

Short Paper

A Novel Approach for Treating Uncertain Rule-based Knowledge Conflicts

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Rule base have traditionally emphasized the verification of structural errors in the rule base. For conflicting or redundant rules, designated rules are usually followed to implement prioritized or direct deletions. However, there exist no proper methods by which to resolve conflicting or redundant rules. Due to the uncertainty of uncertain knowledge itself, it is difficult to treat conflicting rules, and the citation of erroneous knowledge leads to mistakes in decision making. Among users, 94% report perplexity when conflicting or redundant rules are cited. It is therefore a necessity to confirm the existence and reliability of the cited knowledge.

The current study attempts to provide an uncertain rule-based knowledge conflict treatment algorithm by integrating a group decision and an uncertain inference. In the algorithm, a "reliability factor" refers to the reliability level of the conflicting or redundant rules, while the "certainty factor" indicates the existence of the knowledge itself. A "certainty reliability index" is used to show both the existence of the knowledge itself and its reliability. For conflicting or redundant rules, it is suggested that the knowledge with a higher reliability factor be chosen. Among users, 92% reported that the algorithm is helpful to knowledge application and an aid to the decision-making process.

Keywords: group decision, uncertain inference, certainty factor, reliability factor, certainty reliability index

1. INTRODUCTION

A rule-based expert system is a rule base formed after the combining of facts obtained by experts familiar with all realms and rules. There is, however, a possibility of conflicts in the experience of experts engaged in diversified fields. Hence, a rule-based expert system tends to value verification of a rule base. Effort is devoted to checking for any structural errors in order to ensure the quality of the knowledge base and correctness of inference.

Verification of the rule base concentrates on detecting structural errors resulting from interaction between rules. Structural errors may influence consistency in rule inter-

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ference, which involves redundancy, inconsistency, incompleteness and circularity [12, 16]. Structural errors, in other words, include redundancy, inconsistency, incompleteness and circularity of the rule. Incompleteness refers to a lack of completeness when the general rule is used to express the designated field, and covers unnecessary conditions, dead-end rules or dangling conditions. Structural errors will directly or indirectly influence inferences drawn from the system rule. Direct and indirect structural errors are distinguished according to whether or not they exert immediate influence over the rule system. Conflicting rules are direct structural errors while redundant rules, incomplete rules and circular rules are indirect structural errors, as shown in Table 1.

Table 1. Structural errors of the rule base.

Property	Content	Classification
Redundancy	Complete or partial redundancy in rules	Redundant rules
Inconsistency	Mutual conflict in rules	Conflicting rules
Incompleteness	Lack of rules and rules that can't be practically employed Rules with invalid conclusion and rules that fail to achieve the expected result	Incomplete rules
Circularity	There is no end to the rule inference	Circular rules

The currently prevailing method of treating conflicting and redundant rules is to implement prioritized or direct deletion by following designated rules. However, there exist no proper methods to resolve conflicting and redundant rules. Redundancy and inconsistency are likely to result in the incomplete fulfillment of benefits intended to be derived from the knowledge application. Worse, they may produce a negative effect. Additionally, the uncertainty in the uncertain knowledge itself adds difficulty to the treatment of conflicts between uncertain knowledge of various forms. Citation of the erroneous knowledge then leads to mistaken final decisions. To obtain more benefits from knowledge applications, it is essential to confirm the existence and reliability of the cited knowledge.

The current study attempts to provide an uncertain rule-based knowledge conflict treatment algorithm for uncertain rule-based knowledge. In the algorithm, the term "reliability factor" refers to the reliability of the rule item in which there is any redundant and conflicting rules, while the term "certainty factor" indicates the absence or presence of the rule itself. The certainty and reliability factors are combined to show the presence of the knowledge itself and its reliability. For conflicting or redundant rules, rules of higher reliability can then be chosen to treatment of all uncertain rule-based conflicting or redundant rules. By so doing, mistaken decisions can be effectively prevented.

2. LITERATURE REVIEW

2.1 Knowledge Representations

As a rule, knowledge as understood in this paper can be represented in the following ways: as rule-based knowledge, as frame-based knowledge, as a semantic network, as case-based knowledge, or as ontology.

Rule-based knowledge is the most popular to represent knowledge. In this category, knowledge is represented in a set or sets of rules. The representation model is IF (antecedent) plus THEN (consequent). Frame-based knowledge was proposed by Minsky in 1975. It is formed mainly by the aggregate of knowledge slots. Each slot is the aggregate of knowledge facets and each facet has its corresponding slot value. Each frame is used to represent the relevant knowledge concept or knowledge object [10].

