Advances in Curling Game Information Analysis by Considering Starting Position

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Abstract: Japanese curling teams have been recently preparing for Pyeongchang Winter Olympics in 2018. In curling, there are three factors influencing game performance: physical factor, human factor, and strategic/tactical factor. The strategic/tactical factor is considered as the most important at top level. To support the strategic/tactical factor, we proposed the concept of Curling Informatics. As the first step of Curling Informatics we developed a digital scorebook *iCE* for digital collection of game information, storing it in a database and performing further analysis to improve player performance. In this article, we further contribute to this project by analyzing game information of world national top level teams. We have previously confirmed that correlation between shot accuracy and game score could differ with the team level or position. We also found out that selected tactics and psychological pressure on opponent team has impact on game result. However, previous analyses disregarded the order of teams in play, which could result in confusion of strategic tendencies or play characteristics. In this paper, we carried out analysis of correlations of shot scores considering whether the teams started as the first or the second. We did this to specify the process of how the team strategy/tactics influences game results.

1 INTRODUCTION

Japanese curling teams have greatly improved their performance in recent years. For example, Japan national curling team won second place at the Women's World Championship 2016 in Saskatchewan, Canada, thus winning a medal for the first time. In addition, both men and women players have been achieving excellent results, which allowed them to qualify for the Pyeongchang Winter Olympics in 2018. In the background of this success, there are various strengthening programs developed for Japanese curling (Yanagi and Miyakoshi, 2011; Takahashi, 2011; Masui et al., 2016).

However, it is still necessary to continue working on strengthening such support in order to make Japan capable of obtaining a medal at the Pyeongchang Winter Olympics, which will take place next year. For example, Japan played against Switzerland three times including round robin (type of a tournament in which every team competes against every other team in turns). This suggests that Japan should have already captured the tactics of Swiss team which should help in winning a gold medal or at least improve the team's ranking during the Pyeongchang Winter Olympics in 2018.

An Information Science approach can be mentioned as an example of a method for improving the performance of a team. In the past few years a number of cases to support sports with ICT (Information and Communication Technology) have been reported (Fujimura and Sugihara, 2004; Kagawa, 2006), including curling (Masui et al., 2016). As an example of that, our group proposed a new field called *Curling Informatics* (Masui et al., 2016).

As Figure 1 shows, the research field of Curling Informatics deals with strategic and tactical factors of top curling teams and improves the strategic and tactical skills of curling players. It also focuses on realizing several support environments, such as recording and referring to game information, tactical navigation, and assistance for reflection and tactical training. Specifically, general plan developed within this field aims at implementing the methods to (1) collect, (2)

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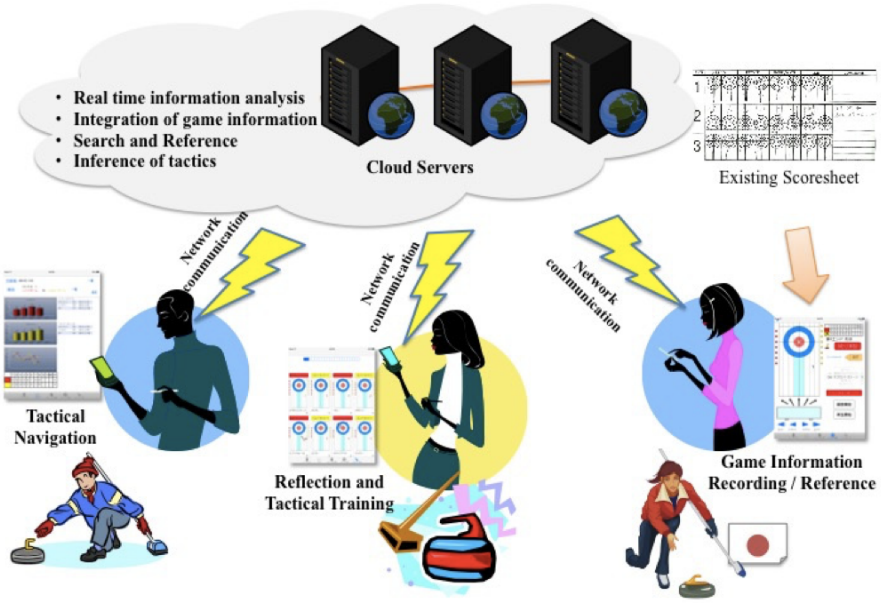

