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Finding Kicking Range of Sepak Takraw Game: Fuzzy Logic and Dempster-Shafer Theory Approach

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Abstract

Sepak takraw is played by two regus, each consisting of three players. One of the three players shall be at the back and he is called a Tekong. The other two players shall be in front, one on the left and the other on the right. Having volley kicked a throw from the net by a team mate, the ball must then travel over the net to begin play. During the service, as soon as the Tekong kicks the ball, all the players are allowed to move about freely in their respective courts. The novel approach is the integration within a Tsukamoto's Fuzzy reasoning and inferences for evidential reasoning based on Dempster-Shafer theory. Sepak takraw is a highly complex net-barrier kicking sport that involves dazzling displays of quick reflexes, acrobatic twists, turns and swerves of the agile human body movement. Because of the humans involvement in the game, the Fuzzy Logic type reasoning are the most appropriate. The individual rule outputs of Tsukamoto's Fuzzy reasoning scheme are crisp numbers, and therefore, the functional relationship between the input vector and the system output can be relatively easily identified. The result reveals that if Tekong is kick far and front player is kick near then another regu's player is kick far, if Tekong is kick near and front player is kick far then another regu's player is kick near, moreover possibility of kicking range is another regu's player is kick far in kicking range.

Keywords: *fuzzy logic; Dempster-Shafer theory; sepak takraw; kicking range*

1. Introduction

Mentioned in the Malay historical text, Sejarah Melayu, there is a description of an incident where Sultan Mansur Shahs son, Raja Muhammad, was accidentally hit with a rattan ball by the son of Tun Perak, in a game that was called sepak raga. In Thai language, it is called takraw, meaning twine-kick, as the ball was made of rattan twines. The game became popular throughout the Southeast Asia and in the 1940s, rules were established and the game became officially known as sepak takraw. Sepak takraw or kick volleyball is a sport native to Southeast Asia, resembling volleyball, except that it uses a rattan ball and only allows players to use their feet and head to touch the ball. A cross between football and volleyball, it is a popular sport in Thailand, Cambodia, Malaysia, Laos, Philippines and Indonesia. The strategies in Sepak takraw are also very similar to those in volleyball. The receiving team will attempt to play the takraw ball towards the front of the net, making the best use of their three hits, to set and spike the ball [1]. In previous work [2], we used Fuzzy Logic to find kicking range of sepak takraw game. The organization of the paper is as follows: section 2 discusses Fuzzy Logic and Dempster-Shafer theory. Section 3 discusses using Fuzzy Logic and Dempster-Shafer theory in sepak takraw game. Conclusion is presented in section 4.

2. Fuzzy Logic and Dempster-Shafer theory

Fuzzy Logic can handle problems with imprecise data and give more accurate results. Professor L.A. Zadeh introduced the concept of Fuzzy Logic [3]; soon after, researchers used this theory for developing new algorithms and decision analysis. Fuzzy sets, proposed by Zadeh [3]

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as a framework to encounter uncertainty, vagueness and partial truth, represents a degree of membership for each member of the universe of discourse to a subset of it.

Assume that the specific case of composition based on the Max-Min operator, then the special case of the above general model of Fuzzy reasoning can be defined using equation 1 as

$$\mu_{B'}(y) = \bigvee_{x \in A} ((\mu_{A'}(x) \wedge \mu_R(x,y)) = \max_{x \in A} min(\mu_{A'}(x), \mu_R(x,y) \quad (1)$$

