-	19-	17-	6+	12+	4.0	23.5	10
6	Denno-kaijin MK2	17-	13-	9+	14-	10+	5-	22+	3.0	21.5	14
7	Oki	18-	14-	16-	21+	11-	15+	10+	3.0	18.5	16
8	Yano-shogi II	19+	22+	3+	1-	20+	2-	4-	4.0	33.0	5
9	Tsubakihara-shogi	20-	16=	6-	13-	21-	10-	11+	1.5	19.5	22
10	SHOUCHAN	21+	4-	5-	22-	6-	9+	7-	2.0	21.5	19
11	Kikuchi 1.02	22-	19-	21+	17-	7+	13-	9-	2.0	20.5	20
12	Takada-shogi V2.1	1-	21+	13+	16+	3-	4-	5-	3.0	26.5	12
13	Ogawa-shogi	2-	6+	12-	9+	18-	11+	14-	3.0	23.5	13
14	Sakashita-shogi V0.5	3-	7+	15-	6+	22+	17-	13+	4.0	22.0	11
15	Kyoto 1200	4+	1-	14+	2-	16-	7-	21-	2.0	28.5	18
16	Hyper Shogi 1	5-	9=	7+	12-	15+	20-	19-	2.5	22.5	17
17	GNU shogi 1.2	6+	2-	18-	11+	5+	14+	1-	4.0	29.0	7
18	Sogin	7+	3-	17+	4-	13+	19+	20-	4.0	28.0	8
19	Amano-shogi 0.6	8-	11+	22+	5+	2-	18-	16+	4.0	25.5	9
20	Tancho under Reiki	9+	5+	4-	3+	8-	16+	18+	5.0	25.0	4
21	OM-1	10-	12-	11-	7-	9+	22-	15+	2.0	16.5	21
22	Sekita-shogi Win.	11+	8-	19-	10+	14-	21+	6-	3.0	21.0	15

+: win, -: lose, =: draw

A typical shogi program consists of an α–β searcher with a static evaluation function, some forward pruning method, iterative deepening and a tsume shogi solver to look ahead for mating.

In Japan, for a long time research on games has been considered unscientific. That is why the tournament above only has commercial programs as participants. Special hardware and super-computers have not yet been used in shogi. Lately, the characteristics of shogi have

[5] The CSA can be contacted at **csa@etl.go.jp**.

attracted the attention of more AI researchers and efforts in computer shogi are gradually increasing. The first workshop on computer shogi was organised by the CSA in 1994. Leading topics were techniques for making a shogi program and a tsume shogi solver (e.g. Yamashita, 1994). Shogi has now been established as an important research topic in AI (Iida & Kotani, 1991). This promises some improvement in playing level, but progress is expected to come at a standstill around the 3-dan grade (ELO estimate: 2100), still far from the level of expert players.

5 Conclusions and future research

In this paper we have explained why we believe that chess→shogi→go is a natural development in game research. Shogi is a chess-like game with a game tree complexity far larger than chess, albeit less than go. This leads us to believe that current AI techniques will not be successful in shogi in the near future, if ever. Shogi is very similar to chess, so it is expected that many research results in chess, both from cognitive science and computer science, will expand to shogi. Therefore, in developing new AI techniques, we can make use of most of the results found in chess. Go, on the other hand, is a entirely different type of game, making it risky to extend claims from chess to go.

In order to research Shogi more effectively, a special environment for Shogi programming has been designed and implemented at our institute (Handa et al., 1991). It is called *OhShow* (PDS) and runs under Unix and X-Windows. In future, the authors will further develop the ideas presented in this paper. A new test method will be developed to measure the playing strength of both human players and computer programs. Also, new AI techniques will be developed, some based on new forward pruning techniques and some based on recent developments in pattern matching theory and machine learning.

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Appendix A A short introduction to Shogi

Shogi, Japanese chess, is played by two players on a board of 9×9 squares. The players make moves alternatively, attempting ultimately to capture the opponent's king. The initial set-up of the game is shown in Diagram 3[6]. Each player has 20 pieces. The first player to move is called **Black** or *Sente* (in Japanese) and plays with the pieces on the bottom three ranks of

[6]Diagrams in Japanese shogi magazines and books are exclusively written in kanji. Diagrams used in this article are for the international community only.

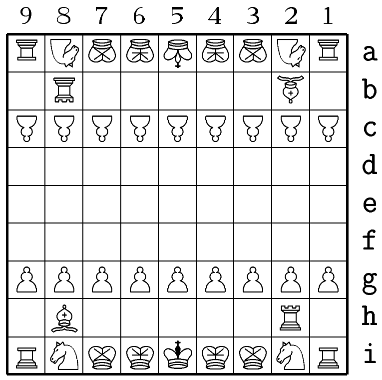

Diagram 3: Initial set-up of *Shogi*

the diagram. The other player is **White** or *Gote* and his pieces are on the top three ranks of the diagram. In the diagram you can see that black's pieces are being displayed normally, while white's pieces are displayed upside down.