Figure 1: The concept of Curling Informatics (Masui et al., 2016).

analyze, (3) visualize and (4) share game information.

In the first step, Masui et al. developed a digital scorebook *iCE* which runs on a tablet computer to collect and analyze game information and they confirmed validity of the system (Masui et al., 2016). As one of the applications of *iCE*, it is possible to check the shot accuracy of each team or player based on collected information sequentially and visually.

In the next step, we have analyzed the data collected with the *iCE* application focusing on the relation between shot accuracy and game score. Masui analyzed *iCE* data and confirmed that there is a strong correlation between the difference in shot accuracies and the difference in game scores and that correlation between shot accuracy and game score differ with level of team or player (Masui et al., 2016).

In addition, we (Otani et al., 2016) analyzed game information of the Sochi Winter Olympics in 2014 and confirmed that correlation of the world national top level was lower than the Japanese top level and that the selected strategies/tactics and psychological pressure on the opponent team had an impact on game result .

However, because this analysis did not consider the order of teams in play (whether the team started as first, or second), it could contain confused information about tendencies in strategies or play characteristics.

In this paper, we advanced the analysis of the relation of shot accuracy with game score by considering the starting positions (later called: Play First and Play Second).

The outline of the article is as follows. Firstly, we introduce the relevant related research in Section 2. Secondly, we describe the notions of team strategy and shot accuracy in Section 3. Next, we provide an overview of applied game information, and the analytical method. The results are explained in Section 5 and discussed in Section 6. In Section 7 we conclude the paper.

2 RELATED RESEARCH

Factors influencing team's performance in curling include: the physical factor (ice condition), the human factor (condition of curling player), and the strategic/tactical factor (knowledge and tactics/strategies). Bradley (Bradley, 2009) points out the strategic/tactical factor as the most important at top level.

As for the human factor, investigations about motion dynamics of curling stone by Shegelski et al. and Denny et al. (Shegelski, 2000; Denny, 2002) are some of the most known research. In recent years, Maeno (Maeno, 2014) also reported a new motion dynamics model for sliding the stone on ice. Regarding the human factor, various research on how to train the players and improve their condition and power balancing, were proposed. Behm (Behm, 2009) proposed an effective training method to improve the requisite motion for curling. Yanagi et al. (Yanagi and Miyakoshi, 2011) verified effective training for college level players by an experimental approach with a college curling team. They also developed a new sweeping brush which conveys the power of player's

motion efficiently based on the analysis of player's sweeping motions from a viewpoint of biomechanics.

In addition, Tanaka introduced ICT (Information and Communication Technology) for human factor analysis (Tanaka et al., 2006). They attempted to carry out an analysis of motion to deliver the stone by utilizing a virtual model of curling environment and players.

About the strategic/tactical factor, Igarashi et al. proposed an application to inverse the problem for curling by policy-gradient methods in Non-Markov decision processes (Igarashi et al., 2007), Ura et al. reported on calculation technique for analysis of strategies/tactics based on game tree (Ura et al., 2008). Also, Sung et al. analyzed game information focusing on first rock and last rock per each end and points out that team strategies/tactics differed in teams which had last rock per end and other teams (Sung, 2013).

