Do Professional Football Players Follow the Optimal Strategies in Penalty Shootout?

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Abstract: Do people and companies choose optimal strategies under various situations? If not so, why not? Pursuing the reason for this helps to understand individuals and companies. In addition, game theory has been heavily involved in the understanding of sports, economics and other social sciences. In this study, we focused on football's penalty shootout where data is relatively easy to collect, mixed strategy can be applied and making a pay-off matrix considering our own probability is possible. Using the pay-off matrix, we obtained optimal strategy of the kicker in the penalty shootout and revealed the gap between the optimal strategy and actual action taken by players. We compared the probability distribution for each data attribute in the dataset in order to obtain the cause of the gap. We use 100 professional penalty shootouts (total 1032 kicks) which were collected from internet video site during the period from 2001-2016. Experimental results showed that there was a gap between the optimal strategy and the actual action taken by players and that it also suggested the position and team attributes and temporary scores of the shootout and kicking order involved in the gap. Considering them we made the hypothesis and estimated the cause of the gap. We hope this method can apply to other fields than sports.

1 INTRODUCTION

'Optimal strategy' is defined the strategy which is played to maximize their own profit by the subject without cooperation with others. The study has been done to find optimal strategies in various fields such as optimal investment behavior (Anderson et al., 2008) in the economic fields and optimal strategy of serve in tennis (Gale, 1971) in sports fields.

However, it is another question whether the optimal strategy matches the actual strategy taken by players. Because even if people and companies are aware of the optimal strategy for the things, they have the possibility not to follow the strategy because of the environmental or psychological factors. In other words, there is a gap between optimal strategy and actual strategy taken by players. Identifying the cause of the gap helps to understand the psychological state in the decision making of people and companies.

This study deals with football's penalty shootout. The penalty shootout takes place when there is no score difference after the specified game time has gone. Five kickers from each team alternately play penalty kick(IFBA, 2016) (hereinafter, this is called 'PK') and compete for their number of success. Only when it can not be determined at the end of 10 people, they take the sudden death system.

The reasons for focusing on football PK game in this paper are as follows.

- Relatively easy to collect data.
- Since player's decision is made before the kicker's kick (Peiyong and Inomata, 2012), we can play game theoretic approach using mixed strategy.
- In the penalty shootout, the optimal strategy may differ from the actual strategy taken by players because the environmental or psychological influence greatly affects the performance (Jordet et al., 2007).

The flow of this study is divided into three steps: Firstly we got an optimal strategy in the penalty shootout. We created a goalkeeper (hereinafter, this is called 'GK')'s pay-off matrix considering failure rate fk_i, fg_j, and clarified the kicker's optimal strategy by using Minimax. Next, we examined there was a gap between the actual data and the optimal strategy. Finally, we extracted the data attributes which are considered to affect the gap. By referring this attribute, we made the hypothesis and estimated the cause of the gap.

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2 KICKER'S OPTIMAL STRATEGY

In this section, we describe how to make GK's pay-off matrix and to get kicker's optimal strategy.

2.1 GK's Pay-off Matrix

In this paper, we consider the direction of the player's strategy in the penalty shootout to three directions : left, center, right, which tear the goal into three equal parts as seen from the kicker like Fig.1. Let π_{ij} be the GK's pay-off. i and j represent kicker's strategy and GK's strategy each other. i,j∈{L (left),C (center),R (right)} is player's strategy.

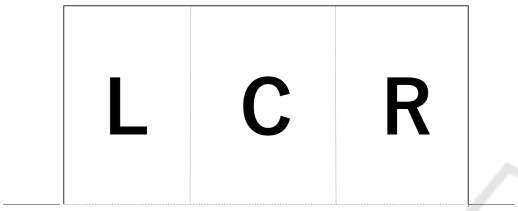

Figure 1: Definition of direction.

Now, we consider that GK's pay-off is '1' when GK's action matches the kicker's action because GK can block the score, and GK's pay-off is '0' when GK's action is different from kicker's action because GK can not block the score. Then GK's pay-off is π_{ij} =1 (i=j) and π_{ij} =0 (i≠j). However, this GK's pay-off ignores the situation that GK fails to block the score even if GK's action matches the kicker's action and kicker fails to score even if GK's action is different from kicker's action.