The semantic network is represented by the directed graph where the node expresses the component of the knowledge or type in the knowledge of a specific field; the arc between nodes indicates the relation between components of the knowledge [11]. Case-based knowledge is usually used to describe knowledge as part of an experience. Ontology expresses the meaning of the existence of knowledge or the being of knowledge [13].

In light of actual needs, the current study presupposes the following restrictions:

- (1) For rule-based uncertain knowledge in the same field, the knowledge conflict treatment is explored. And the knowledge has been sorted by the knowledge engineer and represented in the format characterized by IF <antecedent> THEN <consequent>.
- (2) The explored knowledge conflict treatment refers to the treatment of redundant rules and conflicting rules. Dead-end rules, incomplete rules and circular rules are not categorized into the knowledge conflict in the current study.

2.2 Methods of Representing Uncertainty

A number of theories can represent uncertainty. The most common include the traditional probability and Bayesian probability [1] represented by occurrence probability, the certainty factors theory [5] represented by the intensity of reliability or unreliability, and the fuzzy theory represented by the membership value of the membership function [8].

2.3 Rule Generation and Rule Evolution

H. Sakai *et al.* applied rough sets based algorithms to survey rule in deterministic information systems, and proposed the enumeration method and interactive selection and enumeration method for rule generation in non-deterministic information systems [6]. T. Shang *et al.* proposed the automatic derivation of basic rules from history driving data and the automatic extraction of intention rule from instruction data for knowledge acquisition. Meanwhile they had used genetic algorithm verified the fuzzy system model based on acquired rules could be optimized for the knowledge evolution [15].

2.4 Methods of Treating Knowledge Conflicts or Overlaps

Suwa *et al.* put forward a set of verification checkers to detect conflicting, overlapping and inclusion rules [12]. Cragun *et al.* proposed a decision table base processor to cut and rank the main table into several sub-tables to check whether errors exist [2]. The high-order Petri Nets, together with graphing and mathematical theory, can be used to represent the system [4, 14] by observing serials and forecasting the transfer network model. Although conflicting rules and overlapping rules are detected, only the overlapping rules are usually directly deleted. As for the conflicting rules, they are often treated in chronological order by the designated rules.

3. UNCERTAIN RULE-BASED KNOWLEDGE CONFLICT TREATMENT ALGORITHM

In uncertain rule-based knowledge, as applied in the present study to antecedents or consequents, there may exist varied redundant or conflicting rules as illustrated in Fig. 1.

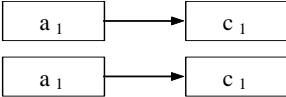
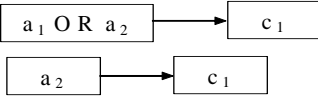
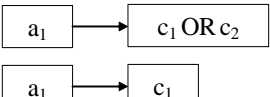
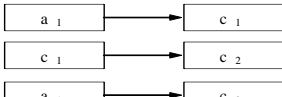
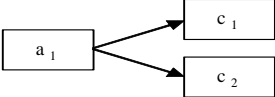
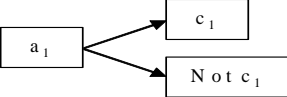
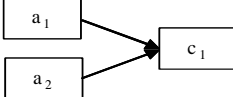
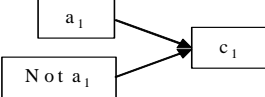
Redundant rules	 <p>(a) The same antecedent a_1 and the same consequent c_1.</p>	 <p>(b) The same antecedent a_2 and the same consequent c_1.</p>
	 <p>(c) The same antecedent a_1 and the same consequent c_1.</p>	 <p>(d) The same antecedent a_1 and the same consequent c_2.</p>
	 <p>(e) The same antecedent a_1 and consequent c_1 is in conflict with consequent c_2.</p>	 <p>(f) The same antecedent a_1 and consequent c_1 is in conflict with Not c_1.</p>
	 <p>(g) The same consequent c_1 and antecedent a_1 is in conflict with antecedent a_2.</p>	 <p>(h) The same consequent c_1 and antecedent a_1 is in conflict with Not a_1.</p>

Fig. 1. Redundant rules or conflicting rules in antecedent or consequent.