Masui et al. suggested that there is a strong correlation between the difference in shot accuracies and the difference in the game scores (Masui et al., 2016). In addition, they observed that Japanese national class is stronger than Japanese junior national class, and that the performance of Japanese national class is rarely influenced by missed shots. It means that the game result could be predicted before the game ends if we knew the difference in the playing teams' shot accuracy. Furthermore, the correlation in world class becomes weaker than Japanese national class because of smaller differences in shot accuracies. It could also be possible that the correlation is negatively influenced by outliers. It can be expected that we could expose the process of how tactics or strategies affect game result or difference in game scores by analyzing the games of outliers.

Otani et al. analyzed correlation of 93 games in Sochi Winter Olympics 2014 to verify the above assumption (Otani et al., 2016). As a result, they confirmed that there is a strong correlation between the difference in shot accuracies and the difference in game scores. Although correlation of the world national top level was lower than the Japanese top level. Additionally, they analyzed game of outliers by focusing on transition of teams' shot accuracies for every end of each game. As a result, they found out that the winning team gave priority to the risk minimizing tactics and led to missed shots performed by the losing team. Therefore, the selected tactics and pressure on the opponent had an impact on game result in which the team with superior shot accuracy lost due to wrong strategical decisions

In curling, the team that plays as a second in turn has a strong advantage. In other words, the plan taken by each team differ depending on starting position. Therefore, to extract strategic tendencies and specific play styles, distinguish Play first from Play second positions in the analysis of game information.

3 TEAM STRATEGIES/TACTICS AND SHOT ACCURACY

Curling is a winter sport in which two teams compete to obtain points by throwing 16 stones at the center of a circular area called a *house* in an ice-based square area called a *sheet*.

One team consists of four players. Each player throws two stones (called *shot*) in rotation, and the score is calculated by each rotation, till all 16 stones are thrown. At this time, the team that has a stone at the nearest position to the center of the house gets the number of points equal to the number of stones on the inside of the opponent's stones in the *house*.

One rotation is called an *end*. One game consists of eight or ten ends, but the game is extended if the score is tied in the final end (Howard, 2009; Coleman, 2014).

Curling is often called "chess on ice" because it is a sport in which tactics plays an important role. It requires a player to form complex strategies in search for effective moves with consideration of the ice condition, stone position in the *house*, etc.

Shots in curling are roughly divided into two types: *draw shot* and *takeout shot*. In *draw shots* the stone stops in the *house*. *Takeout shots* force opponent stones out of the *house*. The thrown shot is given from 0 to 4 points by a team coach or a substitute player. In the special case, such as takeout shot that hits more opposite stones than advised by the skip, 5 points can be given. These points are called "*shot-score*", and shot accuracy (*SA*) is calculated using shot-score according to equation (1). SA has been one of the most important measurements to estimate player's skill and condition.

$$SA = 25 \times \frac{total\ of\ shot\text{-}scores}{number\ of\ shots}(\%) \tag{1}$$

The team which has a higher *SA* is in general capable to throw more accurate shots. Therefore, it gives advantage to the team in the game. The team which has higher *SA* is more likely to succeed when performing the shot in critical situations. And the team which has lower *SA* would raise the probability for scoring by opposite team.

In general, the team that plays as second has an advantage in curling because they can perform the

last shot at an end. Accordingly, the strategies/tactics taken by each team differ depending on whether their playing position is Play first or Play second. In some cases, the strategies/tactics taken by the opposite team are advantageous. In other cases, it is necessary to take the opposite stone out of the house to set advantageous stone position, and put the stone in the house to get a higher score.

The *iCE* application compiles SA databases from the sets of shot scores, to analyze the scores from a variety of viewpoints. To grasp the characteristics and tendencies of each team, we analyzed in detail information in *iCE*'s database containing shot scores. The analysis result could lead to find the difference of strategy between Play first team and Play second team in an objective way.

We formulated a hypothesis that "the relation between SA and final game score (FGS) are different in Play first and Play second", and try to verify the hypothesis in the following parts of the paper based on the game information database.

