On the Relation Between Perception, Memory and Cognition in Games

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Abstract

To use Minsky's *Society of Mind* theory to model human cognitive behavior in games, we first need to understand more about the interaction between perception and knowledge in memory. As a first step, in this paper a reproduction experiment in shogi will be described that confirms or invalidates a number of hypotheses about perception in shogi without the use of game specific knowledge. These hypotheses are: 1) It is easier to perceive one's own pieces than the pieces of the opponent, 2) It is easier to perceive pieces in hand than pieces on the board, 3) It is easier to perceive promoted pieces than pieces that are not promoted, 4) Pieces closer to oneself are easier to perceive than pieces further away, and 5) Bigger pieces are easier to perceive than smaller pieces. The reproduction experiments were only able to confirm the hypothesis that it is easier to perceive pieces in hand than pieces on the board, but based on the strategies of the subjects, the use of nearness and the perception of promoted pieces was also observed.

Keywords: Perception, Memory, Cognition, Society of Mind theory, Game playing

1 Introduction

In game research, the emphasis has been on making strong programs with the ultimate goal of beating the strongest human players in these games. Because of this, strong game programs are sophisticated engineering projects and game programming has been called the Formula 1 of Artificial Intelligence.

The aim of our research is to take game programming back to the roots of Artificial Intelligence by using games to model cognitive behavior of human players. This might not necessarily lead to strong play, but should give us important insights into human problem solving behavior.

The use of cognitive models as the basis for game playing programs has been investigated in the 1960s, but programs like the Greenblatt chess program [2] always ended up with coding game specific knowledge instead of using a general framework for human problem solving.

It is our belief that the reason for the inability to build a general game playing program has been the lack of a general theory of human cognition. Marvin Minsky's *Society of Mind* theory [4] provides such a general theory and the aim of our research is to use this theory as the starting point for building a game playing system.

Minsky uses *agents* and *agencies* as the building blocks of human cognition. He defines an agent as: "Any part or process of the mind that by itself is simple enough to understand". It is important to realize that the cognitive processing units in the brain need to be simple, in the order of agents recognizing color and shapes. Complicated behavior is the result of the interaction between groups of simple agents. These groups of agents are called agencies [1].

To use Minsky's theory in games, the first step is to find out what the most primitive agents are. The most primitive agents are the agents that deal with input and output. For games this translates to agents dealing with the perception of board and pieces (input) and agents dealing with playing moves (output). In this paper, we will investigate the perception of board and pieces, which should give us insights into the nature of the primitive agents used in game playing.

The rest of this paper is built up as follows. In Section 2 we will give a number of hypotheses about perception in the game of shogi. In Section 3 a reproduction experiment will be described that aims at confirming these hypotheses. In Section 4, we will give the experimental results and discuss whether these results confirm or invalidate the hypotheses. Finally, in Section 5 we will end with

[1] In his new book *The Emotion Machine* [5], Minsky uses the term *resource* instead of agent.

conclusions and plans for future work.

2 Perception in Games

Perception in games is aimed at acquiring the necessary knowledge about a board position to make a decision about the next move. It was already pointed out by Chase and Simon [1] that perception in games is strongly related to the concept of *chunks*, which are defined as pieces of knowledge. Stronger players have bigger chunks of game knowledge and are therefore better at extracting vital information from game positions.

We believe that chunks and agencies are related concepts and that chunks of game knowledge will have to be modelled by agents and agencies. Chase and Simon then focused on modelling the behavior of strong chess players [6], but were unable to build a model that could play like human players. We think that the reason for this is that the link between complicated agencies (chunks) and fundamental agents is missing.

To better understand the fundamental agents dealing with perception, we have performed a reproduction experiment in shogi. To make sure that no chunking was used, the reproduction experiment was performed using randomly generated shogi positions. Also, we used beginners at shogi, minimizing the amount of shogi specific knowledge to guide perception using shogi chunks.

