Deep SIRMs Fuzzy Inference Model and its Application to Estimating Roles in a Werewolf Game

Shuhei Kita, Suguru Haruta and Hirosato Seki

Abstract— **Recently, many studies on Werewolf Game have been reported in the field of games with incomplete information. In this paper, we confirm the effectiveness of the SIRMs fuzzy inference model, which has small number of rules than the simplified inference model, and the deep SIRMs fuzzy inference model, by applying them to Werewolf Game.**

I. INTRODUCTION

In recent years, there have been many situations in which artificial intelligence has outperformed humans in perfect information games [1]. However, there are still many problems to be solved in incomplete information games, and there is still much room for development. Similarly, various studies have been reported on Werewolf Game, one of the incomplete information games, including role estimation using deep learning [2] and simplified fuzzy inference.There have also been studies to build a human-like agent[3], [4]. In a previous study [5], fuzzy rules were used to acquire intuitive knowledge for 5-player Werewolf. Furthermore, the obtained models have been applied to the decision making of Werewolf agent. However, simplified fuzzy inference requires long learning time, and it is difficult for Werewolf agent to make inferences in real time. In addition, the log data used in Werewolf is composed of data that contains all information that is not from the player's point of view. Therefore, it is necessary to process the data in real-time to estimate the position of the players. In this paper, we confirm the effectiveness of the SIRMs fuzzy inference model [6], which has fewer rules than the simplified inference model, and the deep SIRMs fuzzy inference model [7], one of the deep fuzzy inference models that considers hierarchical inference, by comparing them with existing fuzzy inference models.

II. DEEP SIRMS FUZZY INFERENCE MODEL

This section describes the deep Single Input Rule Modules(SIRMs) connected fuzzy inference model [7]. The deep SIRMs model is constructed as shown in Fig. 1.

y^l is the output of the $l(=1,2,...,L)$th layer and y is the output of the deep SIRMs model. Also, $\boldsymbol{x} = (x_1, x_2, ..., x_n)$ represents the input vector.

We also show the rules of the deep SIRMs model.

$$\text{Rules-}i : \{\text{if}\, x_i = A^l_{ij}\, \text{then}\, y_i = c^l_{ij}\}^{m^l_i}_{j=1} \tag{1}$$

S. Kita, S. Haruta and H. Seki are Department of Systems Innovation, Graduate School of Engineering Science, Osaka University, Osaka, Japan. {kita,haruta}@inulab.sys.es.osaka-u.ac.jp, seki@sys.es.osaka-u.ac.jp

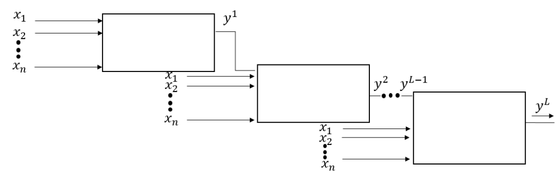

Fig. 1. Schematic of the deep SIRMs model

where m^l_i is the number of rules in the ith rule group of the lth layer. A^l_{ij} and c^l_{ij} are the real values of the fuzzy set and the posteriors for the jth fuzzy rule in the fuzzy partition of the ith input of the lth layer, respectively.

Given $\boldsymbol{x}^0 = (x^0_1, x^0_2, ..., x^0_n)$, the fitness for x_i to the rule in the jth fuzzy partition is given by (2).

$$h^l_{ij} = A^l_{ij}(x^0_i) \tag{2}$$

Then the output y^l_i of the rule module for the input x_i computes a weighted average for each fuzzy partition. In the second and subsequent layers, in addition to (1), a set of rules for the outputs of the previous layer is added as the $n+1$th input. Then, from the weighted sum of the w^L_i weights for the ith input of the Lth layer of y^L_i, the final output y^L is as in (3).

$$y^L = \sum_{i=1}^{n+1} \left(w^L_i \frac{\sum_{j=1}^{m} h^L_{ij} c^L_{ij}}{\sum_{j=1}^{m} h^L_{ij}} \right) \tag{3}$$

III. WEREWOLF GAME

In this paper, we deal with 5-player Werewolf games. 5-player Werewolf Game is played with 2 Villager, 1 Seer, 1 Werewolf, and 1 Possessed. Each player is assigned a role at the beginning, which determines his or her side. Human-side consists of Villager and Seer, and the victory condition is to expel all Werewolf. Werewolf-side consists of Werewolf and Possessed, and the victory condition is to have the same number of Werewolf and non-Werewolf. There are two turns in the game: day and night. During the day discussion time, one player is chosen to be expelled. In the night turn, players with special abilities act. Seer can tell whether a player is Werewolf or not. Werewolf can attack a player and expel him from the game. The game ends when one of the victory conditions is met, repeating day and night turns.