In this study, we use the failure rate fg_j, fk_i.Let N_j^g be the number of i=j and n_j^g be the number of situation that GK can not block score even if GK's action matches the kicker's action (i=j). Similarly, Let N_i^k be the number of i≠j and n_i^k be the number of situation that kicker can not score even if GK's action is different from the kicker's action (i≠j). At this time, failure rate fg_j, fk_i are defined as follows.

$$fg_j = \frac{n_j^g}{N_j^g} \tag{1}$$

$$fk_i = \frac{n_i^k}{N_i^k} \tag{2}$$

A pay-off matrix considering the failure rate is shown in Table 1.

2.2 Kicker's Optimal Strategy

By using GK's pay-off matrix, we calculate kicker's optimal strategy. First, we calculate expected value μ_j of the pay-off in order to get the GK's optimal strategy. Let p_i be the probability that the kicker choose the action i. Then we calculate the expected value μ_j of the pay-off at each of j∈ L, R, CWe compare mu_j in each j = L, R, C and make the strategy with the highest pay-off the GK's optimal strategy. In addition, We also visualized this by mapping to the three-dimensional space of p_R on the x axis, p_L on the y axis and μ_j on the z axis. Let this three-dimensional space be .

Table 1: GK's pay-off matrix considered failure rate.

i \ j	L	C	R
L	1-fg_L	fk_L	fk_L
C	fk_C	1-fg_C	fk_C
R	fk_R	fk_R	$1-fg_R$

By applying the Minimax method to GK's optimal strategy, we got the kicker's optimal strategy. The Minimax is a method by which a subject selects a strategy so that the opponent's pay-off is minimized.

3 THE GAP

Firstly, we found the center of gravity of the kicker's optimal strategy in space in order to obtain the gap between the optimal strategy and actual strategy taken by players. After that, we calculate the gap by comparing the probability distribution of the comparison object with the center of gravity.

3.1 Center of Gravity

In this section, we obtain the center of gravity of the kicker's optimal strategy on the GK's optimal strategy. By finding the center of gravity of the area with the smallest pay-off of the GK, we can reveal the optimal strategy within . Firstly, the GK's optimal strategy which is expressed in three-dimensional space is projected into a two dimensional plane of p_R on the x-axis and p_L on the y-axis. In order to calculate the center of gravity a grid of 0.01 × 0.01 is placed on the area corresponds to GK's optimal strategy. The point (u,v) is the center of gravity of the area if and only if:

(1) the number of grids for x < u is equal to the number of grids for x > u, and

(2) the number of grids for y < v is equal to the number of grids for y > v.

3.2 Calculating the Gap

Now, we describe how to find a gap between the optimal strategy and the actual strategy taken by players.

Let a^z be a number of the kicker who satisfies a condition z (eg defender) and a_i^z be the number of the kickers who choose the action i and satisfy z. Then, the condition z is represented by the following coordinate in the X-Y plane of the :

$$(\frac{a_R^z}{a^z}, \frac{a_L^z}{a^z}) \quad (3)$$

In addition, let d be the distance between center of gravity and $(\frac{a_R^z}{a^z}, \frac{a_L^z}{a^z})$. The d represents the gap from the optimal strategy and is used as an evaluation metric in this study.

4 EXAMINATION AND RESULTS

4.1 Dataset

The dataset used is 100 professional penalty shootouts (total 1032 kicks) which are collected from internet video sites[1] during the period from 2001-2016. The data includes 17 attributes, specifically date, number of spectators, team name, opponent team name, kicking order, choice of the first kick or the second kick[2], the country where the game took place, direction kicked, direction to which GK flew, PK kicker information (player name, position, nationality, dominant foot), and GK information (player name, nationality, height).

4.2 Calculating GK's Pay-off Matrix

We make a GK's pay-off matrix by the method explained in 2.1. In this study, the probabilistic model is created for each of the dominant feet of the PK kickers. In previous work, varying psychological characters were observed among right-footed and left-footed players (Dane and Şekertekin, 2005), and statistically, it was identified that there is a clear difference in the strategic decision of penalty shootout (Palacios-Huerta, 2003). Actually, different trends were also seen in the preliminary experiments in the dataset of this study, thus we consider that it is natural to divide probability models with respect to the dominant foot.

Firstly, we calculate failure rate fg_j, fk_i in each dominant foot. The result is shown in Table 2. The GK's pay-off matrix for right-footed using this is shown in Table 3, for left-footed is shown in Table 4.