The Dempster-Shafer theory originated from the concept of lower and upper probability induced by a multivalued mapping by Dempster [4], [5]. Following this work his student Glenn Shafer [6] further extended the theory in his book ”A Mathematical Theory of Evidence”, a more thorough explanation of belief functions. The Dempster-Shafer theory [6] assumes that there is a fixed set of mutually exclusive and exhaustive elements called hypotheses or propositions and symbolized by the Greek letter Θ, represented as $\Theta = \{h_1, h_2, ..., h_n\}$, where h_i is called a hypothesis or proposition. A hypothesis can be any subset of the frame, in example, to singletons in the frame or to combinations of elements in the frame. Θ is also called frame of discernment [6]. A basic probability assignment (bpa) is represented by a mass function $m : 2^{\Theta} \rightarrow [0,1]$ [6]. Where 2^{Θ} is the power set of Θ. The sum of all basic probability assignment of all subsets of the power set is 1 which embodies the concept that total belief has to be one [7]. Yager and Filev attempted to present a Fuzzy inference system based on Fuzzy Dempster-Shafer mathematical theory of evidence which combining the probabilistic information in the output [8].

The basic probability assignment is a primitive of evidence theory. Generally speaking, the term basic probability assignment does not refer to probability in the classical sense. The bpa, represented by m, defines a mapping of the power set to the interval between 0 and 1, where the bpa of the null set is 0 and the bpas of all the subsets of the power set is 1. In Fuzzy Logic, two-valued logic often considers 0 to be false and 1 to be true. Fuzzy Logic deals with truth values between 0 and 1, and these values are considered as the intensity or degrees of truth. Dempster-Shafer theory provides a method to combine the previous measures of evidence of different sources [6]. This rule assumes that these sources are independent. The combination: $m = m_1 \oplus m_2$, also called orthogonal sum, is defined according to the Dempster's rule of combination [6], given in equation 2. It can be applied repetitively when the sources are more than two. After the combination, a decision can be made among the different hypotheses according to the decision rule chosen.

$$(m_1 \oplus m_2)(A) = \begin{cases} 0; & \text{A} = 0 \\ \dfrac{\sum\limits_{B_i \cap B_j = A} m_1(B_i)m_2(B_j)}{1 - \sum\limits_{B_i \cap B_j \neq 0} m_1(B_i)m_2(B_j)}; & \text{A} \neq 0 \end{cases} \quad (2)$$

Where $A \in 2^{\theta}$, $B_i \in 2^{\theta}$ and $B_j \in 2^{\theta}$.

To use Dempster-Shafer mathematical theory of evidence, there must be the feasible measures to determine basic probability assignment.

3. Using Fuzzy Logic and Dempster-Shafer Theory in Sepak Takraw Game

When a game begins by one serve, a ball can be touched by the attack of one time to three times. The player can use a head, a back, legs, and anywhere except for the arm from the shoulder to the point of the finger. Suppose we are given player position and kicking range in the beginning of sepak takraw game as shown in Table 1.

Table 1. Player position and kicking range

Position	Kicking Range (m)	
	Far	*Near*
Tekong	6.50	4
Front Player	7.50	2
Opponent's Player	9.50	4.50

We have defined the realistic rules according to the kicking range calculations, these rules will become the knowledge base of each of the problems considered in the sepak takraw game. It is necessary to say that the whole knowledge does not necessarily have to be translated in rules, sometimes some of the rules can be redundant. Table 2 shows the rule to find kicking range in sepak takraw game.

Table 2. The Rule

Rule	**IF** Tekong is	**AND** Front player is	**THEN** Opponent's player
Rule 1	Near	Far	Near
Rule 2	Near	Near	Near
Rule 3	Far	Far	Far
Rule 4	Far	Near	Far

[Rule 1] **IF** Tekong is near **AND** Front Player is far **THEN** Opponent's Player is near

[Rule 2] **IF** Tekong is near **AND** Front Player is near **THEN** Opponent's Player is near

[Rule 3] **IF** Tekong is far **AND** Front Player is far **THEN** Opponent's Player is far

[Rule 4] **IF** Tekong is far **AND** Front Player is near **THEN** Opponent's Player is far

During the Sepak takraw game, both teams will make different powerful moves to kick and spike the ball to go to the opponent side and fall within the boundary line of the court, players try to play the ball toward the front of the net, making the best use of their three hits to pass, set and spike. Suppose we are given 5 conditions kicking range in which already known as shown in Table 3.

