Board Maps and Hill-climbing for Opening and Middle Game Play in Shogi

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Abstract. Most strong game playing programs use large, well tuned opening books to guide the program through the early stages of the game. However, in *shogi* (Japanese chess) the classic approach of building a large opening book of known positions is infeasible. In this paper, we present a different approach for opening and middle game play in shogi. This method uses board maps that assign values to each square for each piece in a number of different formations. Hill-climbing is then used to guide pieces to optimal squares. We define board maps for defensive piece formations (castles), attacking formations (assaults) and for recognizing the type of opening position. Results show that using board maps in combination with hill-climbing significantly improves the playing strength of a shogi program. Furthermore, using maps for both castles and assaults is better than using only maps for castles.

Keywords: Hill-climbing, board maps, opening book, shogi.

1 Introduction

In general, two-player perfect information games have different stages. Depending on positional features and the number of moves from the starting position, these stages are usually called opening, middle game and endgame. For game programs, the challenge in the endgame is to find the game theoretical value of a position as early as possible (preferably this should be a win in all variations).

In the middle game searching as deep as possible has been the most successful method to find the best possible next move from a certain position. In this stage a game program is basically on its own and has to rely on the evaluation function for its actions.

Finally, in the opening the aim is to develop one's pieces in such a way that the chances of winning are at least equal to those of the opponent. Although search plays an important role here as well, a game program can make use of the fact that for most games the initial position is known. Furthermore, there is usually a fair amount of information about how to play the opening in the

form of expert games and analysis. This information can be stored in a database called *opening book*. When the board position no longer matches any position in the database, the program is *out of book*.

1.1 Opening Books in Games

For most strong game programs, the opening book has been an important contribution to the playing strength. For the chess program BELLE, Ken Thompson spent one hour a day for three years typing in the opening lines of the *Encyclopaedia of Chess Openings*. This importantly improved the performance of the program [1]. The checkers program CHINOOK needed a book to avoid known book losses which might require a search of more than 40 ply. Initially the opening book had only 2600 entries, but especially for the famous 1994 match against World Champion Marion Tinsley, the large opening book of the program COLOSSUS was added to CHINOOK and COLOSSUS' programmer Martin Bryant to the CHINOOK team [11].

Both CHINOOK and the Othello program LOGISTELLO used opening book learning to find improvements of the opening theory. CHINOOK's opening "cooks" were moves not given in the literature, but with deep search had been shown to improve the winning chances [11]. The opening book learning in LOGISTELLO was important for the 6-0 victory over World Champion Takeshi Murakami in 1997 [4].

Perhaps the most heavily tuned opening book was the one used by the chess program DEEP BLUE. The opening book of DEEP BLUE was built from 700,000 games. For the famous 1997 match against Kasparov the opening book was tuned by no less than four grandmasters (Benjamin, De Firmian, Fedorowicz and Illescas) [5]. As a result, Kasparov didn't dare to play the opening in this match in his usual, aggressive style and this might have been one of the reasons for his historic defeat [12].

1.2 Shogi Compared to Chess

Shogi (Japanese chess) is a two-player perfect information game that is similar to chess. The goal of the game is the same as in chess, namely to capture the king of the opponent. However, there are some important differences between shogi and chess:

Different board size A shogi board has 81 (9×9) squares instead of 64 (8×8) squares like in chess.

Different pieces In shogi each player has one king, one rook, one bishop, two golden generals, two silver generals, two knights, two lances and nine pawns. There is no queen like in chess, but instead there are the shogi-specific pieces golden general, silver general and lance. Also, shogi has more pieces than chess: 40 instead of 32.

Re-use of captured pieces In shogi, captured pieces can be re-used. When it is a player's turn to move, a choice can be made between moving one of the pieces on the board or putting one of the pieces previously captured back on an empty square. This second type of move, where a captured piece is returned on the board, is called a *drop*.

Less mobility for each individual piece In chess, the majority of pieces can move to distant squares. In shogi, each side has only one bishop and one rook with the same move capabilities as in chess. The other pieces can only move to the adjacent squares. Exceptions are the knight and lance. The knight can jump like in chess, but is limited in its movement compared to chess. A shogi knight can only make the two knight jumps to the front. The lance can move multiple squares vertically, but is not allowed to move backwards. Because of these limitations, neither the knight nor the lance can be considered mobile pieces in shogi.

