Thinking Process in the Game of Curling

TAKESHI ITO[†1] KENGO WAKABAYASHI[†2] HITOSHI MATSUBARA[†2]

Abstract: In this article, we examined the thinking process using "next-move-problem" for players of various levels. As a result, it was confirmed that the player of an intermediate level or higher creates many candidate moves, and the stronger the player, the deeper they search. Unlike deterministic games, such as shogi and go, it was suggested that it is important to list many candidate moves.

Keywords: thinking process, expertise, verbal protocol, search depth, candidate moves

1. Introduction

Curling is a sport that requires a high level of strategic thinking. To select the shot of play, several parameters must be considered. These can be remembered by the mnemonic "FESRAIN," which represents the following:

F: free guard zone rule (use it to play offensive)

E: end in play (early – defensive; late – offensive)

S: score (up – defensive; down – offensive)

R: last rock advantage (with – defensive; without – offensive)

A: abilities of teams (play to your team's strength & their weakness)

I: ice conditions

N: number of rocks remaining in the end

In the parameters listed above, the physical condition of the stone on the ice has not been discussed. Therefore, not only are there many things to consider in a curler's strategy, but also due to high uncertainty, it is difficult to handle the strategy of curling scientifically.

Similar to games such as shogi and go, curling is a turn-based game. The position of stones will change upon each move. Their shots affect both the next shot of the opponent as well as the subsequent positions, which may be a reason why this game is called "chess on ice." Although it is a highly strategic game, cognitive scientific research has not been used to investigate how the player conjugates and executes the next shot.

In this study, following the examination of the thought process of the "next-move-problem" used in shogi and go, we created the "next-move-problems" in curling and presented them to players of various levels to examine how they think using a verbal protocol analysis.

2. Related works

2.1 Research on chess and shogi

The study of Chess by De Groot is a particularly famous example [1]. He conducted experiments on the memory of an expert chess player who could accurately memorize the arrangement of pieces on a chess board in a short period of time (time limit: 5 seconds). It also became clear that a top-class chess expert did not always look for more moves than a low-class expert player [2].

Simon and Chase continued the research and explained this recognition ability of an expert by using the "chunk" concept. The important skill when playing chess is the ability to recognize a typical spatial arrangement of pieces on the chess board as a pattern [3].

To confirm the presence of chunks in shogi, Ito et al. repeated the memory experiments of chess in shogi [4][5]. The results of these experiments also yielded similar results to chess in many ways. However, when examined in detail, there was a difference between the ability of intermediate shogi players (amateur Dan level players) and advanced shogi players (professional players). In the opening phase of the game, the intermediate shogi players showed a memory ability that was a little different from those of the advanced players. However, this memory ability decreased significantly by the middle and the end of the game. Ito et al. tried to explain this difference by "changing the quality of chunks" according to the expertise level. First, players learned the partial position of the play; next, they recognized how this position occurred; and finally, they understood how the play was likely to develop. The researchers hypothesized that as the players got stronger, they would acquire not only spatial, but also temporal and causal chunks.

To study this phenomenon further, Ito et al. conducted an experiment by using the "next-move-problem". The results of this verbal protocol data indicated the following two facts: advanced players searched more deeply, and intermediate players generated more candidate moves.

These studies indicated that it is important to conduct a deep and

†1 The University of Electro-Communications
†2 Future University Hakodate

accurate search in deterministic and complicated games like shogi. Thus, as human players become proficient, they can predict a good move; thus, the candidate moves are reduced and deeper searches are perceived.

2.2 Research on curling

What kind of things do players learn in uncertain games like curling? Ito et al. [6] conducted experiments to examine the thought processes for various levels of curling players using the "next-move-problem."

The results showed that as they advanced, players searched deeply and intermediate players generated more candidate moves. However, as the number of subjects was not enough, we could not show any significant differences. In addition, advanced players tended to mention the risk of mistakes.

3. Cognitive Experiment

3.1 Purpose

How does the curling player decide the next shot? Will there be any differences in the thinking process depending on the curling experience? We tried to solve these questions.

3.2 Method

An experiment was conducted as follows:

1) Administer a questionnaire to examine the experiences of curling with subjects.
2) Make the subjects fully understand the experimental procedure and get used to talking alone about practice problems.
3) In the experiment phase, present the subjects with a problem on an actual curling sheet, teach them to convey the thought process, and record their thought process with a video camera.
4) Repeat the presentation of the problem several times.
5) The verbal data was transcribed to letters and the verbal protocol analysis was carried out.