According to the group decision and the uncertain inference, the study provides an Uncertain Rule-based Knowledge Conflict Treatment Algorithm in which any Reliability Factor (RF) refers to the reliability of the rule which is conflicting rules; any Certainty Factor (cf) refers to the certainty of the existing rule itself; and the Certainty Reliability Index (CRI) indicates both the certainty of the existing rule itself as well as the reliability of the rule. These related theories are expounded as follows:

3.1 Reliability Factor Theory

In rule-based knowledge, the treatment of diversified redundant rules or conflicting rules is dependent on the group decision and the concept of resolving disputes, let con-

flicts can be accepted by each group member. In this paper, Reliability Factor refers to the redundant rules or conflicting rules and clearly manifests the reliability of each rule. For instance, if three experts suggest three different treatments for the same problems mentioned in Fig. 2, the final treatment shall be supported unanimously by three experts; that is to say, the final treatment is the intersection of three applications of expertise. The scheme, executed in this way, receives approval from three experts and therefore enjoys the highest reliability.

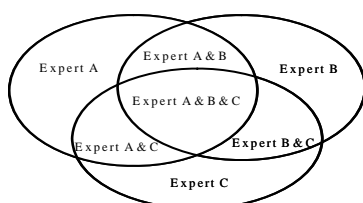


Fig. 2. The concept of treating disputes and conflicts through a group decision.

For knowledge sets which are conflicting or redundant rules, the way to represent the reliability factor is put it forward to accurately indicate reliability.

Definition the reliability factor of the knowledge with the same antecedent

$$RF_i = \frac{\text{The number of the rules with the same antecedent and corresponding consequent in } i^{\text{th}} \text{ interval}}{\text{The number of the rules with the same antecedent}} \tag{1}$$

The reliability factor of the knowledge with the same consequent

$$RF_i = \frac{\text{The number of the rules with the same consequent and corresponding consequent in } i^{\text{th}} \text{ interval}}{\text{The number of the rules with the same consequent}} \tag{2}$$

Additionally, $0 \leq RF \leq 1$.

According to Eqs. (1) and (2), both bounded intervals and unbounded intervals are included in the distribution interval of the antecedent or consequent of the knowledge set which is conflicting or overlapping. Considering that the distribution interval of a rule may have several different reliability factors, we shall discuss ways to calculate the reliability factor of the rule in the following paragraphs:

(1) When the distribution interval of the antecedent or consequent value of a rule is a bounded interval

When the distribution interval of the antecedent or consequent of a rule falls into a bounded interval, it means that the linear strength of the bounded interval is fixed. Suppose the rule has the three different but constant reliability factors RF_1 , RF_2 and RF_i , and their corresponding linear lengths are L_1 , L_2 and L_i respectively, as shown in Fig. 3.

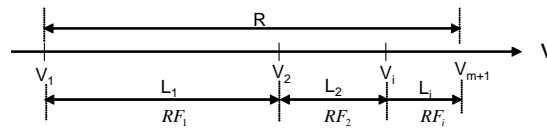


Fig. 3. When the distribution interval of the antecedent or consequent value is a bounded interval.

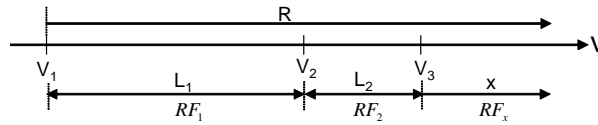


Fig. 4. When the distribution interval of the antecedent or consequent value of a rule is an unbounded interval.

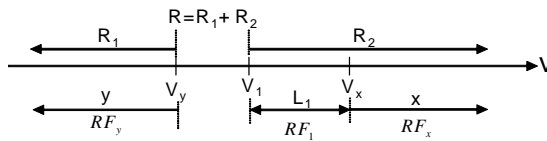


Fig. 5. When the distribution interval of the antecedent or consequent value of a rule are two unbounded intervals.

In accordance with a weighted average (WA) theory, the RF for the rule can be figured out by Eq. (3). If there is a corresponding RF of a fixed point in an interval, due to length of the point equals zero, so the RF for the point can't be calculated through Eq. (3).

$$RF = \frac{L_1 \cdot RF_1 + L_2 \cdot RF_2 + L_i \cdot RF_i}{L_1 + L_2 + L_i} \tag{3}$$

(2) When the distribution interval of the antecedent or consequent value of a rule is an unbounded interval or two unbounded intervals