Different castling rules In shogi there are no standard castle moves. In chess there are only two different castle formations: castling on the king side or castling on the queen side of the board. Furthermore, castling in chess only takes a single move. To put the king in a safe position in shogi, a castle has to be built and the king has to be moved into this castle. There are a number of standard castle formations and there is opening theory about the move order in which this formation should be built based on the moves of the opponent. Although there are more than 50 standard castle formations, new ones are still being invented regularly. Castles can take a long time to complete. For example, building the *anaguma* castle, which is the strongest castle formation is shogi, takes more than 10 moves. Also, castle formations in shogi can have multiple stages. For example, the *mino* castle can be turned into the stronger *high mino*, which can be rebuilt into a *silver crown*.

Different promotion rules In chess only pawns can promote and the pawn can promote to any piece (usually a queen). In shogi most pieces can promote, but the only choice is between promotion and non-promotion. Most pieces in shogi promote to gold (pawn, lance, knight and silver all promote to gold). However, the rook and bishop promote to pieces that add the ability to move one square vertically and horizontally (promoted bishop) or one square diagonally in each direction (promoted rook). Gold and king do not promote in shogi. Another difference between chess and shogi is that in shogi promotion is possible on the top three ranks instead of only on the top rank like in chess.

Recently, the strength of shogi programs has been steadily increasing and the top programs are considered to be about 3-dan, which is strong amateur level [15]. However, only in the mating stage of the game do shogi programs outperform human experts [6]. In all other stages of the game, there is still much room for

improvement and one important research area is the opening, which according to top programmers is still one of the weakest points. Yamashita, author of former world champion program YSS, judges the opening play of his program about 1-kyu [16]. This means that the opening play of the program is between 300 and 400 ELO points weaker than its average level. We will now explain why the opening play is a problem in shogi.

1.3 Using a Standard Opening Book in Shogi

The drop rule (i.e. the re-use of pieces) is generally considered to be the distinguishing feature of shogi. Most research efforts have been spent on dealing with the search explosion that is caused by this rule. Because of this rule, the average branching factor of the search tree in shogi is 80, while in chess the average branching factor is 35 [8]. However, in this paper we will focus on how some of the other differences between chess and shogi affect the opening play.

In the opening, the combination of a bigger board and pieces with less mobility make it less likely that the pieces come into contact early. Therefore, early tactical complications in shogi are quite rare. Furthermore, because multiple moves are needed to build a castle, in most games the priority in the opening is given to building a good defensive castle formation. Of course, these types of quiet, strategic openings also occur in chess, but in shogi they are the rule rather than the exception.

As an initial effort to improve the opening play of the shogi program SPEAR by the first author, a standard opening book was built containing more than a 1000 professional games and the opening variations of more than 20 books on opening theory. The complete opening book built in this way has more than 110,000 positions. This is much smaller than for example the opening book of Deep Blue, but much larger than the ones used in most shogi programs. It is hard to build an opening book that is similar in size to the ones used in chess programs, as worldwide the number of expert shogi players is much smaller than the number of expert chess players. Therefore, in shogi the number of publicly available expert games and the number of books on opening play is much smaller than in chess.

The problem of using an opening book in shogi is illustrated with a test of the use of the opening book in games against strong shogi programs. 25 games each were played against the four strongest shogi programs on the market: AI Shogi (winner of the Computer Shogi World Championship in 1997), Kakinoki Shogi (winner of the Computer Shogi Grand Prix in 1999), Todai Shogi (winner of the Computer Shogi World Championship in 1998, 2000 and 2001) and Kanazawa Shogi (winner of the Computer Shogi World Championship in 1995, 1996 and 1999). In these games, we recorded where SPEAR got out of book. The results of this test are given in Figure 1.

