An AI-Assisted Strategy Learning Support System Using Digital Curling

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Abstract: We propose a system that supports curling players to learn strategy with the assistance of artificial intelligence (AI). This system is based on a digital curling application, which is designed for curling strategy discussion on computer. High-performance AIs, which run on digital curling, have been developed. Our system visualizes AI thought, taking the uncertainties and continuousness of curling into account. The results of the evaluation experiment show the effectiveness of the system and required functions.

Keywords: curling, digital curling, learning support system, game AI, visual display

1. Introduction

Kitasei et al. developed an application called "digital curling," with which you can play curling on a computer and discuss curling strategies [1]. This application uses random noise to represent uncertainties such as the changing conditions of ice and stones as well as the players' skill. Kitasei et al. [1] held artificial intelligence (AI) competitions that used this application, and they provided a forum to facilitate the discussion of strategies, resulting in the development of high-performance AIs. Today, digital curling AIs are reaching the level of experienced human players. This means these AIs are getting good enough for humans to use them to learn strategies.

With AI that surpasses human skill, they are being used to support training for humans [2]. We believe that research on the application of full-fledged AI to support the development of curling strategies is a significant technique for AI-assisted learning support.

In this research, we develop a system that assists players in learning strategies by using AI. We also discuss the techniques required for this kind of system. Using digital curling, we develop functions to assist in learning strategy, and then, we verify the effectiveness of the system using an evaluation experiment.

2. Related Works

2.1 Digital Curling

Digital curling is an application that was developed by Takeshi Ito's Laboratory around 2013 [1]. This application uses Box2D, which is a physics engine, to simulate the movement of stones. It realizes the uncertainties of shots performed in curling by adding normal random numbers. Digital curling uses a server–client application structure; the server administrates the digital curling match, while the client application allows you to connect to a curling AI or a human player to play games. Digital curling is open to the public, which enables further development of the curling AI. We have held curling AI competitions by using this system since 2015, which demonstrate the stability and reliability of the system [3]. This system provides a platform where we can discuss pure strategy on computers; however, digital curling in itself does not offer a function with which you can edit game states. This makes it difficult to create a certain state that players want to discuss. Further, functions concerning strategy support are insufficient, as the system only provides functions to start the game from the initial state and to view an ended game from a log file.

2.2 Curling AI

At present, there are two major algorithms for curling AI development: Monte Carlo tree search (MCTS), represented by "Ayumu," which was developed by Ohto et al. [4]; game tree search with an evaluation function, represented by "Jiritsu-kun," which was developed by Kato et al. [5]. These two AIs play close games, which makes it difficult to determine which one is superior to the other in terms of technique. In the 3rd UEC Cup Digital Curling Tournament in GAT in 2017, Ayumu won the regular league and Jiritsu-kun won the light-weight league, which restricts thinking time and number of threads. These AIs are open to the public, and experienced curlers view them as strong, which suggests they are strong enough for use in strategy support.

2.3 Application of human-surpassed AI

There are games for which AI already surpasses human skill: Othello, Backgammon, Chess, Shogi, and so on. Various approaches have been designed to use these AIs. In Shogi, for instance, it has been attempted to produce commentary by using strong AI [6], a system that dynamically adjusts its strength depending on opponent's level [2], and a system that imitates human-like play style [7].

There is research on the visualization of AI thought: a system that proposes terms of Go (Pang et al.) [8] and a system that supports players' thinking by showing future states produced by Shogi AI (Kobayashi et al.) [9]. In addition to showing the relationship between stones and a move that the terms of Go denote, the system proposed by Pang et al. enables visualization of the state of the game and territory control. The system proposed by Kobayashi et al. was developed as research on the assistance dilemma, which supports learning with room for thinking by showing a state several moves ahead that the Shogi AI proposes.

Since thought-oriented support using AI on curling is unprecedented, we think showing the process of an AI's thought

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itself has significant meaning. We focus on developing a system for which you can edit game states as you prefer, showing AI-suggested candidate shots.

3. Preliminary Investigation

3.1 Purpose

The purpose of this investigation is to identify how actual curling players learn their strategies and the kind of support that they need in order to do that.

