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A New Decision Making Approach for Winning Strategy Based on Muti Soft Set Logic

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Abstract

We introduce a new concept of certainty and coverage of a parameter of the soft set and present a new decision making approach for the soft set over the universe using the certainty of a parameter. Also, we point out the drawbacks of the reduct definition by pointing out the delusion of Proposition 14 given by Herawan et al. [20] and provide the revised definition of the reduct of the multi soft set.

Keywords: Certainty, Coverage, Flow graph, Decision Making, Multi-Valued information system, Multi soft set.

1 | Introduction

Many practical problems involve data that contain uncertainties. These uncertainties may be dealt with existing theories such as fuzzy set theory [1] and rough set theory [2]. In 1999, Molodstov [3] pointed out the difficulties of these theories and he posited the concept of soft set theory. Maji et al. [4] made a theoretical study of soft set in 2003. Soft set theory has rich potential for applications. In [5], Maji et al. presented an application of soft sets in decision making problems and extend the concept into fuzzy soft sets in [6]. In the year 2010, Cagman et al. gave the $uni-int$ decision making algorithm using soft sets [7] and soft matrices [8]. Feng et al. [9] extended Cagman and Enginoglu's $uni-int$ decision making algorithm. They introduced several new soft decision making methods including $uni-int^k, uni-int_s^t$ and int^m-int^n decision making methods. Also, Han et al. [10] initiated the pruning method for solving int^m-int^n decision making method. Feng et al. [11] introduced the concept of discernibility matrix in 2014 and using this, they provided a decision making algorithm for soft sets. Also, in the same year, Dauda et al. [12] presented a decision making algorithm of soft sets using AND and OR operations. In 2020, Wang et al. [13] introduced a novel plausible reasoning based on intuitionistic fuzzy propositional logic and Meng et al. [14] proposed an inequality approach with the quasi-ordered set to evaluate the performances of decision making units. Recently many authors studied the concepts of decision making in terms of fuzzy set and intuitionistic fuzzy sets [15]-[18].

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In this paper, we define a new definition of certainty of a parameter of the soft set and with the help of this definition, we present a new decision making approach for the soft set over the universe which is a partition of objects. The standard soft set deals with a binary-valued information system. For a multi-valued information system, Herawan et al. [19] introduced a concept of multi soft sets in 2009. Also, they [20] introduced the reduct concept in multi soft sets using the value class of the multi soft matrix. In this paper, we point out the delusion of proposition 14 of [20] and provide the revised definition of the reduct of the multi soft set.

Definition 1. [20]. The idea of multi soft sets is based on a decomposition of a multi-valued information system $S=(U,A,V,f)$ into $|A|$ number of binary valued information systems $S=(U,A,V_{\{0,1\}},f)$ where $|A|$ denotes the cardinality of A. Consequently, the $|A|$ binary valued information systems, define multi soft sets $(F,A_m)=\{(F,a_i)\,/\,1\leq i\leq |A|\}$.

Definition 2. [20]. Matrix $M_{a_i}, 1\leq i\leq |A|$ is called matrix representation of the soft set (F,a_i) over universe U. The dimension of matrices is defined by dim $(M_{a_i})=|U|\times|V_{a_i}|$. All entries of $M_{a_i}=[a_{ij}]$ is belong to a set $\{0,1\}$ where $a_{ij}=\begin{cases}0 & if\ |f(u,\alpha)|=0\\ 1 & if\ |f(u,\alpha)|=1\end{cases}$ where $1\leq i\leq |U|, 1\leq j\leq |V_{a_i}|, u\in U$ and $\alpha\in V_{a_i}$.

The collection of all matrices representing (F,A_m) is denoted by M_A. That is, $M_A=\{M_{a_i}\mid 1\leq i\leq |A|\}$.

Definition 3. [20]. Let $M_{a_i}\in M_A$ be a matrix representation of a multi soft set (F,A_m) over U. The value class of M_{a_i}, that is, class of all value sets of M_{a_i}, denoted $C_{M_{a_i}}$ is defined by

$C_{M_{a_i}}=\{\{u\,|\,|f(u,\alpha_1)|=1\},\ldots,\{u\,|\,|f(u,\alpha_{|V_{a_i}|})|=1\}\}, 1\leq i\leq |V_{a_i}|, u\in U$ and $\alpha\in V_{a_i}$. Clearly, $C_{M_{a_i}}\subseteq\wp(U)$.