3.3 Problems

The problems used in this experiment were fabricated by a renowned curling expert with coaching experience. We requested that the problem not be too simple, but one with many factors to consider. In this experiment, a total of 17 problems were used. You can see all problems in Appendix-2. Additionally, two other problems were prepared as exercises for thinking out loud.

3.4 Subjects

The experiment was conducted for the following 31 subjects:

● Hokkaido University curling club: 20 subjects (14 men, 6 women)

● An adult player with curling experience: 1 subject

● Experts players: 4 subjects (3 men, 1 woman)

Players with participation experience in the Hokkaido Curling Championship or in a competition equivalent to it, held in another prefecture.

● Top experts: 6 subjects (5 men, 1 woman)

... Players who secured the third place in the Hokkaido Curling Championship or participated in the Japanese Curling Championship.

The above players were classified as follows according to their expertise level:

● Beginner players: 7 subjects

... Amateur players having 1 to 2 years of experience.

● Intermediate level players: 10 subjects

... (1-4-year experience), players with field experience and experience of participation in the district competition.

● Advanced level players: 14 subjects

... (more than 4 years of experience), players with sufficient experience who aim to be at the top in district competitions or with the experience of participation in the Japanese Curling Championship.

3.5 Results

We examined the verbal data of all subjects against various problems and counted the number of candidate moves and the search depth of each problem. Appendix-1 and 2 lists the number of candidate moves and the search depth for all problems. From these results, we examined whether there was a difference between the number of candidate moves and search depth, with respect to the proficiency level.

First, we examined whether the beginners, intermediate, and advanced players followed a normal distribution by using the Shapiro-Wilk test. The calculation results are as follows:

Number of candidate moves

- Beginner players: $W = 0.49867$; p-value <0.001; average = 1.394958; sample standard deviation = 0.9133519.
- Intermediate players: $W = 0.70031$; p-value <0.001; average = 1.482353; sample standard deviation = 0.6637131.
- Advanced players: $W = 0.66999$; p-value <0.001; average = 1.474790; sample standard deviation = 0.7330324.

Search depth

- Beginner players: $W = 0.3327$; p-value <0.001; average = 1.10084; sample standard deviation = 0.3292250.
- Intermediate players: $W = 0.40428$; p-value <0.001; average = 1.141176; sample standard deviation = 0.3816173.
- Advanced players: $W = 0.53524$; p-value <0.001; average = 1.273109; sample standard deviation = 0.5634729.

In all of the above sets, the null hypothesis was rejected, and we observed that these did not follow a normal distribution.

Since it was observed that the number of candidate moves and

the search depth are not in accordance with the normal distribution, the significant differences between the data were calculated using Mann-Whitney's U test. The calculation results are as follows:

Number of candidate moves

- Between beginner and intermediate players:
  U = 8608; p-value = 0.008899, a significant difference.
  Intermediate > Beginner
- Between beginner and advanced players:
  U = 12484; p-value = 0.02535, a significant difference.
  Advanced > Beginners
- Between intermediate and advanced players:
  U = 20786; p-value = 0.5802, no significant difference.

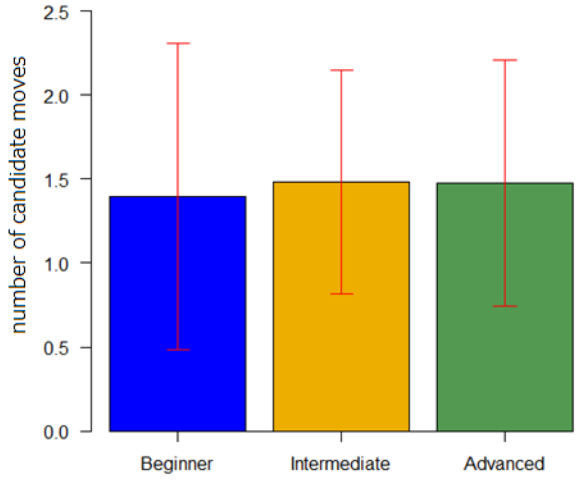

Fig. 1 Relationship between proficiency level and number of candidate moves

The relationship between the proficiency level and the number of candidate moves is expressed in Fig. 1.

The above calculations show that intermediate players and advanced players consider significantly more candidate moves than beginners.