3.2 Methods

We conducted an attitude survey on the members of the Kitami Institute of Technology curling club, which is at the top level among Japanese universities. We used a questionnaire for which the question items are of the three categories listed below, with each category having detailed questions.

1) Questions on individual status and experience in curling
2) Questions on experience learning curling strategies
3) Questions on requests for digital curling

The survey was conducted in April 2017, and it had 48 respondents. Since there were several new members, we selected 23 experienced players who had played curling for more than 6 months as analysis subjects.

Table 1: Experience in curling

Experience in curling	Number of respondents
Over 10 years	1
5 to 10 years	3
3 to 4 years	5
2 to 3 years	11
1 to 2 years	2
6 months to 1 year	1
Under 6 months	24

3.3 Results

In response to the question, “How did you learn curling?” most of them provided verbal responses such as, “from a coach,” or, “from senior or experienced players,” while there were only three who answered, “from a strategy book.”

In response to the question, “How do you want to learn strategies?” several of them answered, “from practice,” while highly experienced top players wrote concrete requests such as “learning from a highly-experienced instructor” and “learning patterns of strategies by comparing top players’ thoughts in each situation.”

From the questions on digital curling, in response to the question, “Have you used digital curling?” 12 out of 23 answered affirmatively. For the question, “Do you think digital curling can assist with strategy?” 11 out of 12 answered “Strongly agree” or “agree.” In response to the questions “How do you want to use it as a strategy support?” and, “What functions do you want?” they answered, “to reflect games by developing towards real situations,” “to compare with the game in practice,” and so on. We could see requests for functions related to sheet conditions such as “to regulate ice conditions,” and “to regulate how stones curl,” and to make adjustments to players’ skills such as “character” and “adjustment of random noise depending on mastery level.”

3.4 Discussion

We can see that players learn strategies mainly through verbal instructions, and many of them do not use strategy books even in the Kitami Institute of technology, where top-level players gather to play. They have relatively high expectations of the application of digital curling toward strategy support. We observe several requests for “functions to edit and realize certain game states” and “functions to edit conditions such as ice conditions and players’ skill.”

4. Proposed System

4.1 Design

There are two characteristics of curling that we have to consider: uncertainty and continuous state space and action space. For uncertainty, we add a function to edit conditions such as adding a random number. For continuousness, we design functions to set stones in detail and represent shots by their trajectories.

4.2 Overview

The proposed system is based on the digital curling application. This system consists of three functions: game-state editor, conditions editor, and candidates display. In the game-state editor, users can create game states that they would want to discuss. In the conditions editor, conditions such as ice conditions can be edited. Under the conditions provided by the two functions above, the candidates display presents the candidate shots as thought by the AI. This system supports strategy learning by visualizing candidate shots under given situations and conditions.

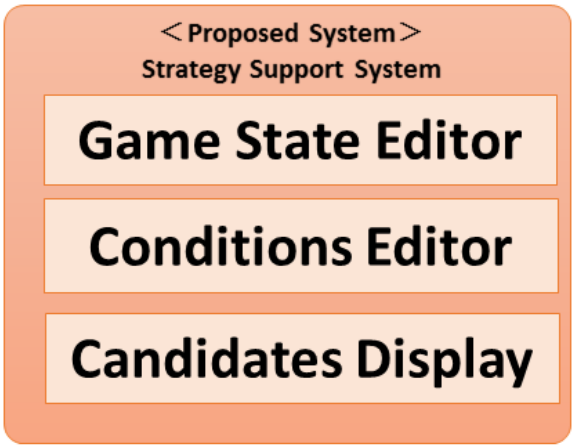

Figure 1: Overview of the proposed system

4.3 Game-State Editor

We developed a function called “game-state editor” where certain game states can be designed. This function allows editing of the positions of stones, the number of remaining stones, total ends of game (the length of the game), current end (end is a portion of curling game), scores, etc.; the edited game states can be saved and loaded. Stones can be placed intuitively using the drag-and-drop input. In order to place stones with more precision,

the function allows the moving of stones using arrow keys and direct input of the coordinates of stones.