Table 3. Kicking range of tekong and front player

Position	Condition				
	Condition 1	*Condition 2*	*Condition 3*	*Condition 4*	*Condition 5*
Tekong	6	5.50	5	4.5	4.25
Front Player	2.5	3.50	4.50	5.50	6.50

Kicking range of tekong is the range of kicking the ball from tekong to front player. Kicking range of front player is the range of kicking the ball from front player to opponents player. Figure 1 shows graphic of kicking range of tekong and front player.

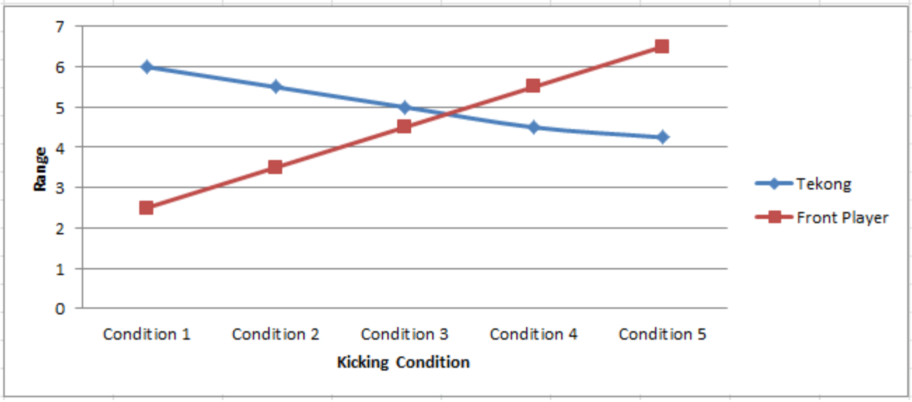

Figure 1. Graphic of kicking range of tekong and front player

Tekong

$$\mu(\text{Tekong}_{\text{near}}[x]) = \begin{cases} 1, & x \leq 4 \\ \frac{6.5-x}{2}, & 4 < x \leq 6.5 \\ 0, & x \geq 6.5 \end{cases} \quad (3)$$

$$\mu(\text{Tekong}_{\text{far}}[x]) = \begin{cases} 0, & x \leq 4 \\ \frac{x-4}{2.5}, & 4 < x \leq 6.5 \\ 1, & x \geq 6.5 \end{cases} \quad (4)$$

Membership value
$\mu(Tekong_{\text{near}}[6]) = \frac{6.5-6}{2.5} = 0.20$

$\mu(Tekong_{\text{far}}[6]) = \frac{6-4}{2.5} = 0.80$

Front Player

$$\mu(\text{Front Player}_{\text{near}}[y]) = \begin{cases} 1, & y \leq 5.5 \\ \frac{7.5-y}{5.5}, & 5.5 < y \leq 7.5 \\ 0, & y \geq 5.5 \end{cases} \quad (5)$$

$$\mu(\text{Front Player}_{\text{far}}[y]) = \begin{cases} 0, & y \leq 5.5 \\ \frac{y-2}{5.5}, & 5.5 < y \leq 7.5 \\ 1, & y \geq 7.5 \end{cases} \quad (6)$$

Membership value
$\mu(FrontPlayer_{\text{near}}[2.5]) = \frac{7.5-2.5}{5.5} = 0.9$

$\mu(FrontPlayer_{\text{far}}[2.5]) = \frac{2.5-2}{5.5} = 0.09$

Opponent Player

$$\mu(\text{Opponent Player}_{\text{near}}[w]) = \begin{cases} 1, & w \leq 4.5 \\ \frac{9.5-w}{5}, & 4.5 < w \leq 9.5 \\ 0, & w \geq 9.5 \end{cases} \quad (7)$$

$$\mu(\text{Opponent Player}_{\text{far}}[w]) = \begin{cases} 0, & w \leq 4.5 \\ \frac{w-4.5}{5}, & 4.5 < w \leq 9.5 \\ 1, & w \geq 9.5 \end{cases} \quad (8)$$

w value for each rule with min function. Figure 2 shows graphic of fuzzy membership function.