(a) When the distribution interval of the antecedent or consequent value of a rule is an unbounded interval, it means the linear length of an interval in the unbounded interval is indefinitely long. Suppose the rule has three different but constant reliability factors, RF_1 , RF_2 and RF_x , and their corresponding linear lengths are L_1 , L_2 and L_x respectively, as is shown in Fig. 4, wherein L_1 and L_2 are constants while x is a variable. Through Eq. (3), the RF for the rule can be calculated, as in Eq. (4). By L'Hospital Rules, the simplified RF in Eq. (4) approximates RF_x .

$$RF = \lim_{x \rightarrow \infty} \left(\frac{RF_1 \cdot L_1 + RF_2 \cdot L_2 + RF_x \cdot x}{L_1 + L_2 + x} \right) = \lim_{x \rightarrow \infty} \left(\frac{RF_x}{1} \right) = RF_x \tag{4}$$

(b) When the distribution interval of the antecedent or consequent value of a rule is two unbounded intervals, it means the linear length of two intervals in the unbounded interval is indefinitely long. Suppose the rule has three different but constant reliability factors, RF_1 , RF_x and RF_y , and their corresponding linear lengths are L_1 , x and y re-

spectively, as shown in Fig. 5, wherein L_1 is a constant while x and y are variables. Through Eq. (3), the RF for the rule can be calculated, as in Eq. (5). Let $y = -x$ and transform the variable to get $|y| = |-x| = x$. The RF in Eq. (5) can be simplified to get the approximate $\frac{RF_x + RF_y}{2}$.

$$RF = \lim_{\substack{x \rightarrow \infty \\ y \rightarrow -\infty}} \left(\frac{RF_1 \cdot L_1 + RF_x \cdot x + RF_y \cdot |y|}{L_1 + x + |y|} \right) = \lim_{x \rightarrow \infty} \left(\frac{RF_x + RF_y}{2} \right) = \frac{RF_x + RF_y}{2} \tag{5}$$

It can be seen from Eqs. (4) and (5) that when the distribution interval of the antecedent or consequent value of a rule has an unbounded interval, then the reliability factors of other intervals of limited length in the rule are absorbed into the reliability factors of indefinitely long intervals. The complete failure to actualize the effect will reduce the precision of RF for the rule, so it is necessary to fill the inadequacy.

The main purpose of treating the knowledge set containing conflicts or overlapping is to choose from the knowledge set the rule of highest reliability. The reliability factor is represented by the relative comparison. Thereby the length of extension in the unbounded interval is restricted and the unbounded interval in which the antecedent or consequent value of a rule is distributed is corrected into two bounded intervals which extend themselves in one direction (positive or negative) or both positive and negative directions. Although the extension length is restricted, the reliability factor for the indefinitely long interval will exert the greatest influence over the reliability factor for the rule.

The distribution interval in a rule may have both various kinds of reliability factors and distribution intervals of different types. In addition, there is a need to correct the reliability factors under the circumstances where operators such as AND or OR are used. They are specified individually as follows:

Definition 1

- V_{max} : the maximal value of the antecedent or consequent of the knowledge set
- V_{min} : the minimal value of the antecedent or consequent of the knowledge set
- r : the distribution interval of the previous values of antecedent or consequent of the knowledge set, namely, $r = V_{max} - V_{min}$
- max : the values of r the definite length of V_{max} extension in the positive direction
- min : the values of r the definite length of V_{min} extension in the negative direction

Based on the aforementioned definitions, the maximal possible distribution interval of the value of antecedents or consequents of a rule can be shown in Fig. 6.

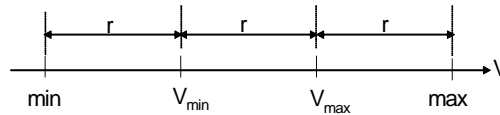


Fig. 6. The maximal distribution interval of the value of antecedent or consequent of a rule.

(3) When the distribution interval of the antecedent or consequent value of a rule extends in a positive or negative direction and becomes an interval of definite length

If the distribution interval of the antecedent or consequent value of a rule extends in a positive or negative direction (here we take the extension in the positive direction for example), suppose a rule has three differently constant reliability factors, RF_1 , RF_2 and RF_x , and the linear lengths of these constants are L_1 , L_2 and x respectively as shown in Fig. 7. According to Eq. (3), the correction to the reliability factor of the rule can be calculated as in Eq. (6).

$$RF = \frac{RF_1 \cdot L_1 + RF_2 \cdot L_2 + RF_x \cdot x}{L_1 + L_2 + x} \tag{6}$$

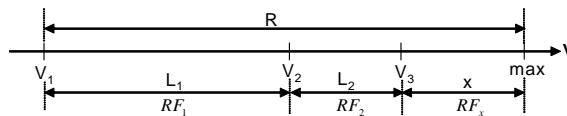


Fig. 7. The distribution interval of the antecedent or consequent value of a rule extends in the positive direction.

