INSIST Vol. 2 No. 1, April 2017 (31 - 35)
http://insist.unila.ac.id/
DOI: 10.23960/ins.v2i1.30
eISSN: 2502-8588
Received: 20/08/2016
Accepted: 19/01/2017
Published online: 01/04/2017

Optimization Model of Fuzzy Rule Based Expert System Using Max-Min Composition and Schema Mapping Translation

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Abstract— Fuzzy Decision Making involves a process of selecting one or more alternatives or solutions from a finite set of alternatives which suits a set of constraints. In the rule-based expert system, the terms following in the decision making is using knowledge based and the IF Statements of the rule are called the premises, while the THEN part of the rule is called conclusion. Membership function and knowledge based determines the performance of fuzzy rule based expert system. Membership function determines the performance of fuzzy logic as it relates to represent fuzzy set in a computer. Knowledge Based in the other side relates to capturing human cognitive and judgemental processes, such as thinking and reasoning. In this paper, we have proposed a method by using Max-Min Composition combined with Genetic Algorithm for determining membership function of Fuzzy Logic and Schema Mapping Translation for the rules assignment.

Keywords— Fuzzy Decision Making, Rule-Based Expert System, Membership Function, Knowledge Based, Max-Min Composition, Schema Mapping Translation

I. Introduction

Fuzzy Decision Making involves a process of selecting one or more alternatives or solutions from a finite set of alternatives which suits a set of constraints [1]. In the rule-based expert system, the terms following in the decision making is using knowledge based and the IF Statements of the rule are called the premises, while the THEN part of the rule is called conclusion [2]. Membership function and knowledge based determines the performance of fuzzy rule based expert system[3], [4]. Membership function determines the performance of fuzzy logic as it relates to represent fuzzy set in a computer [3]. Knowledge Based in the other side relates to capturing human cognitive and judgemental processes, such as thinking and reasoning [5]. In every day content most of the problems involve imprecise concept. To handle the imprecise concept, the conventional method of set theory and numbers are insufficient and need to be extended to some other concepts. Fuzzy concept is one of the concepts for this purpose. A relation is a mathematical description of a situation where certain elements of sets are related to one another in some way. Fuzzy relations are significant concepts in fuzzy theory and have been widely used in many fields such as fuzzy clustering, fuzzy control and uncertainty reasoning. They also play an important role in fuzzy diagnosis and fuzzy modeling. When fuzzy relations are used in practice, how to estimate and compare them is a significant problem. Uncertainty measurements of fuzzy relations have been done by some researchers[6].

Fuzzy relation in different product space can be combined with each other by the operation called "Composition". There are many composition methods in use, e.g. max-product method, max-average method and max-min method. But max-min composition method is best known in fuzzy logic applications[7]. Using Max-Min Composition, we have a degree of relationship between the elements. Relations on fuzzy stating how strong the relationship between elements in fuzzy. The higher degree of relation level means the stronger the relationship between elements. Genetic algorithms (GAs) are a class of evolutionary algorithms made popular by John Holland and his colleagues during the 1970s [8]. Genetic Algorithm is a searching method used for choosing the best solution of the different problems, based on the mechanism of natural selection. That is, from the initial population, through several evolutionary steps, a set of new more appropriate solutions are achieved that led to the global optimal solution [9]. This algorithm perform an intelligent search for a solution and have a broad spectrum of possible sollution. We can combine the max-min composition method to get an idea of the strength of the relationship between elements. Based on the strength of that relationship we can determine the interval membership function by using a genetic algorithm. After defining the Membership function, we can determine the knowledge based using Schema Mapping Translation. A fuzzy designer normally uses intuition and trial and error method for the rules assignment [4]. Actually, there are several methods than can be used for getting the better combination of fuzzy rules. One of the method that can be used is Schema Mapping Translation. A schema mapping translation is a domain of the data manipulation [10].

II. Literature Review

A. *Working of Fuzzy Logic*

Fuzzy logic continues to grow, at this time we have known type 2 fuzzy logic. Type-2 fuzzy sets (T2 FSs), originally introduced by Zadeh [12], provide additional design degrees of freedom in Mamdani and TSK fuzzy logic systems (FLSs), which can be very useful when such systems are used in situations where lots of uncertainties are present [13]. The resulting type-2 fuzzy logic systems (T2 FLS) have the potential to provide better performance than a type-1 (T1) Fuzzy Logic System [14].