Our experiment was designed to test the following hypotheses:

Hypothesis 1: It is easier to perceive one's own pieces than the pieces of the opponent. This hypothesis was based on the fact that the kanji characters of the pieces of the opponent are reversed and therefore more difficult to perceive.

Hypothesis 2: It is easier to perceive pieces in hand than pieces on the board. This hypothesis is based on the fact that pieces in hand cannot be promoted and knowledge about the square on which the piece is placed is not necessary.

Hypothesis 3: It is easier to perceive promoted pieces than pieces that are not promoted. This hypothesis is based on the fact that the kanji for promoted pieces is more simple than the kanji for unpromoted pieces.

Hypothesis 4: Pieces closer to oneself are easier to perceive than pieces further away. This is the general perception principle of information about things near to oneself being more important than information about things that are further away.

Hypothesis 5: Bigger pieces are easier to perceive than smaller pieces. This is also a general perception principle of bigger things being more important than smaller things.

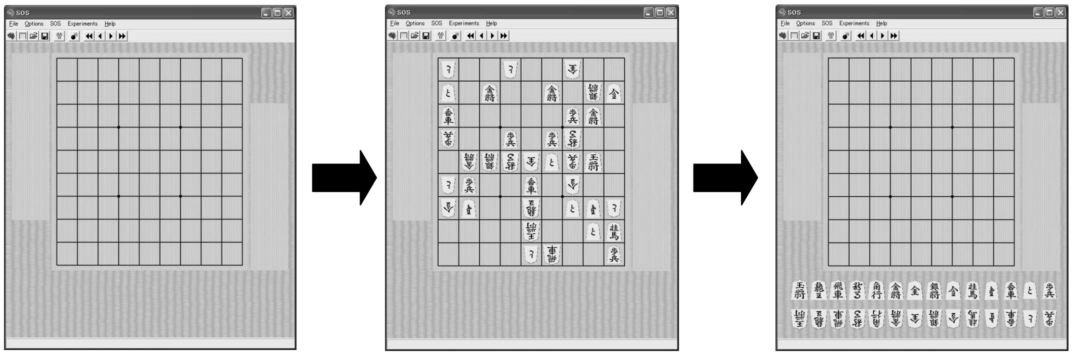
3 Reproduction Experiment

The reproduction experiment to test the hypotheses was performed as follows (see Figure 1). First, subjects were shown a shogi board without any pieces. When they felt ready to be shown the position, they pushed a button and a position would appear. This position would be shown for 5 seconds and then it would disappear, being replaced by an empty board with pieces lined up at the bottom of the screen. These pieces could then be moved to the board or to the piece stand. There was no time limit for the reproduction phase of the positions. When the subjects felt that they were finished, they could click on a button and be shown the next position.

There were two practice positions used to explain the experiment. No data for the practice positions was recorded. In the experiment 10 positions were used. The first five positions had only pieces on the board, while the latter five positions also had pieces in hand. The positions were generated randomly, with a small bias toward pieces on the board instead of pieces in hand. The positions we used in our experiments are given in the Appendix.

The experiment is similar to reproduction experiments we performed earlier [3], but with a few important differences. The most important difference is that the positions in our earlier experiments were generated by playing randomly from the starting position. Because of this, the generated position will have similarities with a well-known position, thus risking the use of chunks by the subjects. The other important difference is the generation of positions with pieces in hand to test the difference between the perception of board pieces and pieces in hand. In our earlier experiment, pieces in hand only occurred when the random move generation included a capture, and as a result the number of pieces in hand was very low.

We used 11 subjects in this experiments, all in their early twenties. Nine of the subjects had only a rudimentary knowledge of shogi, and two played a little more seriously in elementary school, but without ever gaining an official grade.



5 seconds

Figure 1: Example of a position from the reproduction experiment.