[1]https://www.youtube.com/

[2]The referee tosses a coin and the team whose captain wins the toss decides whether to take the first or the second kick. (IFBA, 2016)

Table 2: Failure Rate.

	fg_R	fg_L	fg_C	fk_R	fk_L	fk_C
right	0.523	0.610	0	0.097	0.070	0.170
left	0.575	0440	0	0.121	0.018	0.342

Table 3: GK's pay-off matrix (right-footed).

i \ j	L	C	R
L	0.391	0.070	0.070
C	0.170	1	0.017
R	0.097	0.097	0.477

Table 4: GK's pay-off matrix (left-footed).

i \ j	L	C	R
L	0.561	0.018	0.018
C	0.342	1	0.342
R	0.121	0.121	0.425

4.3 Calculating Kicker's Optimal Strategy and Center of Gravity

We calculate the kicker's optimal strategy and center of gravity from the results in Section 4.2. Fig.2 and Fig.3 show the kicker's optimal strategy and center of gravity for each dominant foot respectively, calculated by the method described in Section 2.2 and 3.1. The x axis represents the probability of kicker kicking to the right p_R. The y axis represents the probability of kicker kicking to the left p_L, and the z axis is GK's expected pay-off μ_j. We get the kicker's optimal strategy by applying these GK's optimal strategy to Minimax.

From Fig.2 and Fig.3, we can see that the closer p_R and p_L get to 0, the more GK's expected pay-off gets for both right-footed and left-footed. From this result, it is found that the kicker should avoid to aim to the center, and on the contrary, GK's the pay-off is low in the area μ_j : 0.25-0.3 in each dominant foot, thus this area is considered kicker's optimal strategy.

In order to know the more accurate optimal strategy, we obtain the center of gravity in the pay-off area of μ_j : 0.25-0.3. By determining the center of gravity it becomes possible to represent the kicker's optimal strategy by one coordinate. As a result, the center of gravity is (0.51, 0.41) and (0.33, 0.60) respectively in right-footed left-footed as visualized by cross mark. There is also a difference depending on the dominant foot. We find that right-footed and left-footed kicker's optimal strategy is right and left, respectively, which means that the optimal strategy is different depending on the dominant foot.

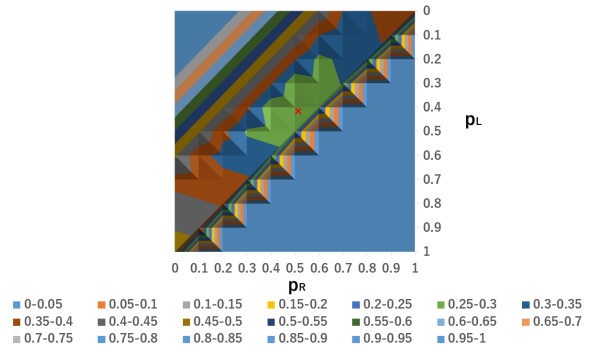

Figure 2: Center of gravity in kicker's optimal strategy area (right-footed).

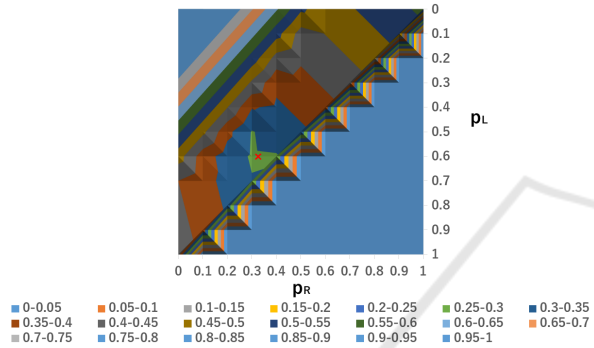

Figure 3: Center of gravity in kicker's optimal strategy area (left-footed).

4.4 Calculating the Gap

Here, we verify whether the actual professional football player's penalty shootout follow the optimal strategy. After that, we examine the probability distribution in each attribute and search for the cause of the gap.

4.4.1 Comparing with Actual Data

As a result of examining the probability distribution for each dominant foot in the data set, right-footed player's probability distribution is (p_R, p_L) = (0.37, 0.48) and left-footed player's probability distribution is (p_R, p_L) = (0.44, 0.40). The distance d from the center of gravity was d = 0.162 in the case of right-footed kickers and d = 0.230 in the case of left-footed kickers. They also did not fit within the area of the expected pay-off of 0.25 - 0.3 which is regarded as the optimal strategy area, therefore it is found that professional football players do not follow the optimal strategy.