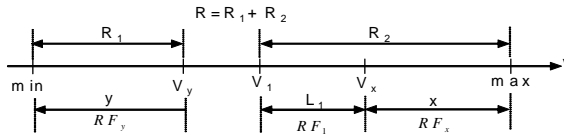


Fig. 8. When the distribution interval of the antecedent or consequent value of a rule extends both in positive and negative directions.

(4) When the distribution interval of the antecedent or consequent value of a rule extends both in positive and negative directions and becomes a bounded interval

If the distribution interval of the antecedent or consequent value of a rule extends in both positive and negative directions, suppose a rule has three differently constant reliability factors, RF_1 , RF_2 and RF_x , and the linear lengths of these constants are L_1 , x and y respectively as shown in Fig. 8. According to Eq. (3), the reliability factor of the rule can be calculated as in Eq. (7).

$$RF = \frac{RF_1 \cdot L_1 + RF_x \cdot x + RF_y \cdot y}{L_1 + x + y} \tag{7}$$

(5) When the antecedent or consequent value of a rule is connected with the operator AND or OR

When the antecedent or consequent value of a rule is connected with the operator AND or OR, and the respective reliability factors of V_i and V_j are constants, RF_i and RF_j , the RF of the rule can be calculated separately as in Eqs. (8) and (9).

- R1: IF a_1 THEN $(V = V_i \text{ AND } V = V_j)$
- R2: IF a_1 THEN $(V = V_i \text{ OR } V = V_j)$
- The RF of R1: $RF = \min[RF_i(V = V_i), RF_j(V = V_j)]$ (8)
- The RF of R2: $RF = \max[RF_i(V = V_i), RF_j(V = V_j)]$ (9)

Instance 1: The following six rules are ones with the same antecedent; the consequents are different in value and include the logic operators AND and OR.

- R3 : IF a_1 THEN $V > 42$
- R4 : IF a_1 THEN $30 < V \leq 50$
- R5 : IF a_1 THEN $(V < 20)$ AND $(V > 70)$
- R6 : IF a_1 THEN $V < 60$
- R7 : IF a_1 THEN $V = 50$
- R8 : IF a_1 THEN $(V = 48)$ OR $(V > 56)$

The distribution interval of the consequent values of these six rules with the same antecedent is an unbounded interval, in which $V_{max} = 70$ and $V_{min} = 20$, $r = 50$, $max = 120$, $min = -30$ as in Fig. 9.

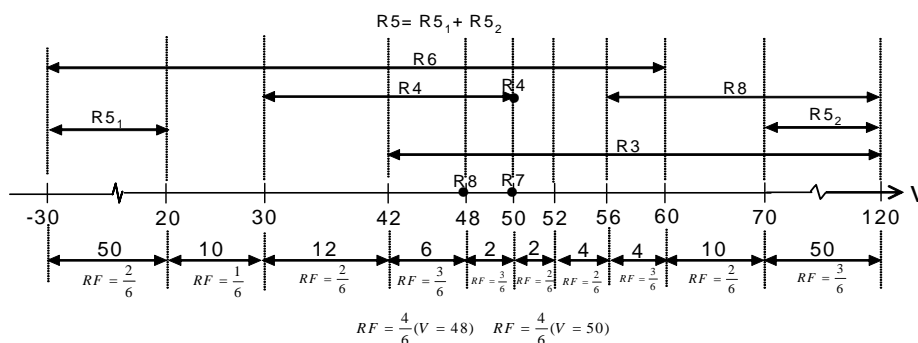


Fig. 9. When six rules with the same antecedent and logical operators AND and OR are used in the consequents which different from each other.

