In our previous study, we considered that a player’s RSP strategy can be represented by a set of simple typical strategies, and the following four strategy algorithms were assumed as the basic strategies.

1. Simple pattern strategy: SP strategy
2. SP strategy with random elements: SP_R strategy
3. Probability strategy: Pb strategy
4. Probability transition strategy: Pb_T strategy

We clarified the validity of a method for predicting the future hand sign from past hand sign sequences using the hand sign sequences given by these strategy algorithms. The results of the experiment showed that the method of using genetic programming is effective for strategies 1 and 2, and the method of using the tug-of-war dynamics is effective for strategies 3 and 4 [3].

The effective prediction method of a player’s hand sign sequences differs in accordance with the opponent’s strategy, as described above. If it is possible to estimate the strategy of the opponent, a more effective prediction method can be applied. Then, the accuracy of the player’s hand sign prediction can be improved. Therefore, the purpose of this study is to propose a method of estimating the strategy of the players in the RSP game.

To estimate a player’s RSP strategy, it is effective to compare the player’s hand sign sequences and the hand sign sequences given by each typical strategy algorithm on the basis of similarity. Therefore, in this study, we focused on the method for calculating the similarity between sequences using a homology search.

First, we explain the four strategy algorithms assumed to be the elements of a person’s RSP strategy. Next, our previous study is summarized. Finally, we explain the RSP strategy estimation method proposed in this study. We show the results of evaluating whether the proposed method is effective for estimating the RSP strategy.
2. Human Strategy in RSP Game

Here, we explain the four typical strategy algorithms assumed to be elements of human strategy in the RSP game.

2.1 Simple pattern (SP) strategy

In the SP strategy, a short pattern of rock, scissors, paper, which are the hand signs of the RSP game, are repeatedly output. For example, the strategy of repeating the order of “rock, scissors, paper, scissors, paper” can be expressed as a type 5 pattern strategy. This example is denoted as SP5.

2.2 SP strategy with random elements (SP_R) strategy

The SP_R strategy is a strategy in which there is a random hand sign every fixed number of outputs in the SP strategy pattern. For example, in a strategy of outputting a random hand sign to replace every third output of the 5 pattern strategy “rock, scissors, paper, scissors, paper”, the sign output is as follows: “rock, scissors, (random hand sign), scissors, paper, (random hand sign), scissors, ...”. This pattern is denoted as SP5_R3.

2.3 Probability (Pb) strategy

The Pb strategy has a bias in the output probability of "rock, scissors, paper" hand sign. For example, the output probabilities of "rock, scissors, and paper" are respectively biased as 10%, 10%, and 80%. This example strategy is denoted as PS101080.

2.4 Probability transition (Pb_T) strategy

In the Pb_T strategy, the output probabilities of hand signs are changed every certain number of repetitions of the Pb strategy. For example, when the initial output probabilities of “rock, scissors, paper” are 10%, 10%, 80%, the output probabilities undergo the transitions 10%, 10%, 80% → 80%, 10%, 10% → 10%, 80%, 10% → 10%, 10%, 80% → ... Here, this strategy is denoted as PTS101080.

3. The Results of Our Previous Studies

In our previous studies, we verified the effectiveness of three methods of predicting a player’s hand sign sequence using the four typical RSP game strategy algorithms described in the previous section. The three prediction methods are as follows. The results are shown in Table 1.

- **Method of using genetic algorithm: GA method**
- **Method of using genetic programming: GP method**
- **Method of using tug-of-war dynamics: ToW method**

As shown in Table 1, the GA method is effective for the SP strategy and the Pb strategy, the GP method is effective for all strategies except the Pb_T strategy, and the ToW method is effective for the Pb strategy and the Pb_T strategy. These results indicate that it is possible to cover all strategies by using the GP method and the ToW method. Therefore, if it is possible to estimate an opponent’s strategy, there is a possibility that a more effective behavior prediction method can be applied.

To estimate the opponent’s strategy, it is effective to compare the opponent’s hand sign sequences and the hand sign sequences given by each typical strategy algorithm on the basis of similarity. As a method of finding the similarity between hand sign sequences, a homology search (HS) is applied.