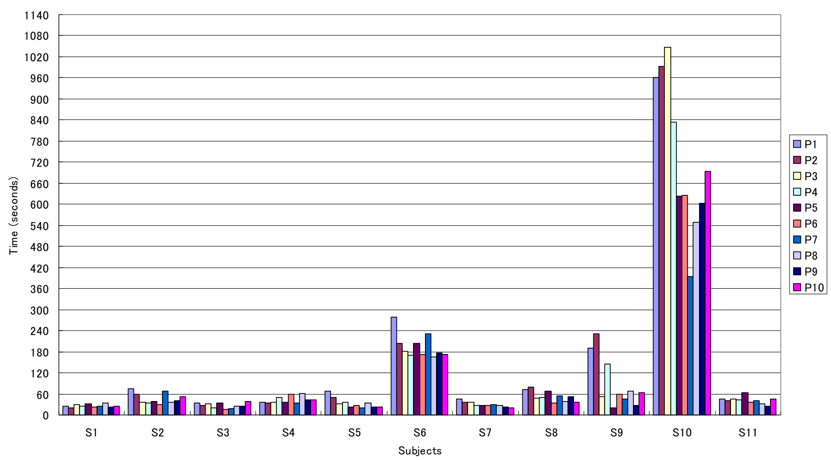


Figure 2: Reproduction time for each subject.

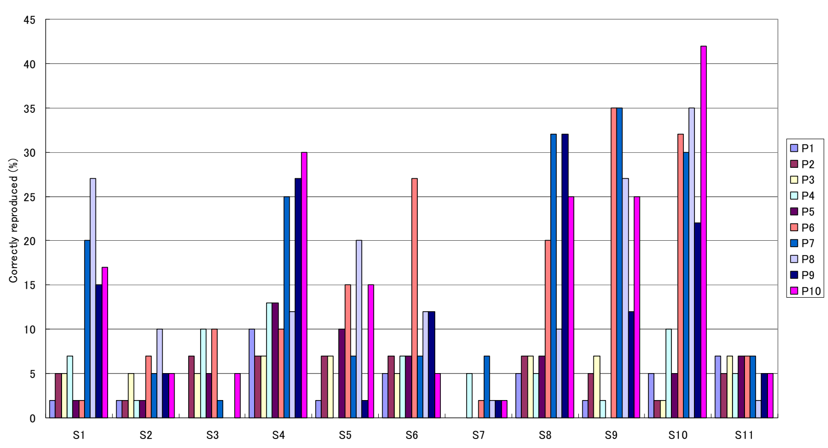


Figure 3: Percentage of correctly produced pieces per position for each subject.

Table 1: Reproduction differences between own pieces and opponent pieces.

Subject	*Own*	*Opp*
S1	11	8
S2	12	7
S3	7	16
S4	8	19
S5	10	12
S6	88	89
S7	10	7
S8	14	9
S9	51	52
S10	103	112
S11	7	11
Total	321	342
(%)	30.7	31.7

Table 2: Reproduction differences between board pieces and pieces in hand.

Subject	*Board*	*In hand*
S1	10	28
S2	24	0
S3	19	0
S4	3	24
S5	3	28
S6	174	24
S7	15	0
S8	11	44
S9	18	52
S10	141	61
S11	20	0
Total	438	280
(%)	30.2	37.4

4 Experimental Results

Although it is not directly related to the hypotheses, we first present the results for the reproduction times of the subjects (Figure 2) and the number of pieces that were reproduced correctly (Figure 3). In Figure 2, we see that reproduction times for most subjects were less than a minute per position, with notable exceptions for subjects S6 and S10, who took much longer to produce a position. That this longer reproduction time didn't translate to a higher percentage of correctly reproduced pieces can be concluded from Figure 3. Specifically, S6 didn't do significantly better than any of the other subjects. S10 had a very high percentage of correctly reproduced pieces for positions 5 to 10, but this can be explained by a strategy also followed by other subjects, namely concentrating on the pieces in hand instead of the pieces on the board.