4 GAME ANALYSIS CONSIDERING PLAY FIRST AND PLAY SECOND

To verify the hypothesis mentioned in Section 3, we compared the relation between difference in *SA* and difference in FGS ($DFGS$) for game information in Play first and Play second. Figure 2 shows the analysis procedure.

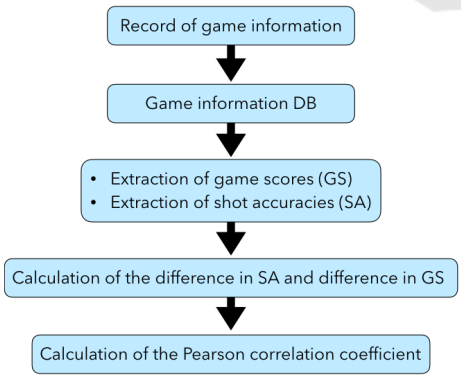

Figure 2: Analysis procedure.

Specifically, we extracted the DFGS and shot accuracy for each collected game. We define the mean value of *SA* regarding all ends as Total Shot Accuracy (TSA), the mean value of SA regarding end for Play first teams as Play first Shot Accuracy ($1stSA$) , the mean value of SA regarding an end for Play second teams as Play second Shot Accuracy ($2ndSA$).

Furthermore, we examined the correlation between DFGS and difference in SA[1] .

As the target data we used the game information of 93 games (45 games for men, 48 games for women) covering around 15,000 shots in Winter Olympic Games 2014 as game data of world national top level. We used the data of World Curling Federation as a reference[2].

5 RESULT OF ANALYSIS

5.1 Comparison of 1stSA and 2ndSA

Here we describe the result of comparative analysis of 1stSA and 2ndSA data. Firstly, we carried out the Shapiro-Wilk test which is one of the tests of normality to confirm normalization for data aggregate of DTSA, D1stSA, D2ndSA, DFGS in target data.

As a result, we confirmed that all data aggregate follows a normal distribution. It means the data can be considered as aggregate extracted at random.

Based on the above, we carried out the T-test which is one of parametric methods directed at data aggregate of D1stSA and D2ndSA to investigate if the differences between the two data aggregates are statistically significant.

We considered that D1stSA and D2ndSA are related data because these data were distinguished from the same team's SA. Therefore, we carried out the paired T-test.

The results were confirmed two that the data aggregates did not have statistical significance.

5.2 Relation between SA and GS

Here we describe the relation between SA and GS separately for Play first and Play second cases. Figure 3 shows a diagram representing a correlation between DTSA and DFGS and a regression line. In Figure 3, the X axis shows DTSA for each game and the Y axis represents the DFGS.

Pearson's correlation coefficient between the two differences for total data was 0.670. It means that the two differences in Figure 3 have positive correlation.

Similarly, we investigated the correlation between P1stSA and DFGS, P2ndSA and DFGS. Figure 4 shows a diagram representing a correlation between

[1]Hereinafter, this is called Difference in Total Shot Accuracy ($DTSA$), Difference in Play first Shot Accuracy ($D1stSA$), Difference in Play second Shot Accuracy ($D2ndSA$).

[2]https://www.olympic.org/sochi-2014/curling

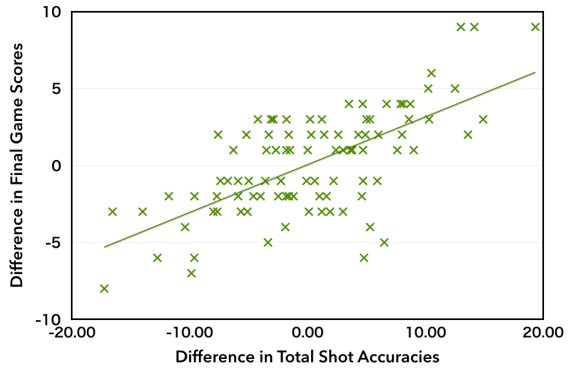

Figure 3: Correlation between DTSA vs. DFGS.