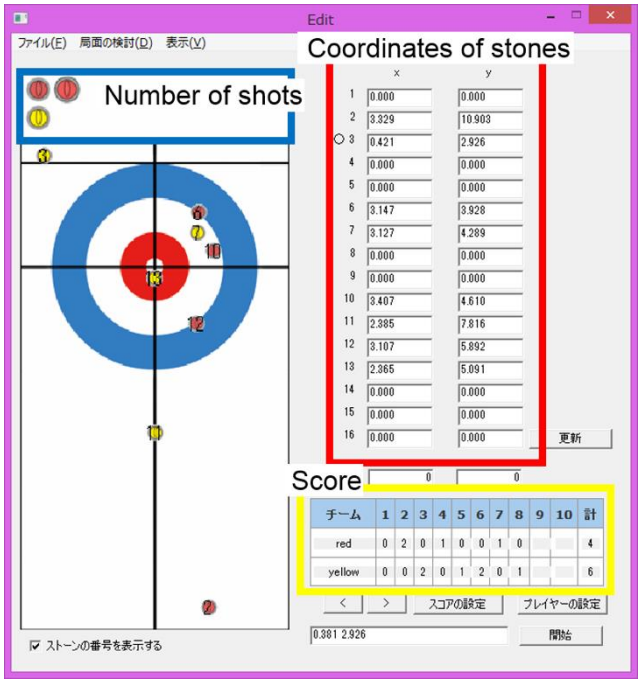

Figure 2: Interface of the game-state editor. Text boxes inside the red frame display the coordinates of stones. The blue frame shows the graphics of stones indicating the number of shots (or number of remaining stones). The yellow frame is the score board.

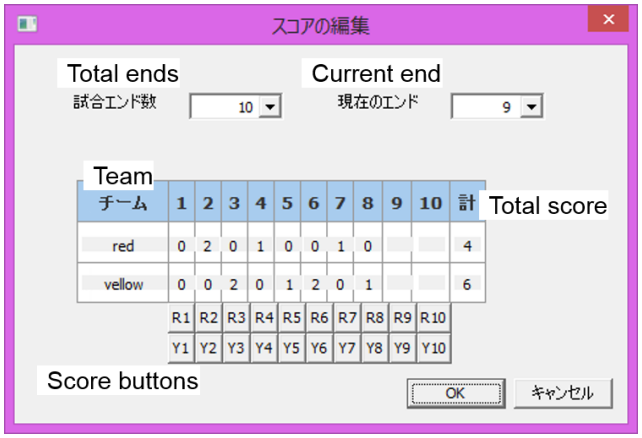

Figure 3: Score editor dialog box. In this dialog box, you can edit the total number of ends (length of the game), current end (end is a portion of curling game), and scores. In the case above, total number of ends is 10, current end is 9, and the red team had scored 4 points and the yellow team had scored 6 points by End 8. Buttons below the score board are used to edit the score. By pressing R*x*, where R is red, *x* is the number of an end, 1 point is added to the red team or subtracted from the yellow team at the end *x*. Similarly, there are buttons for Y*x*, where Y is yellow, and *x* is a number of an end.

4.4 Conditions Editor

In the conditions editor, you can edit the dynamic coefficient of friction between the stone and the ice, the amount of curl, and the random number. Digital curling stores the edited values and allows using them. Currently, changes made in this function are not reflected in other functions such as those for generating the initial-shot velocity vector from the target position and the AI's thinking.