Hypothesis 1: It is easier to perceive one's own pieces than the pieces of the opponent. To test this hypothesis, we collected data about the difference between the reproduction of own pieces (kanji characters on the pieces displayed in the normal way) and opponent pieces (kanji characters displayed in reverse). The results are given in Table 1. In these results the reproduction of pieces in hand has not been included. From these results it can be concluded that in this experiment there was no evidence to support the hypothesis. Only four subjects reproduced more of their own pieces than pieces of their opponent and in only one case this difference seemed to be significant (S8).

Hypothesis 2: It is easier to perceive pieces in hand than pieces on the board. This hypothesis was tested by looking at the differences between the reproduction of board pieces and the reproduction of pieces in hand. The results are given in Table 2. It should be noted that in the five positions with pieces in hand, the total number of pieces on the board was 132, while the number of pieces in hand was 68. When looking at the results in the table, we see that the percentage of pieces in hand that was reproduced was significantly higher than the percentage of reproduced board pieces. Furthermore, four subjects (S2, S3, S7 and S11) didn't reproduce any pieces in hand. They either didn't understand there were pieces in hand or might have been mistaken into thinking that only board pieces should be reproduced. Finally, when we go back to Figure 3, the reason for improved performance in reproduction for S1, S4, S8, S9 and S10 is clearly caused by reproducing pieces in hand rather than pieces on the board. Our conclusion is that perception of pieces in hand is easier than perception of pieces on the board. This is caused by the information that is needed to store a board piece in memory: piece (piece color, piece type), promoted or not and location. For pieces in hand only the piece type and piece color needs to be stored.

Hypothesis 3: It is easier to perceive promoted pieces than pieces that are not promoted. To test this hypothesis, the differences between the reproduction of promoted pieces and non-promoted pieces was investigated. The results of this comparison are given in Table 3. From these results it can be seen that in general non-promoted pieces are reproduced more than promoted pieces,

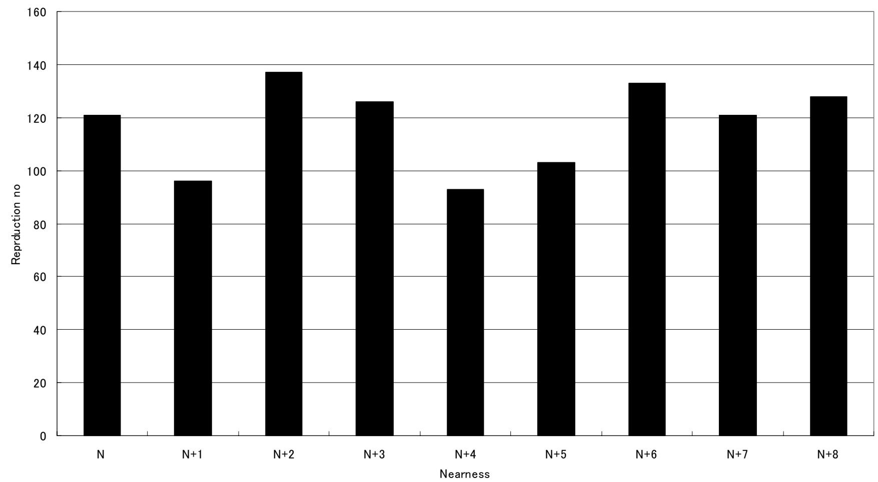


Figure 4: Comparison between the reproduction of pieces in relation to nearness. N represents the rank of the board closest to the subjects.

Table 3: Reproduction differences between promoted pieces and non-promoted pieces.

Subject	*Non-prom*	*Prom*
S1	10	9
S2	5	13
S3	7	16
S4	13	14
S5	10	12
S6	141	36
S7	16	1
S8	11	12
S9	78	25
S10	155	60
S11	7	11
Total	453	209
(%)	40.0	21.1

invalidating the hypothesis. However, there are a number of subjects (S2, S3 and S11), who made an effort reproducing promoted pieces instead of non-promoted pieces. This did not lead to better performance regarding the correctness of the reproduced pieces, so this strategy does not seem to be help to store the information in memory. This seems to indicate that the necessary information for memory storage only lies in the difference between promotion versus non-promotion, which is unrelated to the complexity of the perceptual stimulus.