Definition 4. [20]. Let $M_{a_i}=[a_{kl}], 1\leq k\leq |U|, 1\leq l\leq |V_{a_i}|$ and $M_{a_j}=[a_{mn}], 1\leq m\leq |U|, 1\leq n\leq |V_{a_j}|$ be two matrices in M_A. The AND operation between M_{a_i} and M_{a_j} is defined as M_{a_i} AND $M_{a_j}=M_{a_{ij}}=[a_{pq}]$ with dim$(M_{a_{ij}})=|U|\times(|V_{a_i}|\times|V_{a_j}|)$ where $a_{p1}=min\{a_{k1},a_{m1}\}, a_{p2}=min\{a_{k1},a_{m2}\},\ldots,a_{p(|V_{a_i}|\times|V_{a_j}|)}=min\{a_{k|V_{a_i}|},a_{m|V_{a_j}|}\}$.

Proposition 1. Let M_A be a multi soft matrix over U representing multi soft set (F,A_m). A set of attributes B of A is a reduct for A if only if $C_{\underset{b\in B}{AND}M_b}=C_{\underset{a\in A}{AND}M_a}$.

2| Soft Sets

In this section, we define a new definition for soft set over the universe.

Definition 5. Let (F,E) be a soft set over U. Suppose U is partitioned into t classes, namely, $U_1,U_2,\ldots,U_t$. If $U_1=\{u_1,u_2,\ldots,u_i\}, U_2=\{u_{i+1},u_{i+2},\ldots,u_j\},\ldots,U_t=\{u_{k+1},u_{k+2},\ldots,u_n\}$, then the soft set tabular representation of (F,E) as follows.

Table 1. Tabular representation of soft set.

U	e_1	e_2	…	e_m
u_1	$f(u_1,e_1)$	$f(u_1,e_2)$	…	$f(u_1,e_m)$
u_2	$f(u_2,e_1)$	$f(u_2,e_2)$	…	$f(u_2,e_m)$
…	…	…	…	…
u_i	$f(u_i,e_1)$	$f(u_i,e_2)$	…	$f(u_i,e_m)$
u_{i+1}	$f(u_{i+1},e_1)$	$f(u_{i+1},e_2)$	…	$f(u_{i+1},e_m)$
u_{i+2}	$f(u_{i+2},e_1)$	$f(u_{i+2},e_2)$	…	$f(u_{i+2},e_m)$
…	…	…	…	…
u_j	$f(u_j,e_1)$	$f(u_j,e_2)$	…	$f(u_j,e_m)$
…	…	…	…	…
u_{k+1}	$f(u_{k+1},e_1)$	$f(u_{k+1},e_2)$	…	$f(u_{k+1},e_m)$
u_{k+2}	$f(u_{k+2},e_1)$	$f(u_{k+2},e_2)$	…	$f(u_{k+2},e_m)$
…	…	…	…	…
u_n	$f(u_n,e_1)$	$f(u_n,e_2)$	…	$f(u_n,e_m)$

where $f(u_i,e_j)=1$ if $u_i \in F(e_j)$ and $f(u_i,e_j)=0$ otherwise.

Definition 6. Let (F,E) be a soft set over U with the partitions $U_1,U_2,\ldots,U_t$. Then we define the following.

The support of $e \in E$ is defined as $supp(e)=\sum_{U_i \in U} supp_{U_i}(e)$ where $supp_{U_i}(e)=|\{u_j \in U_i \,/\, f(u_j,e)=1\}|$ and $supp(A_1,A_2)$ is the number of occurrences of A_2 with respect to the parameter A_1.

The coverage of $A_1 \Rightarrow A_2$ is defined by $cov(A_1,A_2)=\dfrac{supp(A_1,A_2)}{|U|}$.

The certainty of $A_1 \Rightarrow A_2$ is defined by $cer(A_1,A_2)=\sum_{U_i \in U} cer(U_i,A_1,A_2)$ where $cer(U_i,A_1,A_2)=\dfrac{supp_{U_i}(A_1,A_2)}{|U_i|}$.