Figure 1 shows that despite the large number of positions in the opening book, the program gets out of book rather quickly. In 32 games the program is out of book within five moves and in 71 games the program is out of book in ten moves or less. On average, the program is out of book after 8.5 moves (note

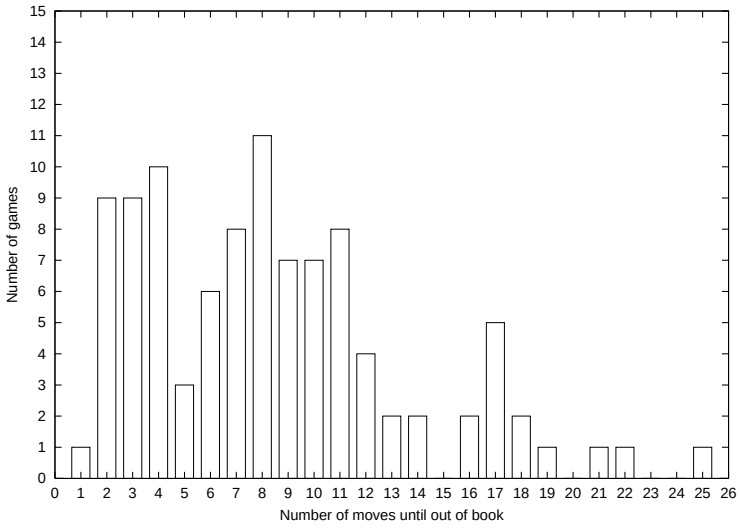

Fig. 1. Full board database matches in 100 games against AI SHOGI, KAKINOKI SHOGI, KANAZAWA SHOGI and TODAI SHOGI.

that this is the number of ply or half-moves, because in shogi a move by each side is counted separately).

To move into the simplest of castle formations called the *boat castle*, at least four moves are required. As said, it takes more than ten moves to move into the *anaguma*, the strongest castle in shogi. Therefore, it is unlikely that a shogi program can use an opening book to complete its opening formation [3]. A different approach is needed for strong opening play.

2 Board Maps for Opening and Middle Game Play in Shogi

In shogi, the rule of thumb for opening play is to build a castle with three generals. The fourth general, the bishop, rook and one knight are used to assault the castle of the opponent. The castle formation and assault formation depend on the position of the opponent's rook. There are basically two types of opening in shogi. One is the type where the rook stays on its original square. This type is called *Ibisha* or *Static rook*. The second type is the type where the rook moves sideways to a different file. This type is called *Furibisha* or *Ranging rook*. Therefore, we need a method where a shogi program can build formations for castles

[3] A simpler test would have been to play SPEAR with and without the book against the other programs and compare the results. Unfortunately, SPEAR is not strong enough to win enough games (independent of opening book use) to draw any conclusions after such a test.

Table 1. Piece formations in shogi.

Ranging rook vs. Static Rook			
Castle	*Assault*	*Own formation*	*Opponent formation*
Mino	Mino assault	Ranging rook	Static rook
High mino	Mino assault	Ranging rook	Static rook
Silver crown	Mino assault	Ranging rook	Static rook
Right anaguma	Right anaguma assault	Ranging rook	Static rook
Static rook vs. Ranging Rook			
Castle	*Assault*	*Own formation*	*Opponent formation*
Boat	Boat assault	Static rook	Ranging rook
Lozenge	Boat assault	Static rook	Ranging rook
Anaguma	Anaguma assault	Static rook	Ranging rook
Left mino	Left mino assault	Static rook	Ranging rook
Left high mino	Left mino assault	Static rook	Ranging rook
Left silver crown	Left mino assault	Static rook	Ranging rook
Static rook vs. Static Rook			
Castle	*Assault*	*Own formation*	*Opponent formation*
Yagura	Yagura assault	Static rook	Static rook
Yagura nakabisha	Yagura nakabisha assault	Static rook	Static rook
Snow roof	Climbing silver assault	Static rook	Static rook
Aigakari	Aigakari assault	Static rook	Static rook
Nakahara formation	Aigakari assault	Static rook	Static rook
Right side king	Mino assault	Static rook	Static rook
Ranging rook vs. Ranging Rook			
Castle	*Assault*	*Own formation*	*Opponent formation*
Minogakoi	Aifuribisha assault	Ranging rook	Ranging rook
Takamino	Aifuribisha assault	Ranging rook	Ranging rook
Ginkanmuri	Aifuribisha assault	Ranging rook	Ranging rook
Maikin	Aifuribisha assault	Ranging rook	Ranging rook

and assaults based on the opponent's strategy, without the help of a standard opening book. In this section we will show how board maps for pieces in combination with hill-climbing can be used to build piece formations in shogi. The definitions have three different levels of abstraction: piece formations, individual pieces and square values.