Hypothesis 4: Pieces closer to oneself are easier to perceive than pieces further away. To test this hypothesis, we need a definition of nearness. We have defined nearness as the rank of the piece on which a piece is placed. The nearest pieces are therefore the pieces placed on the bottom rank, i.e. the rank closest to the player. Each rank further away is considered to be decreasing the nearness of the pieces. This assumption is consistent with the normal way of sitting behind a board. The results of piece reproduction according to this definition of nearness are given in Figure 4. From this graph it is clear that there is no obvious relation between nearness and the reproduced pieces and the hypothesis is therefore invalidated. In this case there was one subject who seemed to use a memorizing strategy where nearness played a role, but this subject reproduced pieces that were furthest away first, contradicting the assumption in the hypothesis.

Hypothesis 5: Bigger pieces are easier to perceive than smaller pieces. To test this hypothesis, we looked at the differences between the piece types of the reproduced pieces. The standard relative sizes of pieces are given in Table 4. These relative piece sizes are used in the positions of our experiment.

According to this table, the king should be reproduced more than the rook and bishop, which should in turn be reproduced more than gold and silver, followed by knight, lance and pawn. The results of reproduction by piece type are given in Figure 5. From this graph we can see that the relation between piece type and reproduction doesn't correlate with the sizes of the pieces. Therefore, this hypothesis was also invalidated.

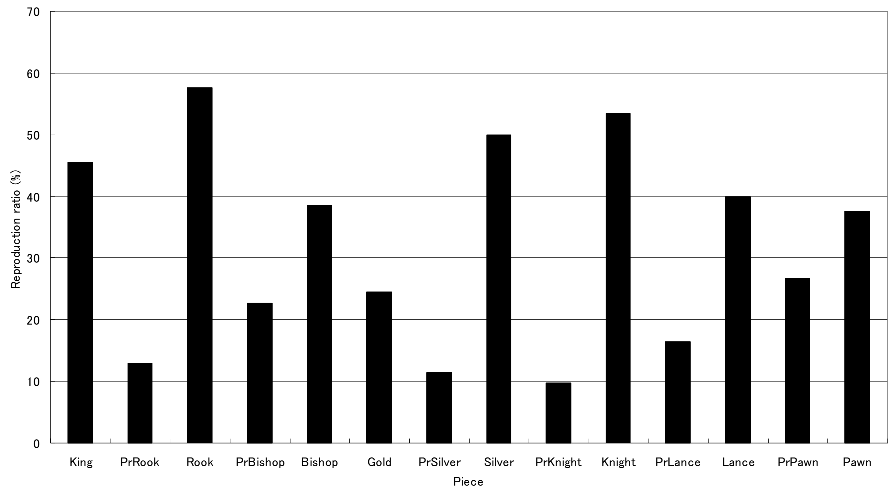


Figure 5: Number of reproduced pieces for each piece type.

Table 4: Piece sizes of shogi pieces in percentages relative to the size of the king. Note: promoted pieces have the same size as their unpromoted versions.

Piece	*RelSize*
King	100
Rook	90
Bishop	90
Gold	79
Silver	79
Knight	69
Lance	59
Pawn	53

5 Conclusions

In this paper, we investigated the relation between perceptual stimuli and memory with a reproduction task using shogi positions. We assumed that there were perceptual differences between 1) own pieces and opponent pieces, 2) pieces on the board and pieces in hand, 3) promoted pieces and non-promoted pieces, 4) pieces that were near and pieces that were further away, and 5) the sizes of the pieces. These differences would influence the memory performance. In our experiments we were only able to confirm the difference between board pieces and pieces in hand, and the conclusion was that pieces in hand are easier to remember than pieces on the board, because less information is involved.