Example 1. Consider the soft set (F,E) over the universe $U=\{U_1,U_2,U_3\}$ where $E=\{e_1,e_2,e_3,e_4,e_5\}, U_1=\{u_1,u_2,u_3\}, U_2=\{v_1,v_2,v_3,v_4\}$ and $U_3=\{w_1,w_2,w_3\}$ whose tabular representation is given below.

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Table 2. Tabular representation of (F, E).

U	e_1	e_2	e_3	e_4	e_5
u_1	1	0	1	0	0
u_2	0	1	1	0	1
u_3	0	0	1	1	0
v_1	1	0	1	0	1
v_2	0	1	0	1	1
v_3	1	0	0	0	0
v_4	0	1	1	1	0
w_1	1	0	1	0	1
w_2	0	0	1	1	1
w_3	1	0	0	0	1

Then $cer(U_1,e_1,1)=\frac{1}{3}$ = 0.333, $cer(U_1,e_1,0)=\frac{2}{3}$ = 0.667, $cer(U_2,e_1,1)=\frac{2}{4}$ = 0.5, $cer(U_2,e_1,0)=\frac{2}{4}$ = 0.5, $cer(U_3,e_1,1)=\frac{2}{3}$ = 0.667, $cer(U_3,e_1,0)=\frac{1}{3}$ = 0.333. Hence $cer(e_1,1)$ = 1.5 and $cer(e_1,0)$ = 1.5. And $cer(U_1,e_2,1)=\frac{1}{3}$ = 0.333, $cer(U_1,e_2,0)=\frac{2}{3}$ = 0.667, $cer(U_2,e_2,1)=\frac{2}{4}$ = 0.5, $cer(U_2,e_2,0)=\frac{2}{4}$ = 0.5, $cer(U_3,e_2,1)=\frac{0}{3}$ = 0, $cer(U_3,e_2,0)=\frac{3}{3}$ = 1. Thus, we have $cer(e_2,1)$ = 0.833 and $cer(e_2,0)$ = 2.167. Also, $cer(U_1,e_3,1)=\frac{3}{3}$ = 1, $cer(U_1,e_3,0)=\frac{0}{3}$ = 0, $cer(U_2,e_3,1)=\frac{2}{4}$ = 0.5, $cer(U_2,e_3,0)=\frac{2}{4}$ = 0.5, $cer(U_3,e_3,1)=\frac{2}{3}$ = 0.667, $cer(U_3,e_3,0)=\frac{1}{3}$ = 0.333. Therefore, $cer(e_3,1)$ = 2.167 and $cer(e_3,0)$ = 0.833. Now, $cer(U_1,e_4,1)=\frac{1}{3}$ = 0.333, $cer(U_1,e_4,0)=\frac{2}{3}$ = 0.667, $cer(U_2,e_4,1)=\frac{2}{4}$ = 0.5, $cer(U_2,e_4,0)=\frac{2}{4}$ = 0.5, $cer(U_3,e_4,1)=\frac{1}{3}$ = 0.333, $cer(U_3,e_4,0)=\frac{2}{3}$ = 0.667. Hence $cer(e_4,1)$ = 1.166 and $cer(e_4,0)$ = 1.834. And $cer(U_1,e_5,1)=\frac{1}{3}$ = 0.333, $cer(U_1,e_5,0)=\frac{2}{3}$ = 0.667, $cer(U_2,e_5,1)=\frac{2}{4}$ = 0.5, $cer(U_2,e_5,0)=\frac{2}{4}$ = 0.5, $cer(U_3,e_5,1)=\frac{3}{3}$ = 1, $cer(U_3,e_5,0)=\frac{0}{3}$ = 0. Thus, $cer(e_5,1)$ = 1.833 and $cer(e_5,0)$ = 1.167.

Also, $cov(e_1,1)=\frac{5}{10}$ = 0.5 and $cov(e_1,0)=\frac{5}{10}$ = 0.5, $cov(e_2,1)=\frac{3}{10}$ = 0.3 and $cov(e_2,0)=\frac{7}{10}$ = 0.7, $cov(e_3,1)=\frac{7}{10}$ = 0.7 and $cov(e_3,0)=\frac{3}{10}$ = 0.3, $cov(e_4,1)=\frac{4}{10}$ = 0.4 and $cov(e_4,0)=\frac{6}{10}$ = 0.6, $cov(e_5,1)=\frac{6}{10}$ = 0.6 and $cov(e_5,0)=\frac{4}{10}$ = 0.4. Then the flow graph associated with certainty and coverage is given in the following *Fig. 1*.