2.1 Piece Formations in Shogi

To guide the building of castle formations and assault formations, we have defined *castle maps* for a number of common castle formations in shogi and the *assault maps* for each castle. The list of castle maps and assault maps currently implemented is given in Table 1. The list includes the different castle formations (*Castle*), the best way to assault these castles (*Assault*) and for which type of position this castle is best suited (split into *Own formation* and *Opponent formation*). For example, the *mino castle* is best build when one's own rook has

Table 2. Individual board maps for a mino castle.

Piece	*Board maps*	
	Unpromoted piece map	*Promoted piece map*
Pawn	Mino pawn	Mino gold
Lance	Mino lance	Mino gold
Knight	Mino knight	Mino gold
Silver	Mino silver	Mino gold
Gold	Mino gold	–
Bishop	Mino bishop	Mino bishop
Rook	Mino rook	Mino rook
King	Mino king	–

moved sideways, while the opponent has adopted a static rook strategy. On the other hand, the *boat castle* is best played when one's own rook is still in the original position, while the opponent has a ranging rook formation. The best assault against the mino castle is defined by the maps in *mino assault*, while the best assault against the boat castle is defined by the maps in *boat assault*.

2.2 From Piece Formations to Individual Pieces

For each of the formations in Table 1 we need to define for each individual piece where it is best positioned. For the mino castle formation the board maps for each individual piece are given in Table 2. As mentioned before, gold and king do not promote, so there is no board map for these promoted pieces. Pieces that promote to gold (i.e. pawn, lance, knight and silver) have the same maps as a gold. Promoted rook and promoted bishop have the same board maps as the rook and bishop respectively. Promotion in shogi is only possible in the enemy camp (top three ranks of the board) and castles are built in one's own camp (bottom three ranks). Therefore, board maps for promoted pieces do not play an important role in the opening and middle game as castles are never built that far up the board and most pieces in shogi have very limited backward movement, making it highly unusual that a promoted piece can move all the way back to one's own camp. Exceptions are the rook and bishop, for which it is not unusual to move back in defence. Especially a promoted bishop is considered a strong defensive piece and the board map for the promoted bishop can be important for the castle formation.

2.3 From Pieces to Square Values

Finally, for each individual piece we need to define where it is positioned best on the board. This is done by giving a value to each square on the 9×9 board for each individual piece. An example of the board map for the king in the mino castle formation (i.e. *Mino king* in Table 2) is given in Figure 2.

9	8	7	6	5	4	3	2	1	
−9	−9	−9	−9	−9	−9	−9	−9	−9	a
−9	−9	−9	−9	−9	−9	−9	−9	−9	b
−9	−9	−9	−9	−9	−9	−9	−9	−9	c
−9	−9	−9	−9	−9	−9	−9	−9	−9	d
−9	−9	−9	−9	−9	−9	−9	−9	−9	e
−9	−9	−9	−9	−8	−1	−1	−1	−1	f
−9	−9	−9	−9	−7	0	4	8	5	g
−9	−9	−9	−8	−6	2	8	14	6	h
−9	−9	−9	−7	−5	−1	8	8	6	i

Fig. 2. *Mino king*: The board map for the king in the mino castle.

From the values in this board map it can be inferred that the king in the mino castle is best positioned on square 2h which has the value 14. To move the king to this square, optimal paths can be constructed with a hill-climbing approach: move the piece to a neighbouring square with a higher value. If more than one neighbouring square has a higher value, choose the square with the highest value.

In the example of Figure 2, there are two natural paths to the optimal square from the starting position of the king on 5i (the square with value -5):

1. K5i $\Rightarrow$ K4h $\Rightarrow$ K3h $\Rightarrow$ K2h
2. K5i $\Rightarrow$ K4h $\Rightarrow$ K3i $\Rightarrow$ K2h

Both paths have square values $\{-5, 2, 8, 14\}$.

9	8	7	6	5	4	3	2	1	
−9	−9	−9	−9	−9	−9	−9	−9	−9	a
−9	−9	−9	−9	−9	−9	−9	−9	−9	b
−9	−9	−9	−9	−9	−9	−9	−9	−9	c
−9	−9	−9	−9	−9	−9	−9	−9	−9	d
−9	−9	−9	−9	−9	−9	−9	−9	−9	e
−9	−9	−9	−9	−8	−1	−1	−1	−1	f
−9	−9	−9	−9	−7	2	1	4	1	g
−9	−9	−9	−8	−6	1	7	−8	1	h
−9	−9	−9	−7	−1	1	2	−8	0	i

Fig. 3. *Mino silver*: The board map for the silver general in the mino castle.