TABLE I

REPRESENTATION OF EACH ROLE IN FUZZY INFERENCE MODEL

role	output variable	threshold
Villager	0.0	$y^0 \leq 0.165$
Werewolf	0.33	$0.165 < y^0 \leq 0.46$
Seer	0.66	$0.46 < y^0 \leq 0.825$
Possessed	1.0	$0.825 < y^0$

TABLE II

CORRECTNESS RATE (%) AND TRAINING TIME (SECONDS) OF THE WEREWOLF DATA FOR THE SIRMS MODEL

	teach data		
	10 studies	100 studies	1000 studies
Villager	52.0	77.0	77.5
Werewolf	44.0	49.0	47.0
Seer	65.0	58.0	58.0
Possessed	28.0	50.0	50.0
total	48.2	62.2	62.0
Computational time	0.004	0.037	0.364
	test data		
	10 studies	100 studies	1000 studies
Villager	8.5	73.5	76.0
Werewolf	66.0	43.0	41.0
Seer	49.0	50.0	52.0
Possessed	0.0	41.0	38.0
total	26.4	56.2	56.6
Computational time	0.003	0.029	0.291

IV. NUMERICAL EXPERIMENT

In this section, we compare the SIRMs model with the deep SIRMs model to examine the proposed model. A_i^j is a fuzzy set of the first case by dividing each input item into three parts. The initial values of the antecedent are as follows: the center A is 0 and the width B is 1, the center A is 0.5 and the width B is 0.5, and the center A is 1 and the width B is 1. For the learning coefficients, the center and width of the front case were set to 0.001 and the real value of the back case to 0.01 for all models, and the importance of the input was set to 0.01. The deep model was set up in two layers. From the log data of 100 games of 5-player Werewolf intelligence tournament, we extracted 7 features and roles of players, and estimated the role of the player.The player's role is represented as shown in Table I. A fuzzy inference model is trained using a total of 500 data sets (100 games x 5 players), with the 7 features as input variables and each position as an output variable. The inference result $y_0(x^0)$ is used as the threshold to discriminate. As a learning algorithm, the steepest descent method is used to learn the center and width of the fuzzy set and the real value of the posterior case, which are the parameters of the fuzzy rule, so that the evaluation function becomes small [5].

The correct response rates were compared in two experiments: a supervised data experiment in which all the data were used for training and all the data were used as test data, and an unknown data experiment in which the data were divided into five parts and averaged, with four parts as teach data and one part as test data. The obtained response rates are shown in Table II and III.

V. CONCLUSIONS

We have applied the SIRMs fuzzy inference model and the deep SIRMs fuzzy inference model to Werewolf Game, which is a type of incomplete information game, in order to estimate the positions in 5-player Werewolf. The simplified inference model, which requires a large number of rules as the number of inputs increases, is difficult to apply to werewolf agents that must run in real time under time constraints, but the various SIRMs models are superior because of their extremely fast computation time. Since the proposed model is represented by fuzzy rules, the input-output relationship is easier to understand than that of neural networks. Future work will focus on the application of this method to werewolf agents. In learning, the deep SIRMs model converges very quickly, so it is possible to apply the model to more complex problems, since it is prone to overlearning if the number of training sessions is large due to its high learning ability.

TABLE III

CORRECTNESS RATE (%) AND TRAINING TIME (SECONDS) OF THE WEREWOLF DATA FOR THE DEEP SIRMS MODEL

	teach data		
	10 studies	100 studies	1000 studies
Villager	0.0	77.5	76.5
Werewolf	72.0	46.0	48.0
Seer	36.0	63.0	58.0
Possessed	0.0	43.0	51.0
total	21.6	61.4	62.0
Computational time	0.011	0.097	0.964
	test data		
	10 studies	100 studies	1000 studies
Villager	0.0	51.0	75.0
Werewolf	72.0	53.0	41.0
Seer	64.0	61.0	70.0
Possessed	0.0	10.0	21.0
total	27.2	45.2	56.4
Computational time	0.008	0.077	0.763

ACKNOWLEDGMENT

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