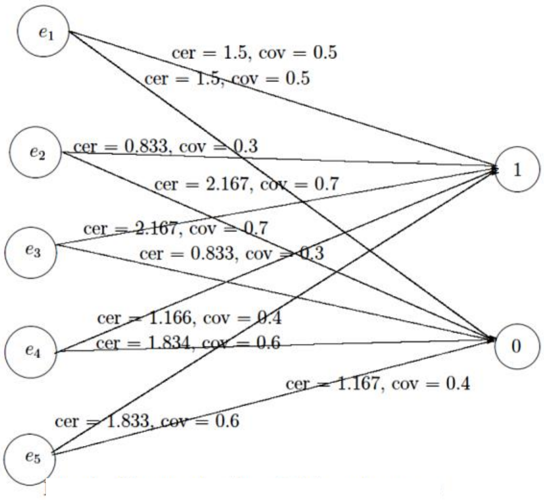

Fig. 1. Flow graph with certainty and coverage.

From the *Fig. 1*, the approximate graph for the flow graph is given as follows.

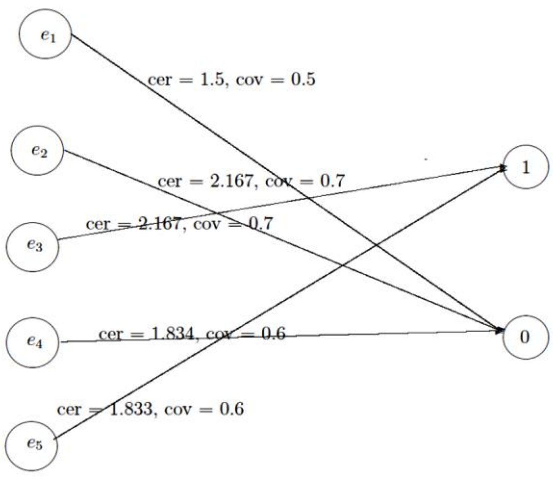

Fig. 2. Approximate graph.

3| Experimental Results

In this section, we illustrate the proposed approach through an example of a data set. Let (F,E) be a soft set over the universe $U=\{U_1,U_2,U_3,U_4\}$ and $E=\{e_1,e_2,e_3,e_4,e_5\}$ where e_1 stands for the Party 'A', e_2 stands for the Party 'B', e_3 stands for the Party 'C', e_4 stands for the Party 'D', e_5 stands for the Party 'E' and $U_1=\{u_1,u_2,u_3,u_4,u_5,u_6,u_7\}$ is the set of people who are politicians, $U_2=\{v_1,v_2,v_3,v_4,v_5,v_6,v_7,v_8,v_9,v_{10}\}$ is the set of formers, $U_3=\{w_1,w_2,w_3,w_4\}$ is the set of government employees and $U_4=\{x_1,x_2,x_3,x_4,x_5,x_6,x_7,x_8\}$ is the set of students.

Table 3. Tabular representation for the given soft set (F, E).

U	e_1	e_2	e_3	e_4	e_5
u_1	0	1	1	0	0
u_2	1	1	0	0	0
u_3	0	1	0	1	0
u_4	1	0	1	1	0
u_5	0	1	0	1	1
u_6	1	1	1	0	0
u_7	0	1	0	1	0
v_1	1	0	1	1	0
v_2	0	1	1	0	0
v_3	1	0	1	0	1
v_4	1	1	0	1	0
v_5	0	0	1	0	1
v_6	1	0	1	1	1
v_7	1	1	0	0	0
v_8	0	1	0	1	0
v_9	1	0	0	1	0
v_{10}	0	0	1	0	0
w_1	0	1	1	0	0
w_2	1	0	1	0	0
w_3	1	1	1	0	0
w_4	0	1	0	1	0
x_1	1	0	0	1	0
x_2	1	1	0	1	0
x_3	1	0	1	0	0
x_4	1	0	0	1	0
x_5	1	1	0	0	0
x_6	1	1	1	0	0
x_7	1	0	1	1	0
x_8	1	1	1	1	0

Then the certainty and coverage of each party is given in the following *Table 4*.