In future work, we will also investigate the order in which pieces were reproduced. Furthermore, to compare the knowledge used during perception by beginners with the knowledge used by more advanced players, we will also do these experiments with more advanced shogi players. This will tell us if the hypotheses that were invalidated for beginners are valid for more advanced players or not.

References

[1] W. Chase and H. Simon. Perception in chess. *Cognitive Psychology*, 4:55–81, 1973.

[2] R. Greenblatt, D. Eastlake III, and S. Crocker. The Greenblatt Chess Program. In *Proceedings of the Fall Joint Computer Conference*, pages 801–810, 1967.

[3] T. Ito, H. Matsubara, and R. Grimbergen. Cognitive Science Approach to Shogi Playing Processes (1) -Some Results on Memory Experiments-. *Journal of the Information Processing Society of Japan*, 43(10):2998–3011, 2002. (In Japanese).

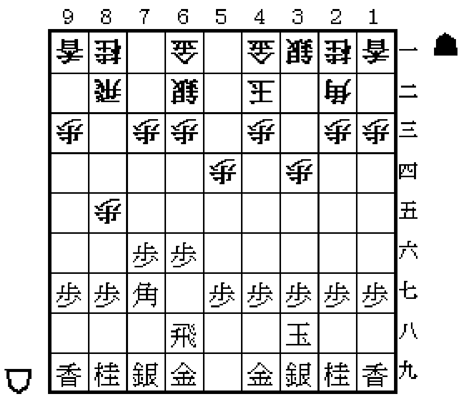
[4] M. Minsky. *The Society of Mind*. New York: Simon and Schuster, 1988. ISBN 0-671-65713-5.

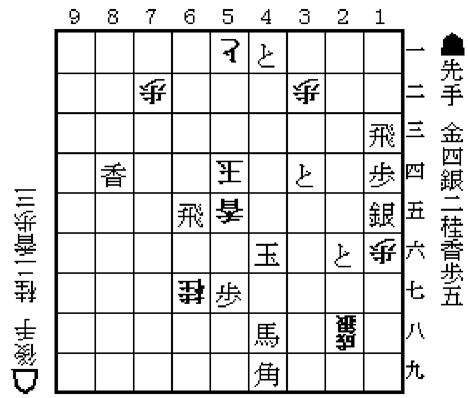
[5] M. Minsky. *The Emotion Machine*. New York: Simon and Schuster, 2006. ISBN 0-7432-7663-9.

[6] H. Simon and W. Chase. Skill in Chess. *American Scientist*, 61:394–403, 1973.