D1stSA and DFGS and regression line and Figure 5 stands for a correlation between D2ndSA and DFGS. The correlation for Play first teams was 0.557 and for Play second teams it was 0.530.

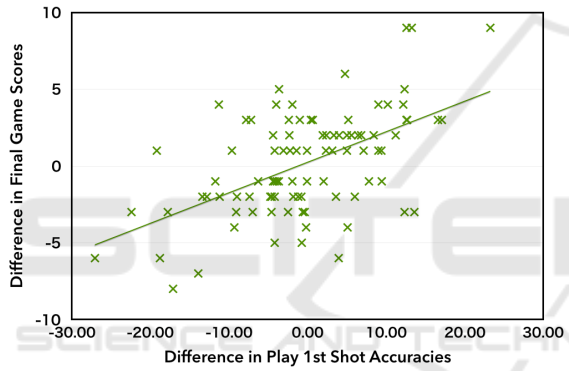

Figure 4: Correlation between D1stSA vs. DFGS.

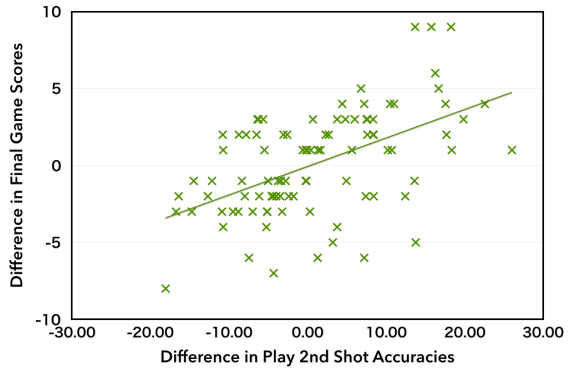

Figure 5: Correlation between D2ndSA vs. DFGS.

Next, we analyzed the correlation for male and female players using a similar technique. Table 1 shows the correlation between between each difference in SA and DFGS separated by sex.

As shown in Table 1, there was a tendency that the correlation between DTSA and DFGS was stronger

Table 1: Pearson's correlation between each difference in SA and DFGS separated by sex.

	All games	men	women
Total	0.670	0.634	0.707
Play first	0.557	0.564	0.545
Play second	0.530	0.532	0.547

than when a team was in Play first and Play second positions. Therefore, we carried out the *test for the hypothesis that several correlations are estimates of the same correlation* (Paul, 1989) to examine the Pearson's correlation between each difference in SA and if DFGS were statistically significant.

As a result of the test, there were no significant differences between the three correlations (DTSA and DFGS, D1stSA and DFGS, and between D2ndSA and DFGS).

Similar results were obtained from game information for men and women, there were no significant differences in all cases.

These results mean that the relation between DTSA and DFGS, D1stSA and DFGS, D2ndSA and DFGS were correlated to the same degree in 93 games from the applied data and the same was true of 45 games for men and 48 games for women.

6 DISCUSSION

In this section, we describe the discussion on analysis results. Primarily, there were no significant differences between correlations when teams were in Play first and Play second positions. Therefore, it dismissed the previously proposed hypothesis that "the relation between SA and GS are different in Play first and Play second". Below we present a detailed discussion to explain this situation.

We focused on SA in target data. Figure 6 shows SA in analysis subject. In Figure 6, the X axis shows SA and the Y axis represents the TSA, 1stSA, 2ndSA.

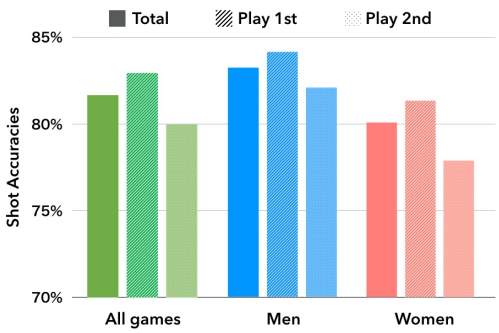

Figure 6: SA divided by sex and playing position.