Table 4. Certainty and coverage of parties.

E	Certainty	Coverage
$(e_1,1)$	2.52857	0.65518
$(e_1,0)$	1.47143	0.34483
$(e_2,1)$	2.50714	0.58621
$(e_2,0)$	1.49286	0.41379
$(e_3,1)$	2.27857	0.55173
$(e_3,0)$	1.72143	0.44827
$(e_4,1)$	1.94643	0.51723
$(e_4,0)$	2.05357	0.48276
$(e_5,1)$	0.44286	0.13793
$(e_5,0)$	3.55714	0.86207

From *Fig. 3*, branches of the flow graph represent the parties together with their certainty and coverage factors. For instance, the $(e_1,1)$ has the certainty factor 2.52857 and coverage factor 0.65518.

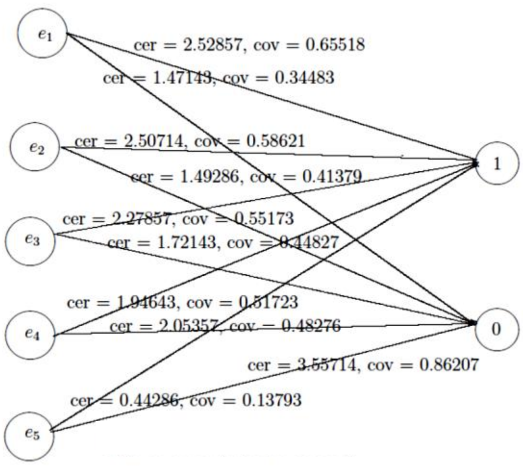

Fig. 3. Flow graph for Table 4.

The flow graph gives a clear insight into the winning strategy of all parties. We can replace flow graph shown in Figure by "approximate" flow graph shown in *Fig. 4*. From the *Fig. 4*, we can conclude that the Parties A, B and C are the winning parameters whose the coverage of 0.65518, 0.58621 and 0.55173, respectively.

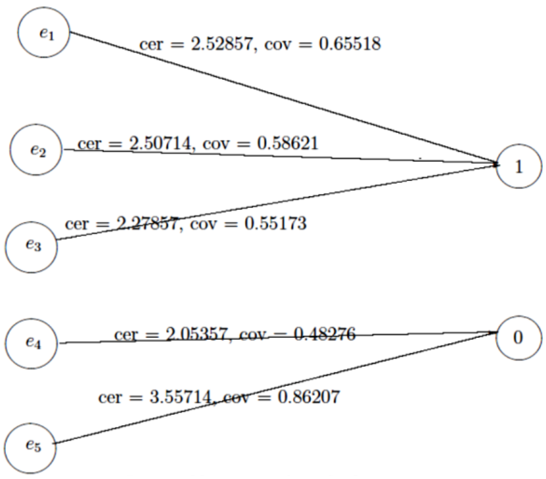

Fig. 4. Approximate flow graph.

4| Erratum

In [10], the authors defined the reduct of a multi soft set and gave a characterization for reduct of a multi soft set. The following Example shows that reduct of a multi soft set under the *Proposition 1* need not be unique.

Example 2. Consider the multi-valued information system given in *Example 15* of [10]. Then the matrices representing the multi soft set (F, A_m) is $M_A = \{M_{a_1}, M_{a_2}, M_{a_3}, M_{a_4}\}$ where

$$\mathrm{M}_{a_1} = \begin{bmatrix} 1 & 0 \\ 1 & 0 \\ 0 & 1 \\ 0 & 1 \\ 1 & 0 \end{bmatrix}, \mathrm{M}_{a_2} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \\ 0 & 1 \\ 0 & 1 \\ 0 & 1 \end{bmatrix}, \mathrm{M}_{a_3} = \begin{bmatrix} 1 & 0 \\ 1 & 0 \\ 1 & 0 \\ 1 & 0 \\ 0 & 1 \end{bmatrix}, \mathrm{M}_{a_4} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \\ 0 & 0 & 1 \\ 0 & 1 & 0 \end{bmatrix}.$$

Here M_{a_3} AND $M_{a_4} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \end{bmatrix}$ and $C_{\underset{1 \le j \le 4}{AND} M_{a_j}} = \{\{1\}, \{2\}, \{3, 4\}, \{5\}\}$.