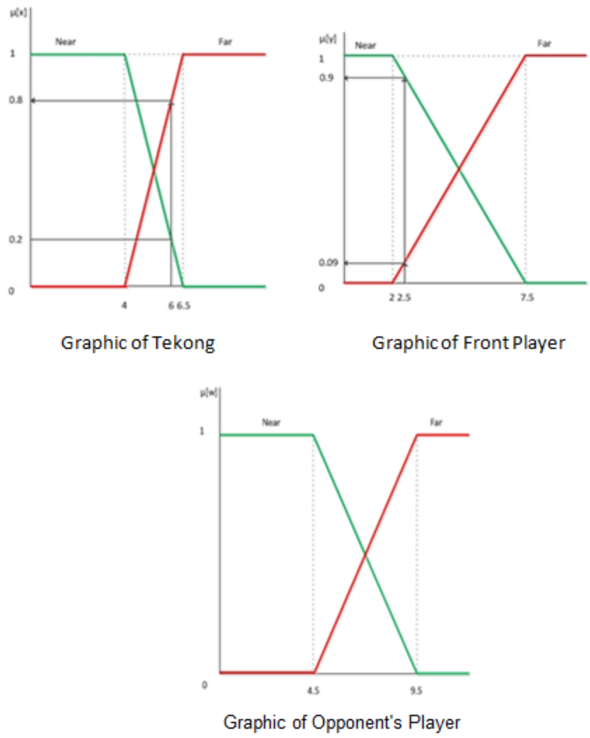

Figure 2. Graphic of fuzzy membership function

$\alpha_1 = \mu(\text{Tekong}_{\text{near}}) \cap \mu(\text{Front Player}_{\text{far}}), \alpha_1 = min(\mu(\text{Tekong}_{\text{near}}[6] \cap \mu(\text{Front Player}_{\text{far}}[2.5])$
$\alpha_1 = min(0.2, 0.09), \alpha_1 = 0.09$

From the calculation above, we have four rules. ON is opponents player near in range, OF is opponents player far in range. With Dempster-Shafer Theory:

1. Rule 1

   $m_1\{ON\} = 0.09, m_1\{\theta\} = 1 - 0.09 = 0.91$

2. Rule 2

   $m_2\{ON\} = 0.2, m_2\{\theta\} = 1 - 0.2 = 0.8$

   The calculation of the combined m_1 and m_2 is shown in Table 4. Each cell of the table contains the intersection of the corresponding propositions from m_1 and m_2 along with the product of their individual belief.

Table 4. The first combination of the risk of Rule 1 and Rule 2

		{**ON**}	**0.2**	θ	**0.8**
{**ON**}	**0.09**	{ON}	0.018	{ON}	0.07
θ	**0.91**	{ON}	0.18	θ	0.73

The first two bpas m_1 and m_2 are calculated to yield a new bpa m_3 by a combination rule as follows:

$m_3\{ON\} = \frac{0.018+0.18+0.07}{1-0} = 0.27, m_3\ \{\theta\}$ = $\frac{0.73}{1-0} = 0.7$

3. Rule 3

$m_4\{OF\} = 0.09, m_4\{\theta\} = 1 - 0.09 = 0.91$

The calculation of the combined m_3 and m_4 is shown in Table 5. Each cell of the table contains the intersection of the corresponding propositions from m_3 and m_4 along with the product of their individual belief.