4.4.2 The Cause of the Gap

In Section 4.5.1, we found that the kicker's optimal strategy derived by the Minimax is different from the behavior of professional football players. Therefore we have a question why the professional athletes tends to depart from a strategy that follows the optimal strategy. In this section, we hypothesize the reason.

First, we calculate the probability distribution (p_R, p_L) for each attribute in the data set and got the gap d' from the center of gravity. Next, the attributes responsible for the gap are identified based on the difference between the gap d of the actual data obtained in Section 4.5.1 and the gap d'. The results are shown in the Table 5. The following nine attributes are analyzed : position, nationality, the country where the game took place, players in the side taking the first/second kick, temporary scores of the shootout difference, team attributes, kicking order, the number of audiences, and GK's height. The score difference represents the superiority or inferiority at the moment when kicking carries out. Nationality is classified into four regions : Europe, Africa, East Asia, and South America because the amount of data for each nationality is too small. For the same reason, we regard 6th, 7th and 8th kickers as one case in the kicking order.

When $d - d' > 0$, it indicates that it is closer to the optimal strategy than the actual data, and conversely when it is $d - d' < 0$, it indicates that it is farther.

The Table 5 shows $d - d'$ for each attribute. We consider that the cases with $d - d' > 0$ for each dominant foot is related to factors that follow the optimal strategy, and conversely, the cases with $d - d' < 0$ is related to factors that tends to depart from the optimal strategy. We regard the cases with different plus and minus values of $d - d'$ due to the dominant foot as having low relevance because the influence of attribute is independent with respect to each dominant foot. There are seven cases with $d - d' > 0$ for each dominant foot: position is defender (right-footed: 0.063, left-footed: 0.011), team attribute is club team (right-footed: 0.001, left-footed: 0.015), first/second kick is second kick (right-footed: 0.004, left-footed: 0.005), order is 4 (right-footed:0.033, left-footed: 0.076), order is 5 (right-footed: 0.007, left-footed: 0.056), order is 6 or later (right-footed: 0.002, left-footed: 0.148), score difference is tie (right-footed: 0.009, and left-footed: 0.010) kicker. On the other hand, there are two cases with $d - d' < 0$ for each dominant foot: team attribute is national team (right handed: -0.002, left handed: -0.044), and order is 3 (right handed: -0.062, left handed: -0.100).

Table 5: The result of analysis.

Data attribute	type	right-footed				left-footed			
		N	(p_R, p_L)	d'	$d-d'$	N	(p_R, p_L)	d'	$d-d'$
Position	Striker	221	(0.31,0.54)	0.240	-0.078	52	(0.44,0.40)	0.230	0.071
	Midfielder	388	(0.38,0.47)	0.144	0.058	106	(0.43,0.42)	0.230	-0.018
	Defender	176	(0.42,0.44)	0.099	0.063	81	(0.41,0.40)	0.219	0.011
Nationality	Europe	365	(0.35,0.51)	0.240	-0.078	118	(0.47,0.42)	0.229	0.001
	Africa	47	(0.40,0.49)	0.132	0.030	10	-	-	-
	East Asia	167	(0.34,0.48)	0.189	-0.027	49	(0.37,0.43)	0.176	0.054
	South America	147	(0.40,0.44)	0.113	0.049	34	(0.50,0.32)	0.325	-0.095
Place	Home	196	(0.33,0.51)	0.205	-0.043	60	(0.37,0.48)	0.122	0.108
	Away	197	(0.37,0.47)	0.113	0.049	67	(0.48,0.37)	0.271	-0.041
	Neutral	397	(0.38,0.49)	0.145	0.017	114	(0.46,0.37)	0.264	-0.034
first/second kick	first	405	(0.36,0.48)	0.166	-0.004	127	(0.45,0.41)	0.225	0.005
	second	385	(0.37,0.49)	0.158	0.004	114	(0.45,0.41)	0.225	0.005
Score difference	Superior	173	(0.35,0.48)	0.173	-0.011	42	(0.36,0.38)	0.221	0.009
	Inferior	328	(0.38,0.50)	0.164	-0.002	90	(0.42,0.41)	0.210	0.020-
	Tie	331	(0.36,0.45)	0.153	0.009	109	(0.46,0.42)	0.220	0.010
Team attributes	National	229	(0.37,0.50)	0.164	-0.002	62	(0.45,0.35)	0.274	-0.044
	Club	561	(0.36,0.48)	0.161	0.001	179	(0.44,0.41)	0.215	0.015
Order	1	147	(0.35,0.45)	0.161	0.001	53	(0.50,0.40)	0.272	-0.042
	2	153	(0.38,0.49)	0.153	0.009	47	(0.49,0.36)	0.287	-0.057
	3	157	(0.35,0.53)	0.220	-0.062	43	(0.51,0.33)	0.330	-0.100
	4	143	(0.38,0.44)	0.129	0.033	47	(0.34,0.45)	0.154	0.076
	5	95	(0.37,0.47)	0.155	0.007	28	(0.36,0.43)	0.174	0.056
	6,7,8	95	(0.40,0.53)	0.160	0.002	23	(0.30,0.52)	0.082	0.148
Audience	50000 to 80000	250	(0.36,0.50)	0.173	-0.011	76	(0.42,0.43)	0.189	0.041
	15000 to 50000	369	(0.40,0.46)	0.123	0.039	125	(0.46,0.38)	0.257	-0.027
	to 15000	171	(0.31,0.53)	0.231	-0.069	40	(0.43,0.40)	0.221	0.009
GK's height	height185cm	560	(0.37,0.49)	0.163	-0.001	156	(0.44,0.42)	0.206	0.024
	height<185cm	230	(0.37,0.47)	0.158	0.004	85	(0.45,0.35)	0.273	-0.043