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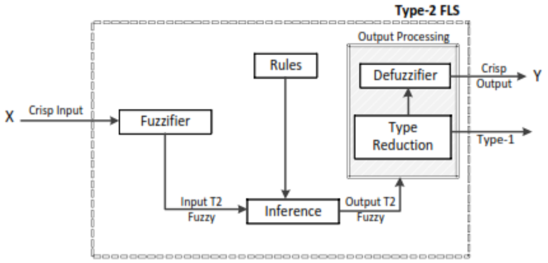

Fig 1. Type 2 Fuzzy Logic Process [15]

B. Fuzzy Rule-Based Expert System

Rule-based expert systems have the ability to emulate the decision making ability of human experts. They are designed to solve problems as humans do, by exploiting encoded human knowledge or expertise. This knowledge can be extracted and acquired directly through interaction with humans, as well as from printed and electronic resources such as books, magazines and websites. The extracted knowledge forms the knowledge base of the rule-based system. The other major component of rule-based systems draws conclusions from this knowledge, and is referred to as the inference engine. The conclusions and suggestions offered by the rule based system satisfy users' needs for expertise within the chosen domain.

Rule-based systems are designed to solve problems in a selected domain. Every domain has its own knowledge and reasoning humans, which can be emulated and even replaced through automated rule-based systems. Many domains contain a large amount of knowledge that can be captured fully only through an information system, since humans may not access or immediately retrieve fully the needed information. There are many advantages of rule-based expert systems: They decrease costs since they reduce the need for human experts; they are permanent; they can be used for different knowledge systems, which increases functionality; they increase reliability since they minimize errors that humans are prone to; and if designed by multiple experts, can increase confidence. Finally, they lack human emotions, which are sources of mistakes in human based systems. The advantages of rule-based expert systems are multifold and they can considerably facilitate human life for the better. In this paper, we present and describe two rule-based recommender systems projects, both in the domain of university education [16].

III. RESEARCH DESIGN

A. Max-Min Composition

Let X, Y and Z be universal sets and let R be a relation that relates elements from X to Y, i.e [6].

$$R= \{((x,y), \mu_R(x,y))\} \quad x\in X, y\in Y, R\subset X \times Y \tag{1}$$

And

$$Q= \{((y,z), \mu_Q(y,z))\} \quad y\in Y, z\in Z, Q\subset Y \times Z \tag{2}$$

Then S will be a relation that relates elements in X that R contains to the elements in Z that Q contains, i.e.

$$S= \{((x,z), \mu_S(x,z))\} \quad x\in X, z\in Z, S\subset X \times Z \tag{3}$$

Max-Min Composition is then defined as

$$\mu_S(x,z) = \max_{y\in Y}(\min(\mu_R(x,y), \mu_Q(y,z))) \tag{4}$$

B. Genetic Algorithm

Genetic Algorithm (GA) is adaptive heuristic based on ideas of natural selection and genetics. Genetic algorithm is one of the most known categories of evolutionary algorithm. A GA works with a number of solutions which collectively is known as population in each iteration which is chosen randomly. These are adaptive heuristic search algorithms postulated on the evolutionary ideas of natural selection and genetic. The basic concept of these evolutionary algorithms is to stimulate process in natural system necessary for evolution. GA's are used for numerical and computational optimization and based on study the evolutionary aspects of models of social systems. The GA performs a balanced search on various nodes and there is a need to retain population diversity exploration so that any important information cannot be lost because there is a great need to focus on fit portions of the population.
The simplest form of genetic algorithm involves three types of operators: selection, crossover, and mutation [11].

C. Determining Membership Function Using Max-Min Composition and Genetic Algorithm

Assume that we have Fuzzy Logic System with the following rules.

1. If X is X1 and Y is Y1 then Z is Z1
2. If X is X1 and Y is Y1 then Z is Z3
3. If X is X1 and Y is Y1 then Z is Z4
4. If X is X1 and Y is Y2 then Z is Z1
5. If X is X1 and Y is Y2 then Z is Z2
6. If X is X1 and Y is Y2 then Z is Z3
7. If X is X1 and Y is Y4 then Z is Z1
8. If X is X1 and Y is Y4 then Z is Z2
9. If X is X1 and Y is Y4 then Z is Z3
10. .....