Table 5. The second combination of Rule 1, Rule 2 and Rule 3

		{**OF**}	**0.2**	θ	**0.8**
{**ON**}	**0.27**	$\emptyset$	0.02	{ON}	0.25
θ	**0.73**	{OF}	0.07	θ	0.66

The second two bpas m_3 and m_4 are calculated to yield a new bpa m_5 by a combination rule as follows:

$m_5\{OF\} = \frac{0.07}{1-0.02} = 0.07, m_5\{ON\} = \frac{0.25}{1-0.02} = 0.26, m_5\ \{\theta\}$ = $\frac{0.66}{1-0.02} = 0.67$

4. Rule 4

$m_6\{OF\} = 0.8, m_6\{\theta\} = 1 - 0.8 = 0.2$

The calculation of the combined m_5 and m_6 is shown in Table 6. Each cell of the table contains the intersection of the corresponding propositions from m_5 and m_6 along with the product of their individual belief.

Table 6. The third combination of Rule 1, Rule 2, Rule 3, and Rule 4

		{**OF**}	**0.8**	θ	**0.2**
{**OF**}	**0.07**	{OF}	0.06	{OF}	0.01
{**ON**}	**0.26**	$\emptyset$	0.21	{ON}	0.05
θ	**0.67**	{OF}	0.54	θ	0.13

The third two bpas m_5 and m_6 are calculated to yield a new bpa m_7 by a combination rule as follows:

$m_7\{OF\} = \frac{0.06+0.54+0.01}{1-0.21} = 0.77, m_7\{ON\} = \frac{0.05}{1-0.21} = 0.06, m_7\{OF\} = \frac{0.13}{1-0.21} = 0.16$

Finally, the final ranking of the degree of belief is 0.77 $>$ 0.06 $<$ 0.16. The degree of belief is the $m_7\{OF\}$ that is equal to 0.77 which means the possibility of kicking range is another regu's player is far in kicking range as shown in the figure 3.

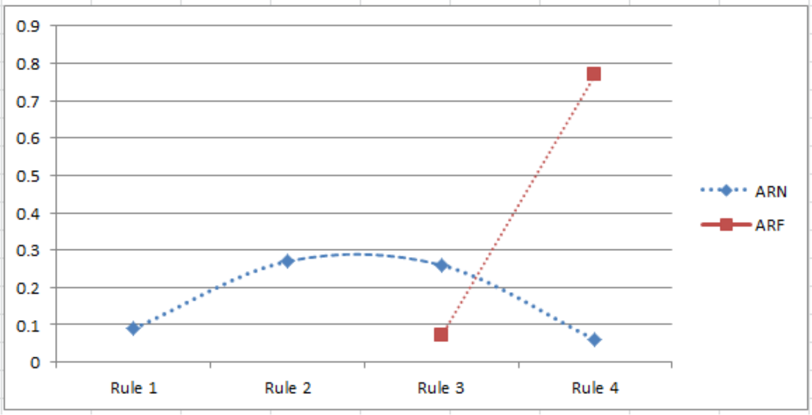

Figure 3. Graphic of fuzzy membership function

4. Conclusion

We have described a method to find kicking range of sepak takraw game using Tsukamoto's Fuzzy reasoning and Dempster-Shafer theory. The vagueness present in the definition of terms is consistent with the information contained in the conditional rules when observing some complex process. Even though the set of linguistic variables and their meanings is compatible and consistent with the set of conditional rules used, the overall outcome of the qualitative process is translated into objective and quantifiable results. Fuzzy mathematical tools and the calculus of Fuzzy IF-THEN rules provide a most useful paradigm for the automation and implementation of an extensive body of human knowledge heretofore not embodied in the quantitative modelling process. These mathematical tools provide a means of sharing, communicating, and transferring this human subjective knowledge of systems and processes. The result reveals that if tekong is far and front player is near then another regu's player is far, if tekong is near and front player is far then another regu's player is near, moreover possibility of kicking range is another regu's player is far in kicking range.

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