Search depth

- Between beginner and intermediate players:
  U = 9741; p-value = 0.3325, no significant difference.
- Between beginner and advanced players:
  U = 12336; p-value = 0.002722, a significant difference.
  Advanced players > Beginners
- Between intermediate and advanced players:
  U = 18347; p-value = 0.01664, a significant difference.
  Advanced players > Intermediate players

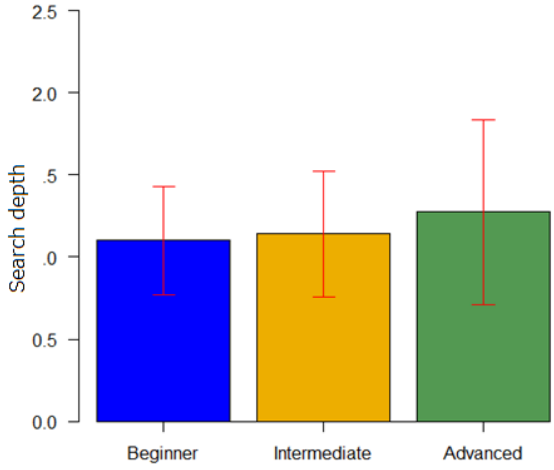

Fig. 2 Relationship between proficiency level and search depth

The relationship between the proficiency level and search depth is expressed in Fig. 2.

The above calculations show that the advanced players present significantly more candidate moves than beginners and intermediate players.

In curling, the degree of involvement in the strategy varies depending on player's position. In general, the skip often generates a strategy and gives instructions to other players. Therefore, if the players have the experience of being a skip, it may influence on the degree of mastery of the strategy.

We divided the subjects into: with or without skip experience and compared the number of candidate moves and the search depth. Skip experienced players were N2, N3, M1, M2, M3, M6, M7, M9, E2, E3, E4, E6, E7, E8, E10, and E12. Non-skip experienced players were N1, N4, N5, N6, N7, M4, M5, M8, M10, E1, E5, E9, E11, E13, and E14. We evaluated the statistical difference between these sets.

We first tested if these sets followed a normal distribution, using the Shapiro-Wilk test. The null hypothesis that it is a normal distribution was rejected in all four sets: skip experience or not both in the number of candidate moves, and in the search depth, respectively.

We examined whether there was a difference in the number of candidate moves depending on whether they had skip experience by using the Mann-Whitney's U test.

Number of candidate moves

- Skip experience: average = 1.543253
- No skip experience: average = 1.357143
  U = 39574; p-value = 0.0003559.

This result shows that players who had skip experience showed a significant increase in the number of candidate moves.

Similarly, we examined whether there was a difference in the search depth depending on their skip experience, using the Mann-

Whitney's U test.

Search depth

- Skip experience: average = 1.280277
- No skip experience: average = 1.084034

U = 39814; p-value = 1.051e-06.

This result showed that the players with skip experience had a significantly increased search depth.

4. Conclusion

We have compared the thought processes of players of various levels in the game of curling by using the next-move-problems. Results similar to those of shogi were observed. Although the players became proficient, there was a tendency to search deeply. On the other hand, unlike shogi, intermediate and advanced players showed a similar tendency to generate candidate moves. Furthermore, depending on the skip experience to deeply consider strategy, there was a tendency to search deeper and raise more candidate moves.

This may represent the nature of games with uncertainty. In uncertainty games, it is important to be able to list a lot of possibilities, so there may be a chance that the advanced players did not reduce the number of candidate moves. We would like to explore this hypothesis by examining higher-level players.

Reference

[1]A.D. de Groot. Thought and Theory in Chess. Mouton Publishers, The Hauge, The Netherlands, 1965.

[2]A.D. de Groot. Perception and Memory in Chess. Van Gorcum, Assen. 1996.

[3] H.A. Simon and W.G. Chase. Skill in Chess. American Scientist, 61:pp.393-403, 1973.

[4] T. Ito, H. Matsubara and R. Grimbergen. The Use of Memory and Causal Chunking in the Game of Shogi. ICCS2001, pp.134-140, 2001.

[5] T. Ito, H. Matsubara, and R. Grimbergen, Chunking in Shogi: New Findings, Advances in Computer Games, Lecture Notes in Computer Science 4250, pp.140-154, 2006.

[6] T. Ito, T. Itakura, Thought process in playing curling. Entertainment Computing 2015, pp.31-36, 2015 (in Japanese).

Acknowledgments

This work was supported by JSPS KAKENHI Grant Number 15H02797.