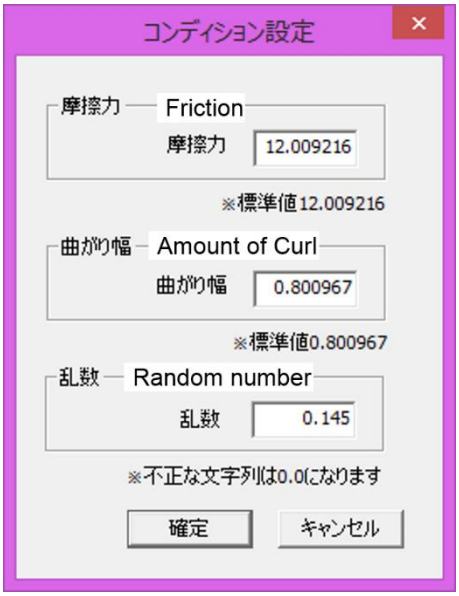

Figure 4: Interface of conditions editor

4.5 Candidates Display

We developed a function called "candidates display," which displays the AI candidate shots. In this function, you can choose up to three AIs. Then, you can let them start thinking under the given edited game state and conditions. It visualizes AI-suggested candidate shots and player-selected shots by showing their trajectories and animations, which allows a comparison of each shot.

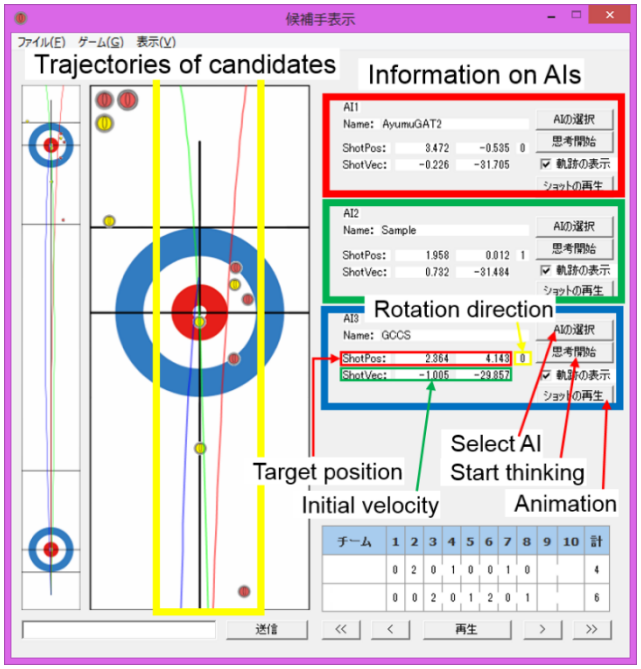

Figure 5: Interface of candidates display. Red, green, and blue

frames represent information on AI1, AI2, and AI3, respectively, and their shots. The yellow frame shows the three trajectories of the shots. The colors of the trajectories, i.e., red, green, and blue, correspond to the colors of the information frames on the AIs (AI1: red, AI2: green, AI3: blue, Human: pink or orange).

5. Evaluation Experiment

5.1 Purpose

The purpose of this experiment was to evaluate the game-state editor and the candidates display for the functions developed in this research.

5.2 Methods

Ten members from the Kitami Institute of Technology curling club participated in the experiment. We sent instructions to the representative and let the representative perform the experiment by following the instructions. We allowed the participants to experience the proposed system for around 15 min. Then, we let them discuss functions for another 15 min. After that, we let them answer the questionnaire. The question items in the questionnaire were as follows:

1) Questions on impressions from use (5-point Likert scale and open-ended)
(i) What is your impression from use? (5-point Likert scale)
(ii) What do you think about your impression from use? (Open-ended question)
2) Questions on usefulness to strategy support (5-point Likert scale and open-ended)
(i) What do you think of the usefulness of this system for strategy support? (5-point Likert scale)
(ii) What do you think about the strategy support of this system? (Open-ended question)
3) Question on requests for the proposed system (open-ended)
(i) Please write the functions you want, any demands, etc. in this system in as much detail as possible.

5.3 Results

Figure 6 shows the results of the questions on the impression from use rated on the 5-point Likert scale. The average score was 3.22 and the standard deviation was 1.09. Three out of the ten participants who answered, “it is a little difficult to use,” commented that “it is difficult to adjust the weight of takeouts” (*weight* is the velocity of the shot; *takeout* is a shot aiming at removing other stones), “the amount of curl is too small,” etc.