To obtain a sequence of moves to built a formation, the maximum improvement over all board maps for the pieces is obtained. In Figure 3 and Figure 4 the board maps for the silver general and golden general in the mino castle are given. If the king is again supposed to be on square 5i, the golden generals on squares 4i and 6i and the silver general on square 3i, the optimal sequence is as

9	8	7	6	5	4	3	2	1	
−9	−9	−9	−9	−9	−9	−9	−9	−9	a
−9	−9	−9	−9	−9	−9	−9	−9	−9	b
−9	−9	−9	−9	−9	−9	−9	−9	−9	c
−9	−9	−9	−9	−9	−9	−9	−9	−9	d
−9	−9	−9	−9	−9	−9	−9	−9	−9	e
−9	−9	−9	0	1	2	2	0	0	f
−9	−9	−9	2	2	5	4	2	0	g
−9	−9	−9	2	4	3	−1	1	−1	h
−9	−9	−9	1	2	9	−4	0	−1	i

Fig. 4. *Mino gold*: The board map for the golden general in the mino castle.

follows:

$$\text{K5i} \overset{+7}{\Longrightarrow} \text{K4h}, \text{K4h} \overset{+6}{\Longrightarrow} \text{K3h}, \text{K3h} \overset{+6}{\Longrightarrow} \text{K2h}, \text{S3i} \overset{+5}{\Longrightarrow} \text{S3h}, \text{G6i} \overset{+3}{\Longrightarrow} \text{G5h}$$

Note that the second sequence for moving the king that was given earlier is not optimal here, as the silver has to move from square 3i first to allow the king to move to that square. The silver move from 3i to 3h only gives an improvement of +5, while the move K4h-3h gives an improvement of +6.

The assault maps are defined in exactly the same way. For each assault there is a table like Table 2 to define the maps of each piece. For each individual piece there is a map like Figure 2, where the square evaluation of each piece for this particular assault formation is given.

3 Using the Maps to Guide the Opening and Middle Game Play

In our implementation, the maps are used to select the castle formation that can best be built from the current position. This is the castle formation that resembles the current formation most, i.e. the castle formation for which the total of the square values of all pieces is the highest. When the castles for both sides have been identified, the assaults for both castles are defined by Table 1. After this selection, the hill-climbing defined by the map values guides the search towards moves that improve the chosen castle formation and assault formation. This is done by adding the castle and assault values to the positional evaluation of each individual piece in the evaluation function.

Note that one of the side effects of the method is that formations which for some reason have gone astray can be fixed. Even if the optimal move order is no longer possible, the hill-climbing approach might still generate non-optimal moves to get the pieces into the right formation. For example, if there is a piece on 4h in the mino castle but not on 4i, the map of Figure 2 can still generate a path for the king to move into the mino castle (K5i ⇒ K4i ⇒ K3h ⇒ K2h).

There are several other ways in which the maps can be useful in a shogi program. The maps establish the correct order in which a castle or assault formation should be built, guide the use of the opening book and help in establishing the difference between opening and middle game. We will now discuss each of these in detail.

3.1 Playing Moves in the Correct Order

For most castle and assault formations in shogi, there is a standard order in which the formation should be built. Building a formation in the wrong order can give the opponent the time to anticipate on the formation and take countermeasures that make it impossible to reach the intended formation, resulting in an unfavourable position.

If castle values and assault values are only added in the evaluation function, this might result in the program playing moves in the wrong order. From the point of view of the evaluation function, playing king move K, silver move S and gold move G in the order $K \Rightarrow S \Rightarrow G$ will have the same value as when the order would have been $G \Rightarrow S \Rightarrow K$. As shown in the example above, the maps define the optimal move order for building a formation. To enforce this move order, we add bonus values to moves. These values are relative to the improvement of the castle value and assault value and are also relative to the search depth. Playing the move with the best improvement first will therefore have a higher bonus than playing this move later in the search.

3.2 Opening Book Guidance

The maps can help with a problem that often occurs in game programs with a large opening book. This is the problem that the program blindly follows the opening book and ends up in a position that human experts judge as better but the program does not understand because of the limitations of the evaluation function. Rather than trying to reach a position that is objectively better, the program should aim for a position it can understand. The maps provide a way to do this. If the opening book move decreases the map value of the moving piece, it should not be trusted as it might put the pieces in a position the program does not like. Therefore, such a move should not be played without search. Of course, it should not be discarded either, as it might have been the only way to avoid losing the game.