As Figure 6 shows, there was a tendency that 1stSA were higher than 2ndSA through the whole match. For men, the 1stSA was 84.26%, the 2ndSA was 82.17% and difference between Play first and Play second was 2.09 point. In the SA for women, the 1stSA was 81.84%, the 2ndSA was 78% and difference between Play first and Play second was 3.84 point. These results mean there is a difference of performing 1 or 2 shots per a game.

In addition, SA exceed 80% in all items, except 2ndSA for women. As a reason for 2ndSA for women being lower than others, men players can better adjust the rapidity and curl width of a stone by *sweeping*[3] than women. This indicates that men could be more adjustable than women.

It suggests that there is a difference depending on the starting position and it may be related to shot option and its degree of difficulty.

Next, we investigated the data by focusing on how many of which types of shots were thrown. Figure 7 shows the Ratio of each types of shot in Play first and Play second positions.

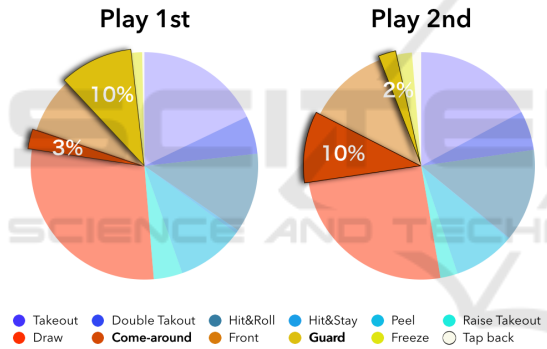

Figure 7: Ratio of shots by types in Play first and Play second positions.

The ratios of each type of shot were different between Play first and Play second. In particular, the ratio of *Guard* shot which is one o the *draw shots* for Play first were performed more often than in Play second. In the *Guard* shot the stone stops in the area outside the *house* to block opponent stones from entering the *house*.

On the other hand, in Play second, the ratio of the *Come - around* shot which goes around the guard stone and stops in the *house* was higher than in Play first.

It can be guessed that the shot requested and its degree of difficulty differ depending on starting position because the player has to perform a shot considering the state of one's own team or the match situation.

This supports our hypothesis that the strategies/tactics taken by each team differed in Play first and Play second starting positions.

From the above, we can propose the following reasons for the lack of significant differences between the relation of shot accuracies and game scores when teams were in Play first and Play second positions. Firstly, game information for world national top level has sufficiently high SA. Secondly, the SA was not parametric which characterizes starting position (Play first or Play second).

In the near future, it is necessary to compare the analysis toward game information other than World national top level. Additionally, it is necessary to extend the analysis on other effective parameters (e.g. throwing number by type of shot) other than SA.

7 CONCLUSION

In this paper, we performed an analysis of game information by considering Play first and Play second positions from a number of curling game matches.

We applied the *test for the equality of several correlation coefficients* directed at each difference in shot accuracies and game scores revealed that, there were no significant differences in all cases.

The result confirmed that there were no significant differences between shot accuracies and game scores when teams were in Play first and Play second positions because players kept a high performance in either case, and retained a stable shot accuracy throughout all ends of the game.

Furthermore, we discussed why it was not possible to confirm a significant difference and indicated a need for other influential parameters than shot accuracy.

In the near future, we plan to record game information of world national top level and analyze it focusing on parameters other than shot accuracy (e.g. throwing number by type of shot) in detail. In addition, we will aim to propose techniques for strategies/tactics analysis considering strategic characteristics.

ACKNOWLEDGEMENTS

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[3]If a shot is weak or turns aside from the desired course, other players sweep the ice surface ahead of the moving stone to adjust the course.

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