The important difference between shogi and chess is the possibility of reusing pieces previously captured. Pieces previously captured can be put back on the board on almost any vacant square (this is called "dropping a piece"). In diagram 2 these captured pieces are shown beside the board, black's pieces on the right and white's pieces on the left.

Each square on the board is represented in algebraic notation like in chess, and so are the moves. For example, the white king in Diagram 3 is on square 5a. If it were to move to 4b, this move would be represented by K5a-4b or K4b in short.

As can be seen in Diagram 3 black's camp is on the bottom three ranks (**i** to **g**), which is also white's promotion zone. Correspondingly, white's camp is on the top three ranks (**a** to **c**), which is black's promotion zone. Most pieces in shogi can promote, but promotion is not obligatory like it is in chess. In the diagrams we use in this article the color of a promoted piece is black (see Diagram 2).

In shogi there are eight kinds of pieces. At the initial position of a normal game, each player has a king ♔, a rook ♖, a bishop ♗, two golds ♕, two silvers ♕, two knights ♘, two lances ♖, and nine pawns ♙. For each of the pieces we will now describe how it can move and what happens to the piece if it promotes.

King or Gyoku A king moves like a king in chess, so it can move one square in every direction (horizontally, vertically and diagonally). A king can not promote.

Rook or Hisha A rook moves like a rook in chess, i.e. any number of squares horizontally or vertically, but without the ability to jump over other pieces. The promoted rook keeps its original movement, but the ability to move one square diagonally in every direction is added.

Bishop or Kaku A bishop also moves like a bishop in chess, i.e. any number of squares diagonally (also without jumping over other pieces). A promoted bishop keeps its original movement, but the ability to move one square horizontally or vertically in every direction is added.

Gold or Kin A gold moves like a king, except for the two squares diagonally backwards to which it can not move. A gold can thus move to six squares. A gold does not promote.

Silver or Gin A silver moves like a king, except for the two horizontal squares and the square backwards. A silver can thus move to five squares. A promoted silver moves like a gold.

Knight or Keima A knight moves like a knight in chess, that is one square straight followed by one square diagonally. As in chess, it can jump over other pieces. However, a knight in shogi can only jump to the two squares that are furthest up the board. For example, a black knight on 5f can only jump to 6d or 4d. A promoted knight moves like a gold.

Lance or Kyosha A lance can vertically move any number of squares, but only forward. It can not move backwards and it can not jump over other pieces. A promoted lance moves like a gold.

Pawn or Fu A pawn can only move forward. There is no difference in the first move and capturing pieces is not done diagonally like in chess. A promoted pawn moves like a gold.

Shogi has a history of over 500 years and currently about 10,000,000 people in Japan play the game. There is also a professional competition, which is completely seperated from amateur play. The present top player, Y. Habu, earned over $ 1,000,000 on game fees alone in 1994.

Appendix B A game score played by the top programs

The following game was played at the latest computer shogi tournament (1994) by the two strongest programs Kiwame 2.1 (winner) vs. Morita-Shogi 5 (runner-up).

Black: Kiwame 2.1 (by S. Kanazawa)
White: Morita-Shogi 5 (by K. Morita)
The 5th CSA Computer Shogi Championship
December 4th 1994, Tokyo

1. ♙7f ♙3d	**2.** ♗x2b+ Sx2b	**3.** S8h S3c	**4.** S7g ♙4d	**5.** G7h S6b
6. S4h G3b	**7.** K6i K4a	**8.** G5h G5b	**9.** K7i K3a	**10.** ♙5f G5b4c
11. S5g ♙8d	**12.** ♙2f ♙5d	**13.** ♙2e ♙7d	**14.** ♙1f ♙8e	**15.** ♙1e S5c
16. ♙3f K2b	**17.** ♙4f S6d	**18.** ♙6f ♙7e	**19.** ♙x7e Sx7e	**20.** ♙'7f ♙8f
21. ♙x8f Sx8f	**22.** ♙'8c ♖x8c	**23.** L'7b ♖8b	**24.** ♗x6c+ Sx7g+	**25.** ♘x7g S'8g
26. ♙'8h Sx7h+	**27.** Kx7h ♗'3i	**28.** ♖3h G'2h	**29.** ♖x3i Gx3i	**30.** ♝6d ♙'7c
31. S'7a ♖7b	**32.** ♗'6c ♖x7a	**33.** S'6b ♖'2h	**34.** S4h ♖3a	**35.** ♝x3a Gx3a
36. ♘1g ♗'9b	**37.** ♘6e G3h	**38.** S5i ♖2g+	**39.** ♖'8g ♜x8g	**40.** ♙x8g ♖'2g
41. ♖'5b S4b	**42.** ♘5c+ ♗x5f	**43.** K8h Gx5c	**44.** ♗7d+ S'7g	**45.** K9h ♙x7d
46. ♜x4b Gx4b	**47.** S'3c Kx3c	**48.** S5c ♖'8h		

White resigned.

The symbol ' denotes dropping and + denotes promotion.