Looking at R4 for example, the RF of the bounded intervals $(30 < V \leq 50)$ are 0.33, 0.5 and 0.5 (the corresponding linear lengths are 12, 6 and 2). According to Eq. (3), the RF for the rule as a whole is 0.4. In the same way, in accordance with Eqs. (3) to (9), the RF s for other rules are calculated as follows:

- R3 : IF a_1 THEN $V > 42$ ($RF = 0.466$)
- R4 : IF a_1 THEN $30 < V \leq 50$ ($RF = 0.4$)
- R5 : IF a_1 THEN $(V < 20)$ AND $(V > 70)$ ($RF = 0.415$)
- R6 : IF a_1 THEN $V < 60$ ($RF = 0.336$)
- R7 : IF a_1 THEN $V = 50$ ($RF = 0.667$)
- R8 : IF a_1 THEN $(V = 48)$ OR $(V > 56)$ ($RF = 0.667$)

3.2 Certainty Factor Theory

In this study the certainty factor (*cf*) theory is adopted to represent uncertain knowledge. The certainty factor signals the experts' reliability concerning the knowledge. The previous *cf* lay between -1 and 1 ; it is now revised to the range from 0 to 1 . The greater the *cf* is, the higher the knowledge reliability is. Shortliffe and Buchanan applied *cf* theory to MYCIN [5].

The rules with the same antecedent include three kinds of rules, namely, the rule with a single antecedent, the AND rule and the OR rule. The following are respective instructions for the calculation of the *cf* of these three levels of uncertain knowledge.

- (1) The calculation of the *cf* of the rule with a single antecedent [7, 9]:

R: IF <antecedent (*a*)> THEN <consequent (*c*)> {*cf_a*, *cf_i*, *cf*}

Then the certainty factor of the rule can be figured out as in Eq. (10).

$$cf = cf_a * cf_i \quad (10)$$

cf_a: the certainty factor of the rule with a single antecedent, which represents the reliability of the certainty of the existence of the antecedent. It lies between 0 and 1 .

cf_i: the certainty factor of the rule inference, which represents the reliability of the reference of the rule. It lies between 0 and 1 .

cf: the certainty factor of the existence of the combination of a single antecedent and rule inference, which represents the reliability of the certainty of the existence of the rule.

- (2) The calculation of the *cf* of the existence of the rule with logic operator AND [7, 9]:

R: IF (*a*₁ AND *a*₂) THEN (*c*) {*cf_{a1}*, *cf_{a2}*, *cf_i*, *cf*}

The *cf* of the existence of the rule is calculated as in Eq. (11).

$$cf = \min[cf_{a_1}, cf_{a_2}] * cf_i \quad (11)$$

- (3) The calculation of the *cf* of the existence of the rule with logic operator OR [7, 9]:

R: IF (*a*₁ OR *a*₂) THEN (*c*) {*cf_{a1}*, *cf_{a2}*, *cf_i*, *cf*}

The *cf* of the existence of the rule is calculated as in Eq. (12).

$$cf = \max[cf_{a_1}, cf_{a_2}] * cf_i \quad (12)$$

3.3 Certainty Reliability Index Theory

For uncertain knowledge with conflict or overlapping, the Certainty Reliability Index (*CRI*) is employed to comprehensively represent the reliability of the certainty of the knowledge; this in turn is conducive to knowledge application and auxiliary decision making. Since knowledge can be divided into two types of independent events, certainty events and reliability events, it can be defined in accordance with probability theory:

$$\text{Certainty Reliability Index (CRI)} = \text{certainty factor (cf)} * \text{reliability factor (RF)} \quad (13)$$

In Eq. (13), the *CRI* comprehensively represents the certainty of the existence of knowledge and its reliability, which ranges from 0 to 1. The greater the *CRI* is, the more certain and reliable the knowledge is.

3.4 Uncertain Rule-based Knowledge Conflict Treatment Algorithm

It can be seen from the aforementioned that for integrating the group decision and uncertain inference concepts, our study puts forward the Uncertain Rule-based Knowledge Conflict Treatment Algorithm (URKCTA) and uses the *RF* to represent the reliability of redundant or conflicting rule; the *cf* to indicate certainty on the existence of the knowledge itself; and the *CRI* to indicate certainty on the existence of the knowledge itself and its reliability. The determination of the *CRI* of cited knowledge can effectively avoid the committing of mistakes in decision making. The architecture of the URKCTA is shown in Fig. 10. Coming up next is a description of URKCTA.

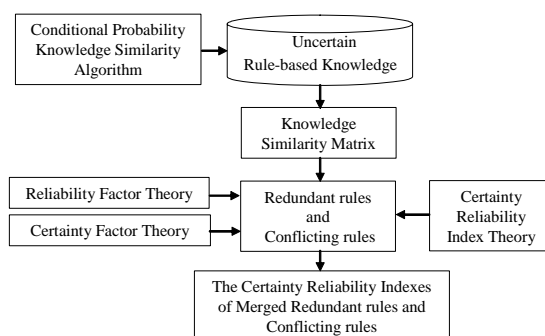


Fig. 10. The architecture of URKCTA.