3.3 Establishing the Difference Between Opening and Middle Game

Maps can help in establishing the game stage. In a shogi program, it is important to make a difference between the opening, middle game and endgame. The weights of the evaluation function features change dramatically based on the stage of the game. Especially the judgment of the transition from opening to middle game is a problem in shogi. The maps can provide extra information to

make the decision whether the current position is still an opening position or a middle game position. Our current implementation uses a threshold on the castle map value combined with information about the optimal position of the king. If the king is in an optimal position and the castle value exceeds a certain minimal value, the position is judged to be a middle game position.

4 Extensions of the Basic Method

The method described so far is static. Once a castle formation has been selected at the start of the search, the program sticks with it, even if during search it turns out that a better castle could have been built. Also, the judgment of the initial castle can have errors, especially in the early stages of the game where several castles can be almost equally likely candidates.

Therefore, in addition to the basic method, some extensions are needed to make the method more dynamic and handle exceptions properly. We have implemented *swapping rules*, *scaling of formation values* and *multiple castles*.

4.1 Swapping rules

There are situations in which the selection of the correct castles can not be made based on the maps alone. For example, in the very early stages of the opening, when it is still possible to build many different castle formations, the selection process needs extra support in the form of common shogi opening knowledge. This has been implemented with a number of swapping rules for castle formations and assault formations. An example of such a swapping rule is:

```
IF Castle = Yagura AND Bishop exchanged
THEN Castle = Kakugawari
```

The difference between a *yagura castle* and a *kakugawari castle* only depends on whether the bishops are exchanged (kakugawari) or not (yagura). Yagura and kakugawari are similar opening strategies, but the option of dropping the bishop has important consequences for the castle and assault maps. This rule makes sure that this is handled correctly.

The swapping rules for assaults are especially important, since there can be more than one assault on a castle. However, from the data structure of Figure 1 only a single assault can be derived for each castle formation. The option of changing this assault based on positional features is therefore vital.

4.2 Scaling of Formation Values

Related to the idea of swapping is the idea of scaling the total values for each formation. The importance of a castle formation and assault formation changes during the game. In the opening it is very important to quickly build the right castle formation, but in the endgame it is more important to mate the opponent

king. Therefore, in the endgame keeping a castle formation intact does not have the highest priority anymore. A global scaling factor based on the stage of the game is attached to each map to account for this.

Scaling factors can also be used to force the program to make the right choice when there is only a subtle difference between two formations. An example of a scaling rule is:

```
IF Castle = Anaguma AND Corner lance on initial square
THEN Decrease castle value by 30%
```

This rule states that even though in general it is a good thing to aim for the strong anaguma castle, this is not necessarily the right castle if the lance in the corner is still on its initial square. In this case the castle value is decreased by 30%, making the selection of a different castle formation as the prime target more likely.

In the current implementation, swapping rules and scaling are hardcoded in the program. At some point it might be necessary to compile the rules into an external knowledge-base which can be loaded at run time.

Swapping rules and scaling are only used when the game is in the opening stage. As soon as a player has committed himself fully to a certain castle or assault formation, scaling and swapping do not play an important role as it is unlikely that there will be time to switch a completely different castle as soon as the game opens up and the fighting starts.

In the opening, swapping and scaling is performed at all nodes in the search tree. By doing this, it is possible to repair castle formations during the search. If the rules are used exclusively at the root node, only moves that improve the formations chosen at the root will get a positive score and opportunities to switch to a better castle might be missed.

4.3 Multiple Castles

A final extension of the method deals with the problem of only selecting a single castle formation and assault formation for each side. Especially in the early stages of the game, where neither player has committed to a certain formation, the values of different formations will be very similar and picking one based on a small difference in the total formation value is almost the same as picking one at random. However, a wrong choice can lead to a quick disaster. To avoid this problem, our implementation has the option of keeping a set of castle formations during the hill-climbing instead of a single formation. Only castle formations that are similar to the castle with the highest value should be kept, so there is a threshold on the value difference between the castle formations:

```
IF Castlevalue ≥ Threshold
THEN Add castle to list of alternatives
```

At each node of the search, only the formation value of the castles in the list of alternatives are calculated. This is usually a small set of only a few castles.