Appendix-1: The candidate moves of all players against all problems

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Skip experience
N1	3	1	1	1	1	2	1	1	1	2	2	2	1	2	1	2	1	n
N2	1	1	1	2	2	2	1	1	2	1	1	1	1	3	1	1	1	y
N3	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	2	1	y
N4	1	1	1	1	1	1	2	2	1	1	1	1	1	1	1	1	1	n
N5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	n
N6	5	1	3	1	3	1	4	1	5	2	2	1	6	1	4	1	4	n
N7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	n
M1	2	2	3	3	3	1	1	2	2	2	2	2	3	2	4	2	1	y
M2	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	y
M3	2	1	2	1	2	1	3	1	1	1	1	1	1	1	2	1	1	y
M4	1	1	1	1	1	1	1	1	2	1	2	1	2	2	1	2	1	n
M5	2	2	2	2	1	1	2	1	1	2	1	2	1	3	1	1	2	n
M6	2	1	1	1	1	2	3	1	1	2	1	1	3	2	3	2	1	y
M7	1	1	1	1	1	2	2	2	1	2	3	2	1	1	1	2	1	y
M8	3	2	1	2	2	1	1	1	1	1	1	1	1	2	1	1	1	n
M9	3	1	1	2	1	2	1	1	2	1	2	2	1	3	1	2	1	y
M10	1	2	2	2	1	1	1	1	1	2	2	1	1	1	1	1	1	n
E1	2	2	1	3	3	1	2	4	1	2	2	2	2	2	1	5	2	n
E2	3	2	1	1	1	1	1	3	1	2	2	2	1	2	1	4	2	y
E3	1	1	1	1	1	1	1	1	1	3	1	1	1	3	1	3	1	y
E4	2	1	1	1	2	1	2	3	1	2	1	1	2	2	1	2	2	y
E5	2	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	n
E6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	y
E7	1	1	2	1	1	1	2	2	1	1	1	1	1	1	1	2	1	y
E8	2	2	1	3	3	2	3	1	2	1	2	1	2	2	3	2	2	y
E9	1	1	1	1	1	1	1	1	2	2	1	1	2	2	2	3	2	n
E10	2	2	2	3	2	1	2	2	1	3	3	1	3	2	4	3	1	y
E11	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	n
E12	1	1	1	1	1	1	1	1	2	1	2	1	1	2	1	1	1	y
E13	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	n
E14	1	1	1	1	2	1	3	2	1	2	2	2	1	2	1	1	1	n

Appendix-2: The search depth of all players against all problems

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Skip experience
N1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	n
N2	1	1	1	2	1	1	1	1	1	1	2	2	1	1	1	1	1	y
N3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	y
N4	1	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	n
N5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	n
N6	1	1	1	1	2	1	1	1	1	1	2	1	1	1	1	2	3	n
N7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	n
M1	1	1	2	1	1	1	1	2	1	1	2	2	2	2	1	2	1	y
M2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	y
M3	1	1	1	3	1	1	1	1	1	1	1	1	1	1	1	1	1	y
M4	1	1	1	1	1	1	1	1	1	1	1	2	1	1	2	1		n
M5	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	n
M6	1	1	1	1	2	1	1	1	1	1	1	3	2	1	2	1		y
M7	1	1	1	1	1	1	1	2	1	1	2	1	1	1	1	1	1	y
M8	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	n
M9	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	y
M10	1	1	2	2	1	1	1	1	1	1	2	1	1	1	1	1	1	n
E1	1	1	1	1	2	1	1	1	2	1	2	2	2	1	1	3	1	n
E2	2	2	1	1	1	1	1	2	1	2	1	2	2	1	1	2	3	y
E3	1	1	2	1	1	1	1	1	1	2	1	1	1	2	2	4	1	y
E4	1	1	1	2	3	1	1	2	1	3	3	2	2	2	1	2	2	y
E5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	n
E6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	y
E7	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	y
E8	1	1	1	1	2	1	3	2	1	1	1	1	3	3	1	2	1	y
E9	1	1	1	1	1	1	1	2	1	1	1	1	1	1	2	2	1	n
E10	1	1	2	3	2	1	1	2	1	3	2	1	2	2	2	2	1	y
E11	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	n
E12	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	y
E13	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	n
E14	1	1	1	1	1	1	1	1	1	1	3	1	1	1	1	1	1	n

Appendix-2: All problems used at the experiment.