Table 1: Characteristics of each behavior estimation method

| Method / Strategy | SP strategy | SP_R strategy | Pb strategy | Pb_T strategy |
|-------------------|-------------|---------------|-------------|---------------|
| GA method         | ✓           | ▲             | ✓           | ▲             |
| GP method         | ✓           | ✓             | ✓           | ▲             |
| ToW method        | X           | X             | ✓           | ✓             |

✓ indicates valid. ▲ indicates no effect. ▲ indicates low effect.

4. The RSP Game Strategy Estimation Method Using Homology Search

4.1 Homology search (HS)

An HS is an operation of searching for sequences similar to the query sequence from the comparison database to estimate the characteristics of the query sequence. It calculates the similarity between the query sequence and each sequence in the comparison database.

Many methods have been proposed for calculating the similarity between sequences used for an HS [4][5]. In this study, we use the Needleman–Wunsch algorithm.

4.2 Needleman–Wunsch algorithm (NW)

In the NW, the similarity between sequences A and B with sequence lengths N and M is calculated from the following equations. The degree of similarity between sequences is $D_{N,M}$.

$$D_{i,j} = \max \left( \begin{array}{c} D_{i-1,j-1} + S(A_i, B_j), \nonumber \\
D_{i-1,j} + \text{Gap}, \\
D_{i,j-1} + \text{Gap} \end{array} \right)$$

$$i = \{1, ..., N\}, j = \{1, ..., M\}$$

$$D_{0,0} = 0, D_{i,0} = \text{Gap} \times i, D_{0,j} = \text{Gap} \times j$$

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In Eq. (1), \( A_i \) is the \( i \)-th element of sequence A and \( B_j \) is the \( j \)-th element of sequence B. \( \text{Gap} \) is the penalty parameter. Then, function \( S \) returns the preset value in the score matrix on the basis of the combination of arguments \( A_i \) and \( B_j \).

Here, the score matrix is a parameter matrix of similarity between the elements of sequences. The score matrix is generally determined using the degree of similarity or replaceability between the elements. In this study, we set +1 when the combination of elements is a match, and −1 in the case of a mismatch. When the elements of hand sign sequences in the RSP game are “R, S, P”, the score matrix shown in Table 2 is obtained.

### Table 2: Score matrix

|   | R  | S  | P  |
|---|----|----|----|
| R | 1  | -1 | 1  |
| S | -1 | 1  | -1 |
| P | 1  | -1 | 1  |

Figure 1 shows the flow of calculations of Eq. (1). As shown in Fig. 1, the degree of similarity between sequences can be calculated by sequentially calculation from the upper left to the lower right.

\[
\begin{array}{cccccc}
A_1 & D_{1,0} & D_{1,1} & \cdots & D_{1,M} \\
D_{0,0} & D_{0,1} & \cdots & \cdots & D_{0,M} \\
\vdots & \vdots & \ddots & \ddots & \vdots \\
D_{N,0} & D_{N,1} & \cdots & D_{N,M} \\
B_j & \cdots & \cdots & \cdots & B_M \\
\end{array}
\]

Figure 1: Flow of calculation in NW

4.3 Application to RSP game strategy estimation

To apply the HS to strategy estimation in RSP games, it is necessary to make databases for the comparison of hand sign sequences (hereinafter, called “databases”). Therefore, in this study, to prepare the database, a certain number of hand sign sequences are generated using the four typical RSP game strategy algorithms described in Section 2. In the SP strategy, the output hand sign sequence is constant for each short pattern of rock, scissors, paper. Therefore, we use many short patterns and generate one sequence for each short pattern. On the other hand, the SP_R strategy, Pb strategy, and Pb_T strategy output sequences that are not constant. Thus, the sequences in each database are generated at random.

Next, the opponent’s hand sign sequence (hereinafter, an “opponent’s sequence”) is set as a “query sequence”, and an HS is performed using each database. As a result, the maximum degree of similarity between the opponent’s sequence and the comparison sequences can be calculated for each database. In addition, it is expected that the higher the degree of similarity between the sequences, the greater the similarity between the strategies. Therefore, in this study, the degree of similarity between sequences obtained by the proposed method is used as the degree of similarity between RSP strategies.

Figure 3 shows the flow of calculating the maximum degree of similarity for each database by performing an HS on the opponent’s sequence.

5. RSP Strategy Estimation Experiment

To show the effectiveness of our proposed method, we
show the results of the RSP strategy estimation by the proposed method.