The castle with the highest total value is then chosen as the target formation from that particular node in the search tree.

5 Results

The castle maps and assault maps were first implemented in the shogi program SHOTEST by the second author in the version that participated in the Computer Shogi World Championship in 1999. For the tournament in 2001, the method was implemented in the program SPEAR. The number of maps was increased considerably and extensively hand-tuned by playing hundreds of games against other commercial programs. The latest version has maps for 35 different castle formations and 20 assault formations [4]. Also implemented are the extensions of the basic method given in Section 4. As these have thus far only been implemented in SPEAR, all the results given below are obtained from tests with this program.

To show the importance of using maps for playing strength we performed a number of self-play experiments. We played three versions of the shogi program SPEAR against each other. One version was using both castle maps and assault maps (*AllMaps*), one version was using only castle maps (*CasMaps*) and one version was not using any maps (*NoMaps*). The basic shogi program has the following features:

- Iterative alpha-beta search.
- Principal variation search [9].
- Quiescence search [3].
- History heuristic and killer moves [10].
- Null-move pruning [2].
- Hash tables for transposition and domination [14].
- Specialized mating search [13].

In this experiment, we specifically wanted to know how the interaction between the opening book and the maps influenced playing strength. Therefore, we had the programs follow the opening book for 5, 10, 20, 30 and 40 moves (a maximum of 20 moves by black and 20 moves by white).

When the opening book is only used for 5 moves (3 moves by black and 2 moves by white), it is impossible to use the opening book for building a castle and assault formation. In this case the program must build a proper formation by using only the board maps.

In Section 1.3 we showed that a standard opening book can be expected to be useful for 8.5 moves on average. The tests in which the opening book is used for 10, 20 and 30 moves are therefore performed to see how the playing strength is influenced after the program is out of book during different stages of the opening.

[4] Some of the swapping rules introduce castles not in the basic set of Table 1, for example the *kakugawari* castle mentioned earlier.

Table 3. Results of self play experiments between a version of SPEAR using both castle maps and assault maps (*AllMaps*), a version using only castle maps (*CasMaps*) and a version not using any maps (*NoMaps*). *Book* is the maximum number of moves the book was used in each game.

Match	*Book*					*Result*
	5	10	20	30	40	
AllMaps-NoMaps	31-19	38-12	30-20	27-23	25-25	151-99
	62%	76%	60%	54%	50%	60%
CasMaps-NoMaps	29-21	36-14	31-19	25-25	25-25	146-104
	58%	72%	62%	50%	50%	58%
AllMaps-CasMaps	28-22	27-23	29-21	29-21	29-21	142-108
	56%	54%	58%	58%	58%	57%
Total	88-62	101-49	90-60	81-69	79-71	439-311
	59%	67%	60%	54%	53%	58%

If the opening book is used longer than 30 moves, the standard opening book often can be used for building a full castle and assault formation, so it was expected that the maps will play a less important role. The test using an opening book for 40 moves was performed to confirm this hypothesis.

When the program gets out of book, the resulting position is played twice: once with each program version playing the black pieces. Each program version played the other versions fifty times, i.e. 25 times with black and 25 times with white. The time limit was 25 minutes per side per game on a 1GHz Pentium III. This is the same time limit that is used in the Computer Shogi World Championship. The results of this self-play experiment are given in Table 3.

From the results, the following conclusions can be drawn. First, when the program has almost no support from the opening book, it benefits significantly from having the castle maps and assault maps. If the database was used for 10 or 20 moves, the version with both castle maps and assault maps beat the version without maps with a score of 68-32. The version with only castle maps has almost the same result with a score of 67-33. The 68-32 result gives a 99.98% probability that the program with maps is stronger than the program without the maps. For the 68-32 result, this probability is 99.97%.

When the opening book is used for 30 or 40 moves, there is almost no difference in playing strength between the version without maps and the two other versions. This is consistent with our expectation that the opening book can be used long enough to build proper castle formations and assault formations.

