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Implementation of Kendo Attack Predictive System Using Markov Chain

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Abstract: Recently, the use of various statistical techniques including IT technology and mathematical technique in establishing strategies and tactics for improving the athletic performance in the sports field has been made around popular events such as baseball and soccer. However, such studies are also needed for unpopular events for the development of society-wide living sports. This study used the Markov chain, a mathematical technique that sequentially records the attack data of a specific player through video reading of the kendo match and then, predicts the future changes based on the status of the past to probabilistically predict the next attack area of the player. This study analyzed the attack data of the kendo match and implemented the predictive system using a Markov chain model and as a result, we obtained the prediction success rate of 78%. It is expected that it will be able to contribute to efficient strategy establishment and match operation of athletes and coaches during the Kendo match. In the future, in order to solve the problem that the player's intuition is involved according to the defensive posture of the opponent and the flow of the match and a relatively low probability of attack is made, a study to supplement the predictive system by substituting the defense pattern of the defensive player with the prediction formula using the attack data of the attacker should be continued.

Key words: Markov chain, Kendo, probability model, predictive system, data analytics, prediction

INTRODUCTION

In modern sports, the context analysis and prediction have a major impact on victory and defeat which acts as one of the most important factors for athletes and coaches. The analytical method is also changing from an empirical method relying on existing people to a quantified method using statistics which can get more accurate results and many attempts (Bukiet *et al*., 1997) have been made to predict the outcome of a match based on such match data. As a result, IT technology and statistics are currently used to establish match strategies in various sports events. In fact, it helps athletes or teams to develop strategies, improve athletic performance and coaching skills.

This study analyzed the kendo match of these various sport fields to carry out a study to predict the opponent's next move. In particular, Kendo is a 1:1 individual event, so, it is important that individual players improve their skills unlike group events but the effectiveness of guidance and training programs implemented in a coaching environment is determined by the coach who practices the program (Kim and Kwon, 2006). It can be also seen that physical characteristics, exercise and training factors, physiological factors, epidemiological factors and psychological factors affect the victory and defeat of all sports games and especially, Kendo is a match played through direct physical contact with the opponent as a martial arts sport, indicating that physical characteristics are important (Kim and Park, 2006). However, the existing studies are focused on understanding of the scoring areas of the fragmentary kendo match and the conscious structure of kendo players, etc., not meeting the expectation of the information about the mutual use of information on technology and skills (Gi-Hong and Tae-Won, 2009).

In order to complement these problems and improve the athletic performance of kendo in recent years, many studies have been conducted in various forms different from the existing ones. Representative studies include a study to identify the clear behavioral dynamics by analyzing the change of interpersonal distance in a Kendo match (Okumura *et al*., 2012) and a study on the method of predicting motion using Gaussian Mixture Model

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(GMM) with the data measured by motion capture system using markers attached to athlete's joints, etc. (Tanaka and Kosuge, 2014). This study implemented a system that predicts the next attack by using the Markov chain analysis technique after receiving the attack data of the player. Based on the results obtained through this study, it is expected that leaders will be able to improve the athletic performance of the athletes by identifying the attack method of each player in advance and appropriately operating the match accordingly.

Literature review

Markov chain: The Markov chain is a probability model developed by the Russian mathematician Markov which refers to a process in which the interstate transition depends solely on previous n states (Kim *et al*., 2006). The Markov chain shows the state change of the system over time and every hour, the system transfers or maintains the same state. The chain feature means that when the past and present states are given, the probability of occurrence of the future state is determined by the influence of the present state independently of the past state. That is, if regarding X(t), X(t+1) and {X(k), ≤t-1} as the current state, the future state and past state , respectively, Markov chain is expressed as Eq. 1:

$$P[X(t_{k+1}) = x_{k+1} \mid X(t_k) = x_k, ..., X(t_1) = x_1] = P[X(t_{k+1}) = x_{k+1} \mid X(t_k) = x_k] \quad (1)$$

Generally, the discrete Markov process is called Markov chain and the Markov process is composed of set of states, initial state probability and transition probability matrix. This Markov chain is a mathematical technique that analyzes the dynamic state characteristics of the past to predict future changes (Miller and James, 1997) and studies are conducted in various fields.

Kendo effective attack area: The attack areas of Kendo are four of the head, the wrist, the sting, the waist and points are scored by effectively hitting these areas with a bamboo knife. In addition, the attack patterns can be classified into three types of 'before of before; 'before; and 'before of after'. Of the three patterns above, 'before of before' and 'before' which are hard to tell in a match and can be considered the same pattern in a certain portion are brought together to divide them into two patterns of 'before' and 'before of after' and each pattern is applied to four areas of the head, wrist, sting and waist to divide them into eight attack patterns of 'head of before', 'wrist of before', 'sting of before', 'waist of before', 'before head of after', 'before wrist of after', 'before sting of after', 'before waist of after' (Kim *et al*., 2016). Previous studies have analyzed and reported effective attack patterns for four areas of the head, wrist, sting, waist using SPSS, which is a statistical analysis technique without distinguishing the patterns of 'before' and 'before of after' (Lee, 2015).