'N':The number of observation

'-':There are only 10 players who corresponds to this case, thus it is not specified.

5 DISCUSSION

From the pay-off matrix, it is shown that the optimal strategies for right-footed and left-footed player are to kick to right and to left respectively. From 4.5.1, right-footed player's probability distribution is (pR, pL) = (0.37,0.48) and left-footed player's probability distributionis (pR, pL) = (0.44, 0.40), therefore it find that the optimal strategy is different from the actual strategy. The left direction for the right-footed players and the right direction for the left-footed players are assumed to be '*natural direction*'. It is suggested that GK had a high pay-off against the '*natural direction*' kicks because GK know the actual kicker's '*natural direction*' in advance, and conversely, GK had a low pay-off against the '*unnatural direction*' kicks because GK consider that it is rare kicker choose the '*unnatural direction*'. From the kicker's view, kicking to the '*unnatural direction*' is the kicker's optimal strategy.

Why kicker's actual action disagree with their optimal strategy? We hypothesize that there are two reasons: one is to have a unique strategy derived from their original theory while being aware of the optimal strategy, and another is to choose a different strategy considering environmental or psychological factors. In order to identify them, we build the hypotheses based on the $d-d'$ in Table 5. First, we explain assumptions on which the hypotheses are based, then we build hypotheses for the factors.

5.1 The Premise on which the Hypotheses are Based

The analytics staff is people who contribute to the team by analyzing various data and providing the results to the players. Each professional football team usually has analytics staff, and it is assumed that the players obtain various information from the analytics staff beforehand. The player who has a unique strategy derived from their unique experience is a player who ignores the analytics staff's prior information, thus it was excluded from this section. Therefore, we consider the players who are willing to follow the prior information in this section.

In teams whose precision of analytics is high and whose precision of analytics is low, the reliability of

prior information changes, therefore the players in the team with high precision of analytics follow the optimal strategy more often. Furthermore, a player whose skill of kicking the PK is low often follows the optimal strategy based on prior information in order to make the PK successful. Since a lot of stress also has a large influence on the PK kicker, it becomes difficult to make an accurate kick, (Jordet et al., 2007), thus the kicker who has a lot of stress tends to depart from the optimal strategy. In summary, the premise basing on the hypothesis identified as follows:

Prem.1 We consider the players who are willing to follow the prior information.

Prem.2 The players in the team with high precision of analytics follow the optimal strategy more often.

Prem.3 The players whose skill of kicking the PK is low often follows the optimal strategy

Prem.4 The kicker who has a lot of stress tends to depart from the optimal strategy.

5.2 Predicting the Cause of Following Optimal Strategy

Here we make a hypothesis as to why players follow the optimal strategy for each cases that have become $d - d' > 0$ in Table 5. The cases are as follows

Case.1 position is defender

Case.2 team attribute is club team

Case.3 the kicking order is 4 or later.