If the opening book is used for only 5 moves, the results are worse for the two matches *AllMaps-NoMaps* and *CasMaps-NoMaps* compared to using the opening book for 10 moves. We explained in Section 2 that it is important for the choice of the castle formation to know whether the opponent has built a static rook formation or a ranging rook formation. However, when the opening book is used for only 5 moves, it frequently happens that there is not enough information about which formation the opponent will choose. Especially the *NoMaps*

program will not commit itself and not play a known formation, confusing the versions using maps into building the wrong castle formation. Although this is in part a tuning problem (building reasonable formations against uncommitting opponents), it also suggests that using only the board maps is not sufficient. The best performance is achieved by using a standard opening book to set up the formations and use the board maps to complete them.

A final observation is that the two versions with maps have almost the same result against the version without maps: the match *AllMaps-NoMaps* ended in 151-99 and the match *CasMaps-NoMaps* ended in 146-104. However, the version with both castle maps and assault maps beat the version with only castle maps consistently throughout the use of the opening book, the version with both castle maps and assault maps winning three matches 29-21, one match 28-22 and one match 27-23. It seems that if the program has no clue about the castle of the opponent or makes a mistake in assessing the castle, the assault maps have no significant impact. However, if the opponent plays a known castle, the use of assault maps will lead to a significant improvement in playing strength which lasts for a long period of the game.

6 Related Work

We believe that our work is very similar to the so-called *otoshiana* method, which was first used in the shogi program YSS [17] by Hiroshi Yamashita. The *otoshiana* method also uses a hill-climbing approach to build castle formations and it seems likely that the implementation is similar to ours. This is difficult to judge, as Yamashita's description of the *otoshiana* method is short and lacks implementation details. The original description mentions only 9 different castle formations and no assault formations. This could be an important difference, as our results indicate that the use of assault maps considerably improves the playing strength. Furthermore, it is unclear how the *otoshiana* method assesses the type of position that the opponent is building. Yamashita mentions that the position of the rook is taken into account, "among other things", but no details are given. Still, from private conversations with other programmers it can be concluded that most strong shogi programs use a method similar to the *otoshiana* method.

Another idea for shogi, proposed by Kotani, is to use a similarity measure of the current position with positions in the opening book. When the position is similar, the move that was played by an expert in an earlier (slightly different) position might also be a good candidate in the current position. A similarity measure could then be given as a bonus to the move during a normal search [7].

Kotani's idea has some similarities to Deep Blue's *extended opening book* [5], where information of a large database of games is used to guide the search in the direction of the expert consensus. Moves that were played more often are given a higher search bonus than moves that were played infrequently.

In an earlier version of the program SPEAR, a combination of the Kotani and Deep Blue ideas was tried. A similarity measure combined with move

frequency was added as a search bonus. However, we were not able to produce stable opening play with this method and the idea was abandoned in favour of the method presented in this paper.

7 Conclusions

In this paper we have described a new method for constructing piece formations in the opening and middle game in shogi. This method uses board maps to decide the best formation to aim for and uses hill-climbing to improve the selected formation.

In shogi, three different sets of formations are needed: castle formations, assault formations and two special formations that determine the type of position. We have shown that if the program gets out of book in the first 20 moves, the playing strength can be improved considerably by using castle maps and assault maps. Furthermore, using both castle maps and assault maps gives significantly better results than using only castle maps.

We feel that further testing of the method is necessary to establish how important this method is for objectively strong opening play. We have not had the opportunity to separately test the importance of the extensions to the basic method. One problem is that the set of swapping rules and castle scales is not stable yet. Also, the experimental set-up can be a problem, as swapping rules and castle scales do not always influence the opening play. However, as soon as the set of swapping rules and castle scales have stabilized, we need to establish how important these are for the overall performance.

Another problem of our tests is that self-play experiments have the important limitation that only relative improvement is measured. Therefore, it is necessary to have some external measure to evaluate the performance of our idea. One test would be to play our programs against the strong commercial programs mentioned in Section 1.3. Another idea is to have a strong player (preferably a top professional player) evaluate a set of positions that the program produces at different points in the opening and middle game.

We also want to investigate automatic learning of board maps. To apply our method successfully to shogi, a lot of hand tuning was needed. Currently, we are looking into ways to automatically construct the maps from games played by expert players.

As a final note, it is interesting that the *otoshiana* method also includes a number of positional elements unrelated to castle formations and assault formations. For example, having a lance on the back rank is better than having a lance higher up the board and there are penalties for having a knight high up the board or a rook on the third rank. Our current research has focused only on castle and assault formations, but the method might have a more general use for positional evaluation of other piece formations as well. We are planning to investigate such extensions of the method in the near future.

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