That can be represents in relation matrix from *x to y* and from *y to z.*

Assume that matrix relation from *x to y* and *y to z* is as follows.

$$R_1 = \begin{array}{c} \\ x_1 \\ x_2 \\ x_3 \end{array} \begin{array}{c} \begin{array}{ccccc} y_1 & y_2 & y_3 & y_4 & y_5 \end{array} \\ \begin{bmatrix} 0.1 & 0.2 & 0 & 1 & 0.7 \\ 0.3 & 0.5 & 0 & 0.2 & 1 \\ 0.8 & 0 & 1 & 0.4 & 0.3 \end{bmatrix} \end{array}$$

$$R_2 = \begin{array}{c} \\ y_1 \\ y_2 \\ y_3 \\ y_4 \\ y_5 \end{array} \begin{array}{c} \begin{array}{cccc} z_1 & z_2 & z_3 & z_4 \end{array} \\ \begin{bmatrix} 0.9 & 0 & 0.3 & 0.4 \\ 0.2 & 1 & 0.8 & 0 \\ 0.8 & 0 & 0.7 & 1 \\ 0.4 & 0.2 & 0.3 & 0 \\ 0 & 1 & 0 & 0.8 \end{bmatrix} \end{array}$$

And Max-Min Composition from R1° R2 (x, z) can we calculate.

$$\mu_{R_1 \circ R_2}(x_1, z_1) = \max(\min(0.1, 0.9), \min(0.2, 0.2), \min(0, 0.8), \min(1, 0.4), \min(0.7, 0))$$
$$= \max(0.1, 0.2, 0, 0.4, 0) = 0.4$$

Similarly we can determine the grades of membership for all pairs, as we obtain:

$(x_i, z_i), i = 1,2,3, j = 1, \ldots\ldots 4$

$$R_1 o R_2 = \begin{array}{c} \\ x_1 \\ x_2 \\ x_3 \end{array} \begin{array}{c} \begin{array}{cccc} z_1 & z_2 & z_3 & z_4 \end{array} \\ \begin{bmatrix} 0.4 & 0.7 & 0.3 & 0.7 \\ 0.3 & 1 & 0.5 & 0.8 \\ 0.8 & 0.3 & 0.7 & 1 \end{bmatrix} \end{array}$$

Based on the existing relationship, suppose that we specify that the only relationship that has degree> = 0.7 which we will use. Data set that can we get from Max-Min Composition are data set that has degree relation: 0.7 and 0.8. There are 5 data set. Suppose a data set from a relation of X to Z can be seen in Table 1.

Table 1. Data Set of Relation X to Z

Data Number	X	Z
1	1	2
2	2	3
3	4	5
4	6	7
5	7	8

The interval of Triangular membership Function that be determied by genetic algorithm can be seen in Figure 2.

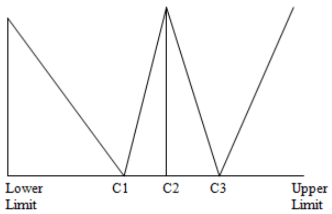

Fig. 2 Triangular MF

The process of the genetic algorithm are as follows.

1. Encode the parameter set (C1, C2, C3) in the form of Bit Strings
   Bit strings are created with random assignment of 1 and 0 at different bit locations. We start with an initial population of five strings (Table 2, column 2). The Strings are 18 bits in length. The first 6 bits encode the C1, the middle 6 bits encode the C2, and the last 6 bits encode the C3.
2. Column 2, 4 and 6, shows the decimal equivalent of their binary coding. These binary values for C1, C2, and C3 are the mapped into values relevan to the problem with these equation.
   $$Ci = C\min + \frac{b}{2^L - 1}(CMaxi - C\min i) \quad (5)$$
   (Here, Cmin i= -2 and Cmax i = 5, using these values we compute C1, C2, and C3)
3. These values shown in Table 2 column 8, 9, 10, 11, and 12 are the values computed using the equation.
   $$Z' = C1X + C2 + C3 \quad (6)$$
   Using the values 0f C1, C2, and C3 from column 3, 5, and 7, respectively for different value of x as given in Table 1.
4. These computed values for the Z' are compared with the Z as the correct values, and the square of the errors in estimated for each string.
   This summation is subtracted from a large number, that can be determined according to the problem (2200 in this problem) to convert the problem into maximization problem.