Case.4 Score difference is tie

Case.5 first/second kick is the second kick

Case.1 The number of players in each position in the dataset is (StrikerMidfielderDefender) = (273493257). Compared with the number of defenders occupied by the formation : 4-4-2, 4-5-1, 4-3-3, 3-5-2[3] which are used frequently in football, it is found that there are few opportunities for the defender to kick the PK[4]. It suggests that the skill of the defender is low. Thus from Prem.3, the hypothesis 'Since defenders' PK kicking skill is relatively low, they tend to obey the optimal strategy.' is built.

[3]These numbers indicate the number of players in each position : defender, midfielder, striker from the left

[4]The players who participate in a penalty shootout are only ones who are in the field at the last moment of a match.

Case.2 There are two major differences between club team and national team. They are the amount of stored data and the availability of opponents' data. Compared with a national team, which is assembled occasionally, a club team who has been analytics for many years has more data. Data analysis generally increases its precision in proportion to the amount of data. In addition, it seems that the data used by the analytics staff of a national team, especially for penalty shootout, is mostly the data from the clubs to which each player belong because a national team lacks data which includes the particular situations of the penalty shootout at a national team. Therefore, the national team precision of analytics is lower than one of club team. Thus from Prem.2, the hypothesis 'Since club teams gives the high precision of analytics, they decide action according to the optimal strategy.' is built.

Case.3 Fig.4 shows the occupancy of each position in each kicking order. It can be seen that the ratio of the defender in this order is increasing. Since the defender follow the optimal strategy as described in **Case.1**, the hypothesis 'Since there are a lot of defenders in the order which is 4 or later, they decide action according to the optimal strategy.' is built.

Case.4 The reason why the tendency of $d - d'$ did not appear at the time of superiority or inferiority is that the degree of stress changes by another factor (eg, first/second kick). On the other hand, at the situation of the tie without temporary score difference, it is considered that there is relatively little stress for the kicker. Thus from Prem.4, the hypothesis 'Since the situation of tie gives relatively little stress, they decide action according to the optimal strategy.' is built.

Case.5 The Table 6 shows the value of $d - d'$ where the type of a kicker is classified into four categories : first kick& FH[5], first kick& SH[6], second kick& FH, second kick& SH. From the table, the first kick approached the center of gravity in the SH and the second kick approached the center of gravity in the FH, which suggests that second kick in the FH has less stress and the kicker second kick in the SH has a lot of stress. As the number of people is about 1.5 times higher in the FH, the influence of second kick in the FH kicker comes out to the entire the kicker second kick and it is found that it approached the center of gravity. Thus the hypothesis 'Since the kicker second kick was influenced by FH the kicker second kick

[5]FH represents kicking order is 1 to 3.

[6]SH represents kicking order is 4 or later.

with less stress, they decide action according to the optimal strategy.' is built.

In summary, the factors that characterize kickers who tend to follow the optimal strategy were estimated as follows

Hyp.1 'Since defenders' PK kicking skill is relatively low, they tend to obey the optimal strategy.'

Hyp.2 'Since club teams have the high precision of analytics, they decide action according to the optimal strategy.'

Hyp.3 'Since there are a lot of defenders in the order which is 4 or later, they decide action according to the optimal strategy.'

Hyp.4 'Since the situation of tie gives relatively little stress, they decide action according to the optimal strategy.'

Hyp.5 'Since the kicker second kick was influenced by FH the kicker second kick with less stress, they decide action according to the optimal strategy.'

Table 6: $d - d'$ where the type of a kicker is classified into four categories.

type	right-footed		left-footed	
	N	$d - d'$	N	$d - d'$
first kick& FH	223	-0.007	77	-0.081
first kick& SH	182	0.012	50	0.109
second kick& FH	234	0.015	66	0.010
second kick& SH	151	-0.041	48	-0.009

5.3 Predicting the Cause of not Following Optimal Strategy

Here we make a hypothesis as to why players tends to depart from the optimal strategy for each cases that have become $d - d' < 0$ in Table 5. The cases are as follows national team, third kicking order players.

Case.6 national team

Case.7 the kicking order is 3.

Case.6 From Section 5.2, a national team is considered to have lower precision of analytics than a club team. Thus from Prem.2, the hypothesis 'Since a national team has low precision of analytics, they decide action which does not follow the optimal strategy.' is built.