Figure 7 shows the results for questions on usefulness for strategy support rated on the 5-point Likert scale. The average score was 3.78 and the standard deviation was 0.97. Three out of the ten participants who answered, “not so useful,” or “mediocre,” commented “I want to make it suitable for beginners to learn,” “I want to know the reason the shot is selected and the shot success rate,” etc.

For the question on requests for the proposed system, some of the respondents answered not only, “I want to adjust the velocity of takeouts and amount of curl,” and, “I want the system to display shot success rate,” but also, “I want an AI which reflects the characteristics of a player.”

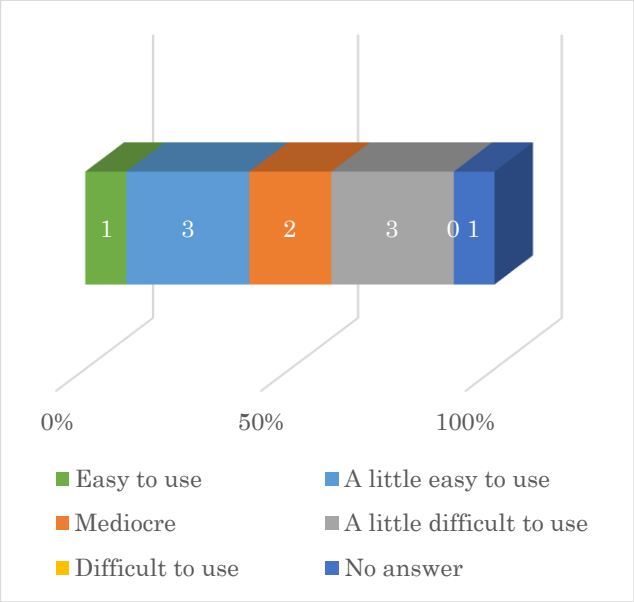

Figure 6: Results of the question on impression from use (5-point Likert scale)

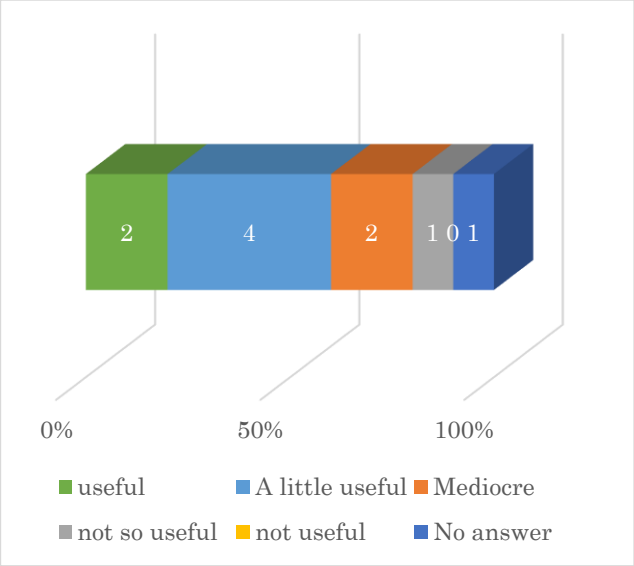

Figure 7: Results of the question on usefulness (5-point Likert scale)

5.4 Discussion

We think that there is a requirement to design functions related to specifications of the system such as adjustment of takeouts and those related to strategy support, such as shot success rate.

5.4.1 Improvement plans

Based on the results of the evaluation experiment, we devised some improvement plans which are now described.

(1) **Displaying a ruler for evaluating the position in the game-state editor**

The survey results presented opinions indicating that it is difficult to understand the position of the coordinates. Therefore, to solve this problem, we suggest displaying rulers on the upper and left edges of the graphic of the rink. We can accomplish this

by adding an image of rulers to the dialog box.

(2) **Addition of a takeouts generator**

The survey results presented opinions such as, “it is difficult to adjust the velocity of the shots,” and, “how to choose takeouts is difficult.” To solve these issues, we suggest developing a takeouts generator. One idea is to decide the position where the stone will pass and the weight of the shot. Zooming in near the passing position can be useful when you aim to hit another stone. Another approach for the design of a takeouts generator is to use the CreateHitShot function in the digital curling simulator. The CreateHitShot function can generate a shot from the position where the stone will pass and the weight of the shot, which we believe is suitable for designing a takeouts generator.