Table 2. First Iteration Using GA

String	C1 (Bin)	C1	C2 (Bin)	C2	C3 (Bin)	C3	Y1	Y2	Y3	Y4	Y5
000111 010100 010101	7	-1.22	20	0.22	21	0.33	-0.67	-1.89	-4.33	-6.77	-7.99
010010 001100 100001	18	-0.00003	12	-0.667	33	1.67	1.00297	1.00294	1.00288	1.00282	1.00279
010101 001100 100001	21	0.33	42	2.67	25	0.78	3.78	4.11	4.77	5.43	5.76
100100 001001 100011	36	2	9	-1	35	1.89	2.89	4.89	8.89	12.89	14.89
001001 001111 101000	9	-0.99	15	-0.33	40	2.44	1.12	0.13	-1.85	-3.83	-4.82

5. We can compute the fitness of each strings.
   Fitness 1 = 2200 - $\sum (zi' - zi)^2$ = 23.7775
   Fitness 2 = 2200 - $\sum (zi' - zi)^2$ = 1800..576
   Fitness 3 = 2200 - $\sum (zi' - zi)^2$ = 2198.678
   Fitness 4 = 2200 - $\sum (zi' - zi)^2$ = 1821.698
   Fitness 5 = 2200 - $\sum (zi' - zi)^2$ = 1026.938
   Best Fitness = 2198.678
6. Determine the value of C1, C2, and C3 from the best fitness.
   According to the best fitness, we can see the value of C1 is 21, C2 is 25 and C3is 42.
7. We can go to the next generation or the next iteration if we want to get the better fitness than the fitness from generation 1.
   At this step we can go to the step of genetic algorithm, such as: selection, crossover, and mutation
8. Process will stop if we feel that we get the best fitness or the fitness value seems not to be changed to next generation.

D. *Mapping of Relations*

Some special instructions are defined to allow the definition of a mapping that use relations. Figure 3 presents an anonymous example of a mapping of relations where the mapping A2C defines the relation between the associations bs and ds of respectively the classes A and D. The mapping B2D defines the relation between the classes B and D [10].

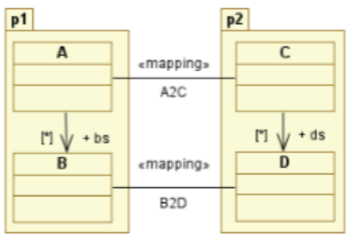

Fig. 3 An Example of Mapping Relations

The mapping of a relation is divided into two parts: its cardinality definition and the optional ordering of the target relation elements. The previous paragraph concerning navigation explained that it is possible to select some elements from a list, this principle is used to order target relation elements as illustrated in the different following definitions of A2C [10]:

```
1: A2C : A -> C {
2: 1 -> |ds|
3: bs[1] -> ds[1]
4: }                                                    (7)
```

Line 3 of the previous code creates a mapping between the first element of both lists. The cardinality of ds is set to 1 at line 2. The next example presents another possible definition of the mapping A2C [10].

```
1: A2C : A -> C {
2: bs -> ds
3: }                                                    (8)
```

Line 2 of the above code is equivalent to bs[i] -> ds[i], i=1..|bs|. It establishes a mapping from each element of bs at the position i to each element of ds at the same position, with i ∊ [1, |bs|]. The following example describes a last possible definition of the mapping A2C [10].

```
1: A2C : A -> C {
2: |bs|/2 -> |ds|
3: bs[i*2-1] -> ds[i], i=1..|ds|
4: }                                                    (9)
```

This code puts in relation each element of bs being at an odd position (i∗2−1) with the element of ds at the position i, with i ∊ [1, |ds|]. Line 2 defines that the cardinality of ds is the half of the cardinality of bs.

E. Determining Fuzzy Knowledge Based Using Schema Mapping Translation

Assume that we have Fuzzy Logic System with the following rules.