Algorithm

Input:

ASM, CSM // (Antecedent Similarity Matrix, ASM) and (Consequent Similarity Matrix, CSM) of *m* rules

cf_a, *cf_l* // Certainty factor for the existence of the antecedents of *m* redundant or conflicting rules and rule inference occurrence factor

m // the number of rules

Output:

cf, *RF* and *CRI* // the certainty factor of the redundant or conflicting rules, reliability factor and certainty reliability index

Step 1: select the knowledge sets with redundant or conflicting rules in accordance with the ASM and CSM of *m* rules

Step 2: calculate the *RF* for each redundant or conflicting rule among the redundant or conflicting rule sets.

Step 3: IF (in the redundant or conflicting rule sets with AND or OR in the antecedent) **THEN** figure out the *cf* for the antecedents of each redundant or conflicting rule.

- Step 4:** calculate cf the cf for each redundant or conflicting rule among the redundant or conflicting rule sets.
- Step 5:** calculate the CRI for each redundant or conflicting rule among the redundant or conflicting rule sets.
- Step 6:** output RF , cf and CRI for each redundant or conflicting rule, and output CRI s of a set of redundant rules are combined into a single rule.
- Step 7:** END

4. PRACTICAL SIMULATION AND KNOWLEDGE APPLICATION

4.1 Practical Simulation

20 rule-based knowledge instances by C. J. Huang in 2006 and ASM & CSM were cited. Besides, the cf_a and cf_i for each rule is designated as in Table 2 [3].

Table 2. Representation of knowledge instances.

Index	Antecedent			Consequent			cf_a	cf_i
	Gender	Height	Weight	Gender	Height_type	Weight_type		
R1	= male	> 190	= Null	= male	= Very_large	= Null	0.85	0.95
R2	= male	= Null	= 45	= male	=Null	= Very_small	0.75	0.75
R3	= male	= Null	< 55	= male	= Null	= Small	0.9	0.9
R4	= female	> 180	= Null	= female	= Very_large	= Null	0.95	0.98
R5	= female	= Null	> 70	= female	= Null	= Very_large	0.75	0.8
R6	= male	= 173	= Null	= male	= Medium	= Null	0.78	0.82
R7	= female	= Null	= 50	= female	= Null	= Small	0.9	0.92
R8	= male	= Null	= 65	= male	= Null	= Medium	0.75	0.7
R9	= male	= 195	= Null	= male	= Very_large	= Null	0.95	0.9
R10	= female	= 160	= Null	= female	= Medium	= Null	0.92	0.95
R11	= female	= Null	< 40	= female	= Null	= Very_small	0.9	0.92
R12	= female	< 150	= Null	= female	= Small	= Null	0.94	0.95
R13	= male	> 180	= Null	= male	= Large	= Null	0.88	0.85
R14	= male	< 162	= Null	= male	= Small	= Null	0.9	0.92
R15	= female	= 160	= Null	= female	= Small	= Null	0.9	0.9
R16	= female	= Null	= 50	= female	= Null	= Small	0.9	0.92
R17	= female	= 160	= Null	= female	= Small	= Null	0.94	0.95
R18	= male	> 180	= Null	= male	= Large	= Null	0.8	0.85
R19	= female	= Null	= 50	= female	= Null	= Small	0.9	0.85
R20	= female	= Null	< 48	= female	= Null	= Small	0.95	0.92

- Step 1:** select the redundant or conflicting rules from the ASM and CSM [3], as in Table 3.
- Step 2:** Figure out the RF , cf and CRI for each redundant or conflicting rule among all redundant or conflicting rule sets, as illustrated in Table 4. A set of redundant rules can be combined into a single rule. Using Eq. (14), figure out the mean value of CRI s for the redundant rules within the set as well as the root mean square error (RMS) of the mode, then choose the smaller of the two root mean square errors. The corresponding CRI of the smaller RMS is used for treating conflicting rules. The CRI s for other rules can be selected by users.

Table 3. Redundant or conflicting rules.

Redundant rules	(1) R7, R16 and R19
	(2) R15 and R17
	(3) R13 and R18
Conflicting rules	(1) {R7, R16, R19} and R20
	(2) {R15, R17} and R12
	(3) R1 and R9

Table 4. *RF*, *cf* and *CRI* of the redundant or conflicting rules.