Predictive analytics system: Predictive analytics is the use of modeling, machine learning or data mining to analyze current or past facts to predict future or unknown events (Wikipedia, 2017). Currently, as the success cases are increasing due to the advent of big data systems and artificial intelligence technology, the application fields and the predictive techniques of predictive analytics are becoming more and more diverse. Studies that can increase crime prediction probability by analyzing the number of past crime types applying Markov chain (Chung *et al*., 2012) and cases that use the analysis of large logs using BigData and utilize the BigData analysis framework for intelligent, long-term security analysis are increasing (Lee and Lee, 2015).

MATERIALS AND METHODS

Structure of attack predictive system: The predictive system consists of three parts as shown in Fig. 1. The first is a stage that processes the attack data to facilitate analysis. Based on the player's attack on the head, wrist, sting and waist during the kendo match to draw an effective blow, each state is defined as the state of S1-head, S2-waist, S3-wrist, respectively. The sting attack was not covered in this study because the frequency of attacks is significantly low.

The second is the data prediction stage. Data prediction uses the Markov chain model to calculate the transition matrix and the initial probability. The transition matrix is a probability representation of the transition state between defined states. It lists the state values, obtains the number of transition from one state to another and then, expresses it as a matrix and the equation is as shown in Eq. 2 and the conditions of Eq. 3 should be satisfied.

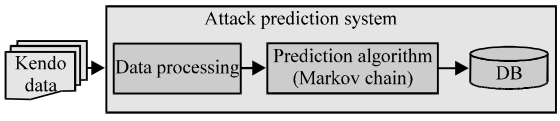

Fig. 1: Attack prediction system structure

$$P = \begin{bmatrix} P_{11} & P_{12} & \cdots & P_{1n} \\ P_{21} & P_{22} & \cdots & P_{2n} \\ \vdots & \vdots & P_{ij} & P \vdots \\ P_{n1} & P_{n2} & \cdots & P_{nn} \end{bmatrix} \quad (2)$$

$$P_{ij} \geq 0, \sum_{j=1}^{n} P_{ij} = 1 i = 1, 2, ..., n \quad (3)$$

The initial probability defines values that can be obtained in the initial state and is defined accordrtding to Eq. 4:

$$P(S_1, S_2, ..., S_n) = P(\frac{a}{F}, \frac{b}{F}, ..., \frac{c}{F}) \quad (4)$$

The third is a stage that stores the attack probability data calculated through the attack data entered and the prediction equation.

Data collection and measurement: To collect the basic data for this study, we selected three matches each among championship records of 3 players including Takenouchi who is the winner of the 62nd championship in 2014, Umegatani who is the prize winner of the 63rd championship in 2015 and Katsumi who is the winner of the 64th championship in 2016 among world-renowned Japan Kendo championships. In order to analyze the attack order of the attackers during the 9 selected matches, three referees of 6 dan or higher qualified by the Korea Kumdo association analyzed and recorded the contents of the recorded target matches. The reliability of the attack records was improved through cross validation of the results organized by each referee in the process of recording. In addition, the criteria for a measurement table recording that analyzes the match contents are to create a measurement table based on three types of attacks, which are the most frequent among the four attacks of 'head', 'wrist', 'waist' and 'stin' to distribute it to a qualified referee and to record the order of attackers' attack in the measurement table. Table 1 shows the attack data measured through this.

Table 1: The 62, 63, 64 All Japan Kendo Championship-Attack data of 3 contestant

Takenouchi 62nd All Japan Kendo Championship			Umegatani 63rd All Japan Kendo Championship			Katumi 64nd All Japan Kendo Championship		
Match 1 attack	Match 2 attack	Match 3 attack	Match 1 attack	Match 2 attack	Match 3 attack	Match 1 attack	Match 2 attack	Match 3 attack
Head	Head	Wrist	Head	Head	Head	Head	Wrist	Head
Head	Head	Wrist	Head	Wrist	Head	Head	Head	Waist
Head	Head	Head	Head	Waist	Wrist	Head	Wrist	Head
Head	Head	Head	Wrist	Wrist	Waist	Head	Head	Head
Head	Head	Head	Waist	Head	Head	Wrist	Head	Head
Waist	Head	Head	Head	Waist	Head	Waist	Head	Wrist
Head	Head	Wrist	Wrist	Waist	Head	Head	Head	Head
Head	Head	Head	Head	Head	Head	Wrist	Wrist	Head
Head	Wrist	Wrist	Head	Wrist	Waist	Wrist	Wrist	Wrist
Wrist	Wrist	Head	Head	Head	Wrist	Wrist	Head	Head
Head	Head	Wrist	Wrist	Head	Waist	Head	Wrist	Wrist
Head	Head	Waist	Head	Head	Head	Wrist	Waist	Head
Wrist	Wrist	Wrist	Wrist	Wrist	Head	Wrist	Head	Head
Head	Waist	Head	Waist	Wrist	Wrist	Head	Head	Wrist
	Head	Wrist	Wrist	Wrist	Head	Wrist	Head	Head
	Waist	Head	Wrist	Waist	Wrist	Head	Wrist	Head
	Head	Head	Head	Wrist	Head	Head	Waist	Head
	Head	Head	Head	Wrist	Head	Head	Head	Head
	Head	Head		Wrist	Wrist	Head	Head	Head
	Wrist	Wrist		Wrist	Wrist		Head	Wrist
	Head			Head	Wrist		Head	Waist
	Wrist			Wrist	Head			Head
				Wrist				Head
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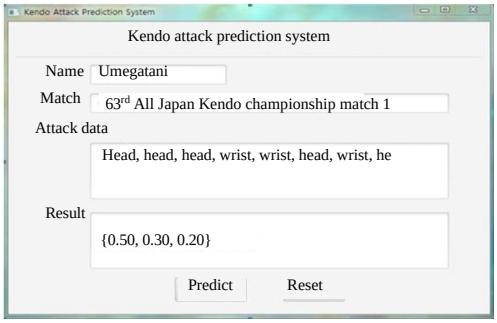