11. If X is X1 and Y is Y1 then Z is Z1
12. If X is X2 and Y is Y2 then Z is Z2
13. If X is X3 and Y is Y3 then Z is Z3
14. If A is A1 and B is B1 then Z is Z1
15. If A is A2 and B is B2 then Z is Z2
16. If A is A3 and B is B3 then Z is Z3
17. If B is B1 and C is C1 then Z is Z1
18. If B is B2 and C is C2 then Z is Z2
19. If B is B3 and C is C3 then Z is Z3
20. .....

Example:

1. Class Diagram A represents relation of X and Y
2. Class Diagram B represents relation of A and B
3. Class Diagram C represents relation of B and C
4. Class Diagram D represents target Z

According to our mapping translation schema that can be seen in Figure 2.

bs represents a relation of X and Y with A and B. ds represents a relation of B and C with target C. According to bs[i*2-1] -> ds[i], we can get a rule like this.

1. If X is X1 and Y is Y1 and A is A1 and B is B1 and C is C1 then Z is Z1
2. If X is X3 and Y is Y3 and A is A3 and B is B3 and C is C2 then Z is Z2

The position of class Diagram A, B, and C can be change between them. As example, if we change the represent of class diagram like this:

1. Class Diagram A represents relation of B and C
2. Class Diagram B represents relation of X and Y
3. Class Diagram C represents relation of A and B
4. Class Diagram D represents target Z

bs represents a relation of X and Y with A and B. ds represents a relation of B and C with target C. According to bs[i*2-1] -> ds[i], we can get a rule like this.

1. If B is B1 and C is C1 and X is X1 and Y is Y1 and A is A1 then Z is Z1
2. If B is B3 and C is C3 and X is X3 and Y is Y3 and A is A2 then Z is Z2

If we change the represent of class diagram like this:

1. Class Diagram A represents relation of A and C
2. Class Diagram B represents relation of X and Y
3. Class Diagram C represents B
4. Class Diagram D represents target Z

bs represents a relation of X and Y with A and B. ds represents a relation of B and C with target C. According to bs[i*2-1] -> ds[i], we can get a rule like this.

1. If A is A1 and C is C1 and Y is Y1 and X is X1 and B is B1 then Z is Z1
2. If A is A3 and C is C3 and Y is Y3 and X is X3 and B is B2 then Z is Z2

IV. Discussion

Max-Min Composition and Genetic Algorithm can be used for determining membership function of fuzzy logic. Using Max-Min Composition, we have a degree of relationship between the elements. Relations on fuzzy stating how strong the relationship between elements in fuzzy. The higher degree of relation level means the stronger the relationship between elements. Based on the strength of that relationship we can determine the interval membership function by using a genetic algorithm. In the process, we can encode the parameter set (C1, C2, C3) in the form of Bit Strings. The Strings are 18 bits in length. The first 6 bits encode the C1, the middle 6 bits encode the C2, and the last 6 bits encode the C3 and the calculate a binary of C1, C2, C3, and also the value of Z'. Next process is calculate the fitness value. According to the best fitness, we can calculate the value of C1, C2, and C3.

There are several methods that can be used in determining the combination of rules in fuzzy logic. One of the method is using schema mapping translation.

Schema mapping translation generally used in document or database for defining a relation between two schemas and it interoperability. We can use the concept of this schema mapping translation in mapping a relation of fuzzy logic rules, so we can get the combination of the rules according to this relation.

Our research uses the schema mapping translation in optimization of fuzzy knowledge based. The result of this research is the modification of the schema mapping translation can be used in optimization of fuzzy knowledge based.

V. CONCLUSION

The conclusion that can be drawn from this study are as follows.

1. Using Max-Min Composition, we have a degree of relationship between the elements
2. Genetic Algorithm can be used in determining membership function of fuzzy logic.
3. Value of C1, C2, and C3 from the best fitness can be used as an interval of membership function in fuzzy logic.
4. Schema mapping translation generally used in document or database for defining a relation between two schemas and it interoperability. We can use the concept of this schema mapping translation in mapping a relation of fuzzy logic rules, so we can get the combination of the rules according to this relation.
5. According to our research, we can know that determining the combination of the fuzzy rules will become a difficult process. The knowledge based that represents by the combination of rules determining the performance of the fuzzy logic, as it main function for capturing human technology.

ACKNOWLEDGMENT

This work was supported in part by the Grant of Ministry of Research, Technology, and Higher Education

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