Case.7 From the Fig.4, the ratio of midfielder occupies is larger than other position, which is considered to indicate that the midfielder has a high skill of kicking the PK. In addition, the third kicking order occupancy rate of midfielder is 52%, which is the second largest proportion. The situation of defeat if you do not score come after the third kicking order, however, it is rare to become such situation at third kicking order : it only happened3 times out of 157 times. Therefore, we consider that midfielder players who are technically stronger but not better at handling stress than the fourth kicking order are placed. Therefore they feel more stress than other players, thus from Prem.4, the hypothesis 'Since the third kicking order kicker has no technical problems, however weak players on the stress are placed, they decide action which does not follow the optimal strategy.' is built.

In summary, the factors that characterize kickers who tends to depart from the optimal strategy were estimated as follows

Hyp.6 'Since a national team has low precision of analytics, they decide action which does not follow the optimal strategy.'

Hyp.7 'Since the third kicking order kicker has no technical problems, however weak players on the stress are placed, they decide action which does not follow the optimal strategy.'

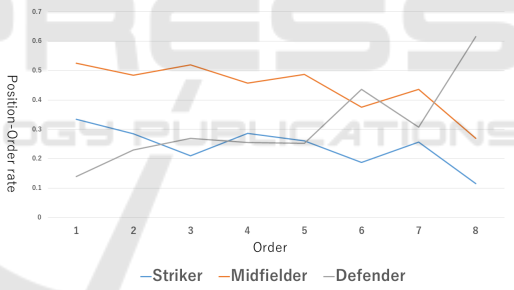

Figure 4: Position-Order rate.

6 RELATED WORK

6.1 Study Related to Penalty Shootout

Studies on penalty shootout have been done from various viewpoints. Geir Jordet et al (Jordet et al., 2007) categorizes 403 penalty kicks in the three most important international football tournaments : World Cup, UEFA Champions League, and Copa America by the type of event, kicking order, position, participation time, and age and determines the success rate of each type, they estimated factors that are influencing the success of the PK. They concluded that psychological effect is the most important factor.

The study also has been done to identify what kind

of information GK uses to predict the kicker's action. Zhou Peiyong et al. (Peiyong and Inomata, 2012) examined the difference in predicted actions for professional football player's PK video performed by experienced GKs and laymen. The results suggested that experienced GKs do not rely on visual information in front of them, therefore GK decides actions with prior information (positions, dominant foot, etc.) regardless of kicker's behavior. Our study was also done based on this assumption. However, Savelsbergh (Savelsbergh et al., 2002) argued that visual information is also necessary. They also made a direction prediction for the experienced GKs and laymen using the PK video kicked by the youth player of the Netherlands league's professional team. As a result, it was concluded that some visual information : head, kicking leg, non-kicking leg, ball, is the most important element because they gazed at the head at an early time and foot and ball at other times. However, since this experiment only gathers gaze at these place, it does not prove that GK is making it as the most important attributes to decide the action, thus we doubt that these are the place that GK naturally sees in PK's sequence of flows.

6.2 Game Theoretic Approach

Ignacio Palacios - Huerta (Palacios-Huerta, 2003) concluded that the kicker's optimal strategy derived from the mixed Nash equilibrium agreed with the actual strategy taken by players by examining 1417 PK in the professional football games. This is a different conclusion from the one in this paper. In Ignacio Palacios-Huerta's study, he only deals with PKs during the match including extra time, with the assumption that each event of PK is the independent decision-making without being affected by each other. However, it is difficult for the assumption to deal with penalty shootout because PK events are done continuously and environmental or psychological factors such as the superiority of temporary scores must influence the strategy. In his research, he also considered the strategy with only two types of directions which are summed up as '*natural direction*' and '*unnatural direction*', that is, i, j = C are collectively considered by '*unnatural direction*'. On the other hand, this paper considered three directions, therefore we can deal with more accurate strategy and our study's precision is higher.

7 CONCLUSION

In this study, we made a GK's pay-off matrix that considers the failure ratio and revealed the kicker's optimal strategy by Minimax method. Next, the presence or absence of the gap between the actual data and the optimal strategy was verified, and the probability distribution of each data attribute was calculated, then attributes considered to be attributable to the gap were extracted. From the attribute, we estimated the cause of the gap between the optimal strategy and the actual strategy taken by players in the penalty shootout. As a result of the verification, it was suggested that the position, team attribute, temporary scores of the shootout and kicking order were involved in the gap. This method can be applied to the optimal strategy in other fields such as investment activities. In the future, we increase the amount of the data and would like to obtain more insight on the optimal strategy for penalty shootout by combining the data attributes.

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