In the experiment, we prepared a total of 18 types of RSP strategies on the basis of the typical RSP strategy algorithm described in Section 2. We set the hand sign sequence given by these 18 RSP strategies as the opponent’s sequence. The list of prepared RSP strategies is shown in Table 3.

Table 3: Opponent’s RSP strategies

| SP strategy | SP_R strategy | Pb strategy | Pb_T strategy |
|-------------|---------------|-------------|---------------|
| SP3         | SP3_R3        | PS101080    | PTS101080     |
| SP4         | SP4_R3        | PS202060    | PTS202060     |
| SP5         | SP5_R3        | PS303040    | PTS303040     |

Then, we calculated the degree of similarity between the opponent’s 18 strategies and each of the four typical strategy algorithms by the proposed method. The results are summarized in Table 4. Table 4 shows the average of the maximum degree of similarity in each database obtained by performing an HS 100 times for each opponent’s RSP strategy. Here, the opponent’s sequence is randomly generated every time the HS is performed.

As described in Section 4.3, the degree of similarity between the sequences obtained here can be regarded as the degree of similarity between strategies. That is, if the HS score between the sequences is high, the similarity between the strategies is also high.

The numbers in bold in Table 4 represent the maximum degree of similarity in each row. For example, we find that the opponent’s strategy SP3 is similar to the SP strategy. From these results, it can be considered that the strategy estimation is performed with high accuracy by our proposed method.

From the results, it was found that the opponent’s strategy could be estimated correctly, except when it was PS303040. This suggests that the proposed method does not perform well when the randomness of the RSP strategy is high. However, it is natural that estimating the strategy of the random sequence is difficult. Thus, we can conclude that our proposed method is effective for opponent’s strategy estimation.

6. Conclusion

From the results of previous studies, we had concluded that applying an appropriate estimation method of RSP game strategy would be effective for predicting the hand sign sequence in the RSP game. For that purpose, it is effective to compare the similarity between the opponent’s hand sign sequence and the hand sign sequences calculated using each strategy algorithm. Therefore, we focused on a homology search (HS), which can be used to evaluate the similarity between the sequences.

In this study, we investigated whether the RSP strategy could be estimated by using an HS. As a result, the HS was found to be effective in estimating the RSP game strategy with a certain accuracy.

As a future task, we will investigate whether changing the values of the score matrix and penalty parameter affects the result. Then, we will investigate whether using other similarity calculation methods affects the result. Furthermore, we will investigate whether the proposed method is effective for estimating the human RSP strategy.

Table 4: Degree of similarity between opponent’s strategy and each strategy algorithm (average of 100 trials)

| Opponent’s hand sign strategy | RSP strategy algorithm |
|-------------------------------|------------------------|
|                               | SP         | SP_R        | Pb          | Pb_T        |
| SP                            | SP5        | 50.00       | 43.05       | 28.88       | 24.15       |
| SP4                           | SP5        | 50.00       | 43.36       | 27.82       | 24.22       |
| SP5                           | SP5        | 50.00       | 44.20       | 28.01       | 24.04       |
| SP_R                          | SP4_R      | 32.86       | 37.98       | 26.90       | 24.46       |
|                               | SP3_R      | 33.78       | 40.11       | 26.15       | 24.48       |
|                               | SP3_R      | 36.34       | 42.58       | 27.28       | 24.30       |
|                               | SP4_R      | 29.41       | 36.36       | 25.72       | 24.24       |
|                               | SP4_R      | 37.44       | 41.66       | 27.44       | 24.31       |
|                               | SP5_R      | 36.72       | 42.40       | 26.99       | 24.23       |
|                               | SP5_R      | 29.03       | 36.48       | 24.95       | 24.05       |
|                               | SP5_R      | 34.30       | 40.15       | 25.53       | 24.45       |
|                               | SP5_R      | 39.74       | 43.70       | 26.55       | 24.22       |
|                               | PS101080   | 30.51       | 35.05       | 37.03       | 22.99       |
|                               | PS202060   | 22.43       | 27.14       | 27.49       | 23.78       |
|                               | PS303040   | 17.56       | 23.33       | 23.10       | 24.06       |
|                               | PTS101080  | 5.97        | 15.29       | 19.37       | 28.66       |
|                               | PTS202060  | 12.64       | 19.79       | 21.95       | 24.91       |
|                               | PTS303040  | 16.69       | 22.62       | 22.76       | 24.06       |

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