Fig. 2: Attack prediction system result

Attack predictive system: The pseudocode of the attack predictive system is shown in Fig. 2. Attack data is entered through the system UI (User Interface). The input data goes though data processing and is converted into S1-head attack, S2-wrist attack and S3-waist attack which are predefined status codes. The transformed values are transformed into a matrix by the transition matrix of the Markov chain. The initial probability was defined as recent 5 attack values and is obtained by Eq. 4. The next attack is predicted by multiplying the two values obtained by the matrix. Both attack data and prediction data are stored in the database (Algorthm 1).

Attack prediction system pseuoocode

```
class Kendo Markov {
    STATE state value define
    STATE_PROBABILITY_COUNT assignment probability count

    READ Kendo attack data

    IF there is a new Kendo attack data THEN

        TRANSITION_MATRIX make a transition matrix

        IF make a transition matrix THEN

            FOR 0 to probability count
                get start probability value
            ENDFOR

            BEGIN
                make a start_probability matrix
                Atrithmetic matrix

                DATABASE Kendo data save

            EXEPTION
                WHEN transition matrix
                    transition matrix error
                WHEN start probability
                    start probability error
                WHEN database
                    Database error

            END
        ELSE
            transition matix error
        ENDIF
    ELSE
        Kendo data error
    ENDIF
}
```

Table 2: Takenouchi, Umegatani, Katumi attack prediction result

	Takenouchi			Umegatani			Katumi		
Measure	S1	S2	S3	S1	S2	S3	S1	S2	S3
Match 1	0.88	0.08	0.04	0.50	0.30	0.20	0.53	0.44	0.03
Match 2	0.68	0.21	0.11	0.40	0.43	0.17	0.69	0.25	0.06
Match 3	0.56	0.39	0.05	0.43	0.34	0.23	0.70	0.21	0.09

RESULTS AND DISCUSSION

Figure 2 shows the result of analyzing match 1 of player Umegatani using the attack predictive system. If, we predict the next attack of the player through this research system, S1 (head attack), S2 (wrist attack) and S3 (waist attack) are expected to occur with a probability of 0.50, 0.30 and 0.2, respectively. In fact, the next attack is a head attack, indicating that the prediction formula was valid.

Table 2 comprehensively analyzes the results of predicting the next attack of all athletes by the above method. We predicted the probability of the next attack of three players and it was found that player Takenouchi showed the results of match-1 match, match-2 mismatch, match-3 mismatch and three attacks matched the probability of the prediction formula in the attacks of player Umegatani and player Katumi. Based on the above results, it was concluded that it is possible to predict the next attack area probabilistically through the normal attack order of each player. As in the case of match 2 and 3 of player Takenouchi, however, the next attack is expected as S1 but sometimes, the relatively unlikely attack of S2 is done. This is because the player's intuition was involved according to the opponent's defensive posture and the situation of the game.

CONCLUSION

The Markov chain applied in this study is a mathematical technique that predicts changes in the future based on observation of past changes and this study implemented a system to predict the next attack through previous attack data by observing the order of attack of kendo players.

For data for system implementation, we analyzed a total of 9 matches, 3 for each player, based on the top three prize winners of the Japan Kendo championships in 2014-2016, entered the attack data of the players into the system and analyzed them to expect the final attack of the players. As a result, we predicted 7 attacks out of 9 prediction attempts, obtaining the success rate of about 78%. Based on the results obtained through the attack predictive system implemented in this study, it is expected that leaders will be able to improve the athletic performance of the athletes by identifying the attack

method of each player in advance and appropriately operating the match accordingly. In order to solve the problem that the player's intuition is involved according to the defensive posture of the opponent and the flow of the match and a relatively low probability of attack is made, future studies need to secure more attack data per player and analyze them. In addition, studies to supplement the predictive system by substituting the defense pattern of the defensive player with the prediction formula using the attack data of the attacker should be continued.

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