(3) **Improvements to the conditions editor**

There is a need for adjusting the amount of curl. Although the system and simulator can store the edited values, some AIs use their own simulator. To calculate the initial velocity of the shot from the target position, the digital curling simulator uses numbers that are dependent on friction and the amount of curl, which are difficult to obtain.

(4) **Alterations to the names of items in candidates display**

There were requests for “explanations of values.” We suggest changing the names of the items that are related to AI-suggested shots. For examples, changing “ShotPos” to “Target Position,” changing “ShotVec” to “Initial Velocity,” and changing rotation directions “0” and “1” to “clockwise” and “counterclockwise,” respectively. Furthermore, we think it will be effective to denote candidate shots by expressions familiar to the curler such as weight, turn, and line since these are intuitively understandable.

6. Conclusion

In this research, we proposed a system that enables editing game states and visualizing AI-suggested shots based on their trajectories and animations. Our evaluation experiment revealed problems related to impressions from use and functions that should be added to the system.

There are two principal problems to solve: (i) improving impressions from use by adding functions. To accomplish this, we need to add a takeouts generator and make the conditions editor work properly. To design the takeouts generator, we suggest a method that generates takeouts using the position to pass and shot velocity. (ii) Enhance the functions for strategic support, such as displaying the reasons for the selected shots, displaying the shot success rate, and developing AI that has particular characteristics such as AI for takeouts. We think it is useful for strategy support to display each shot’s success rate and to make them comparable.

To facilitate effective implementation of improvement plans, we need to conduct supplementary questionnaires to collect detailed opinions from players regarding exactly what they want, and to determine how to respond to their requests as mentioned in the results of the evaluation experiment.

After improving our system, we plan to perform a lengthy experiment with subjects using our system and comparing the improvement in their skill that of curling players who have used the digital curling application without our improvements.

Reference

[1] Takeshi Ito and Yuuma Kitasei: Proposal and Implementation of “Digital Curling”, IEEE Conference on Computational Intelligence and Games (CIG2015), pp.469-473, 2015.

[2] Takafumi Nakamichi and Takeshi Ito: Implementation and qualitative analysis of an adaptive computer Shogi program by producing seesaw game, International Conference on Technologies and Applications of Artificial Intelligence, TAAI2015, pp.453-460, 2015.

[3] Takeshi Ito, Kentaro Mori, Yuuma Kitasei: Report on 1st UEC-cup digital curling tournament, IPSJ SIG Technical Report, 2015-GI-34(2), pp.1-5, 2015. (in Japanese)

[4] Katsuki Ohto, Tetsuro Tanaka: A Curling Agent Based on the Monte-Carlo Tree Search Considering the Similarity of the Best Action among Similar States, Advances in Computer Games (ACG 2017), Vol.10664, pp.151-164, 2017.

[5] Shu Katoh, Hiroyuki Iizuka, Masahito Yamamoto: A Method of Game Tree Search in Digital Curling Including Uncertainty, Journal of Information Processing Society of Japan, Vol.57, No.11, pp.2354-2364, 2016. (in Japanese)

[6] Hirotaka Kameko, Shinsuke Mori, Yoshimasa Tsuruoka: Learning a Game Commentary Generator with Grounded Move Expressions, Proceedings of 2015 IEEE Conference on Computational Intelligence and Games, 2015.

[7] Satoshi Namai and Takeshi Ito: A trial AI System with its Suggestion of Kifuu (Playing Style) in Shogi, International Conference on Technologies and Applications of Artificial Intelligence, TAAI2010, pp.433-439, 2010.

[8] Yuan Feng Pang and Takeshi Ito: Determination System of Terms for Supporting Learning Go, Journal of Information Processing Society of Japan, Vol.59, No.4, pp.1286-1294, 2018. (in Japanese)

[9] Takeshi Ito: A Learning Support System by Using the Future Position, IPSJ SIG Technical Reports, 2017-GI-38(7), pp.1-8, 2017. (in Japanese)

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