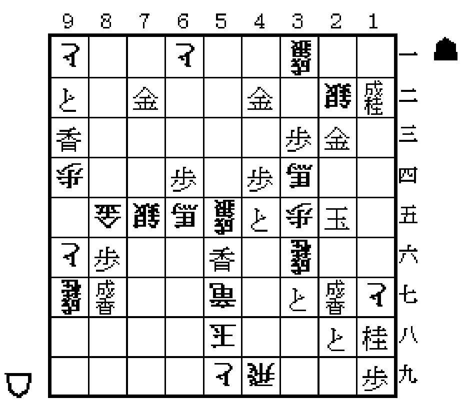
Appendix

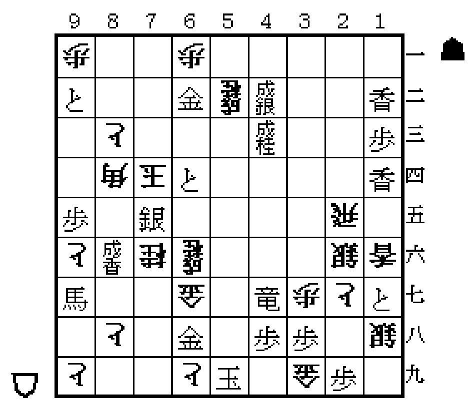
Practice positions

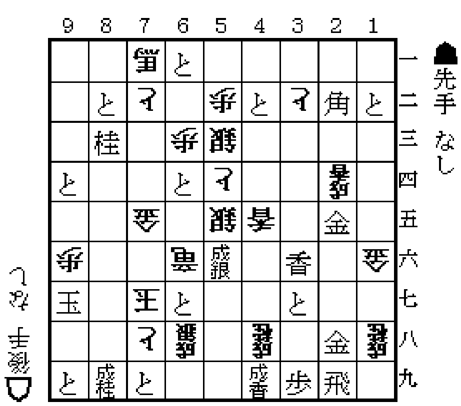


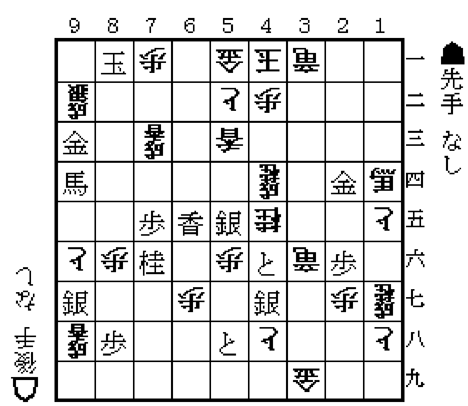


Reproduction positions









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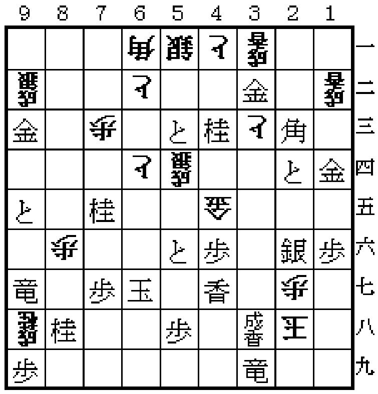

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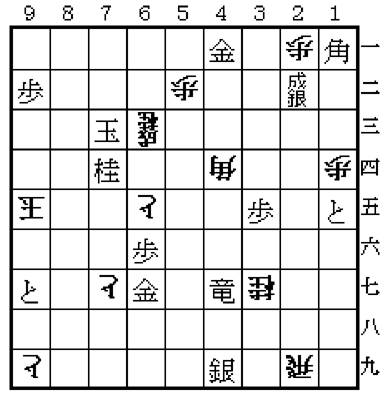

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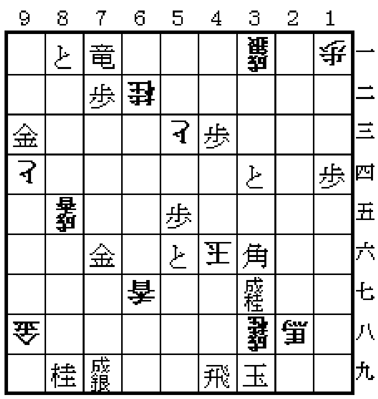

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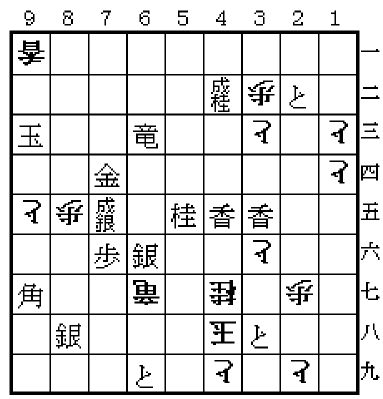

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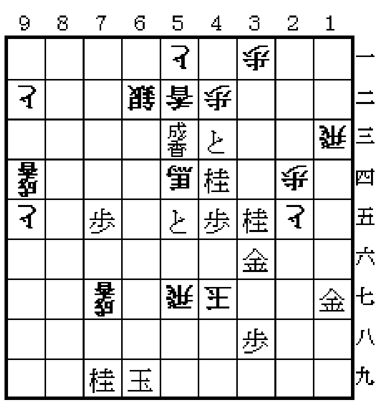

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