Rule type		Index	<i>cf_a</i>	<i>cf_l</i>	<i>cf</i>	<i>RF</i>	<i>CRI</i>	Combined
Redundant rules	(1) R7, R16 and R19	R7	0.9	0.92	0.83	0.75	0.621	0.605
		R16	0.9	0.92	0.83	0.75	0.621	
		R19	0.9	0.85	0.77	0.75	0.574	
	(2) R15 and R17	R15	0.9	0.9	0.81	0.67	0.543	0.571
		R17	0.94	0.95	0.90	0.67	0.598	
	(3) R13 and R18	R13	0.88	0.85	0.75	1	0.748	0.714
R18		0.8	0.85	0.68	1	0.680		
Conflicting rules	(1) {R7, R16, R19} and R20	R7	0.9	0.92	0.83	0.75	0.605	
		R16	0.9	0.92	0.83	0.75		
		R19	0.9	0.85	0.77	0.75		
		R20	0.95	0.92	0.87	0.25		0.219
	(2) {R15, R17} and R12	R12	0.94	0.95	0.89	0.33	0.571	
		R15	0.9	0.9	0.81	0.67		
		R17	0.94	0.95	0.89	0.67		
	(3) R1 and R9	R1	0.85	0.95	0.81	0.5	0.404	
		R9	0.95	0.9	0.86	1		0.855

$$RMS = \sqrt{\frac{\sum_{i=1}^n e_i^2}{n}} \tag{14}$$

RMS: the root mean square error of mean *CRI*s of a set of redundant rules or the modes
e: the error in the mean *CRI* of a set redundant rules or the mode
n: the number of the a set of redundant rules

It can be seen from Table 4 that R7, R16 and R19 are a knowledge set with redundant rules. The mean *CRI* of these three rules R7, R16 and R19 is 0.605 while the *CRI* of the mode is 0.621. The differences between the *RMS* of the mean value and the mode respectively are 0.022 and 0.027. Therefore the *CRI* of the combined rule of R7, R16 and R19 should be represented as 0.605. In the same manner, the *CRI* of the combined rule of R15 and R17 should be shown as 0.571 and that of R13 and R18 indicated as 0.714.

4.2 Knowledge Selection and Application

Since the factors of knowledge certainty and reliability are essential to knowledge application, to avoid the high risk in knowledge application the *CRI* of the cited knowledge shall be greater than 0.5.

As is mentioned in Table 4, there are three knowledge sets with conflicting rules. The combined *CRI* of the first set {R7, R16, R19}, R20 and {R7, R16, R19} is 0.605 but the

CRI of R20 is 0.219. Therefore it is proper to adopt the combined rule of {R7, R16, R19}. In the same way, the second takes the combined rule of {R15, R17} and the third set R9.

A questionnaire was sent to average users to gain a understanding of their judgment of the citation of the knowledge set with conflicting or redundant rules and their needs for additional information on the auxiliary decision or knowledge application, and to check whether the determination of the certainty factor of the conflicting or redundant rules was helpful to knowledge application or auxiliary decision making. One hundred copies of the questionnaire reached individuals who had graduated from universities, were engaged in further research in research institutes, and were employed. Of the 100 copies, the return rate was 94%.

5. CONCLUSIONS AND FUTURE PROSPECTS

The study came up with three conclusions based on the aforementioned analysis:

- (1) For uncertain rule-based knowledge, the study integrated group decision and uncertain inference concepts to put forward URKCTA in which *RF* represents the reliability of the knowledge with conflicting or redundant rules; *cf* represents the certainty of the existence of the knowledge itself; and *CRI* comprehensively indicates the existence of the knowledge itself and its reliability.
- (2) The study clearly revealed the *CRI* for conflicting or redundant rules, and comprehensively showed the existence and reliability of the rule itself for use in determining the certainty and reliability of the cited knowledge. This can then effectively prevent or minimize mistakes in making decisions.
- (3) The questionnaire revealed that: 94% of users admitted it was perplexing to cite conflicting or redundant rules; 92% held that the definite *CRI* for conflicting or redundant rules was helpful to knowledge application and auxiliary decision making; and 90% thought the provision of additional relevant and auxiliary information was needed when they were treating conflicting or redundant rules.

On the basis of the existing URKCTA, our future work will be dedicated to develop a web page-type uncertain rule-based knowledge conflict treatment system and an experimental test for further performance measure of URKCTA.

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