Now, M_{a_2} AND $(M_{a_3}$ AND $M_{a_4}) = \begin{bmatrix} 1 & 0 \\ 0 & 1 \\ 0 & 1 \\ 0 & 1 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \end{bmatrix}.$

Therefore, $C_{M_{a_2} AND M_{a_3} AND M_{a_4}} = \{\{1\}, \{2\}, \{3, 4\}, \{5\}\}$.

Also, M_{a_1} AND $(M_{a_3}$ AND $M_{a_4})=\begin{bmatrix}1&0\\1&0\\0&1\\0&1\\1&0\end{bmatrix}\begin{bmatrix}1&0&0&0&0&0\\0&1&0&0&0&0\\0&0&1&0&0&0\\0&0&1&0&0&0\\0&0&0&0&1&0\end{bmatrix}=\begin{bmatrix}1&0&0&0&0&0&0&0&0&0&0&0\\0&0&1&0&0&0&0&0&0&0&0&0\\0&0&0&0&0&1&0&0&0&0&0&0\\0&0&0&0&0&1&0&0&0&0&0&0\\0&0&0&0&0&0&0&0&1&0&0&0\end{bmatrix}$.

Therefore, $C_{M_{a_1}\, AND\, M_{a_3}\, AND\, M_{a_4}}=\{\{1\},\{2\},\{3,4\},\{5\}\}$. Hence $\{a_1,a_3,a_4\},\{a_2,a_3,a_4\}$ are reductions of (F,A_m). Also, in [10], the authors determined the reductions of (F,A_m) and gave the reductions as $\{a_1,a_2,a_3\}$ and $\{a_3,a_4\}$. That is, the reductions are not unique.

Based on the *Example 2*, we have the following Lemma.

Lemma 1. Suppose E_1 and E_2 are two members of the value class of $\underset{1\le i\le n}{AND} M_{a_i}$. Then for any $e_1\in E_1, e_2\in E_2, \{e_1,e_2\}$ will not be a subset of any value class of $\underset{1\le i\le n+1}{AND} M_{a_i}$.

Proof. Suppose $e_1\in E_1$ and $e_2\in E_2$. Since $E_1\ne E_2, e_{1i}=1$ and $e_{2j}=1$ for some i and j. Suppose $\{e_1,e_2\}\subseteq F$ where F is a value class of $\underset{1\le i\le n+1}{AND} M_{a_i}$. Then $e_{1k}=e_{2k}=1$ for some k. By the definition of "AND" product, $e_{11}=e_{21}=1$ in the matrix $\underset{1\le i\le n}{AND} M_{a_i}$. That is, e_1 and e_2 belong to the same value class of $\underset{1\le i\le n}{AND} M_{a_i}$ which is a contradiction.

The following Theorem shows that superset of a reduct set is again a reduct set.

Theorem 1. If B is a reduction of the multi soft set (F,A_m), then $B\cup C$ is also a reduction of (F,A_m) where $C\subseteq A-B$.

Proof. Suppose B is a reduction of (F,A_m). Then $C_{\underset{a_i\in B}{AND} M_{a_i}}=C_{\underset{a_i\in A}{AND} M_{a_i}}$. That is, the number of value classes of $\underset{a_i\in B}{AND} M_{a_i}$ and the number of value classes of $\underset{a_i\in A}{AND} M_{a_i}$ are equal. Also, by the definition of "AND" product, the number of value classes of $\underset{1\le i\le n}{AND} M_{a_i}$ is less than or equal to the number of value classes of $\underset{1\le i\le n+1}{AND} M_{a_i}$. Therefore, by *Lemma 1*, for any $C\subseteq A-B$, the value classes of $\underset{a_i\in B}{AND} M_{a_i}$ and the value classes of $\underset{a_i\in B\cup C}{AND} M_{a_i}$ are equal. Hence $C_{\underset{a_i\in B}{AND} M_{a_i}}=C_{\underset{a_i\in B\cup C}{AND} M_{a_i}}$.

By the above Theorem, whenever B is a reduction of the multi soft set (F,A_m), $B\cup C$ is also a reduction of (F,A_m). In *Example 15* of [10], the authors gave reduction of the multi soft set as $\{a_1,a_3,a_4\},\{a_2,a_3,a_4\},\{a_1,a_2,a_3\}$ and $\{a_3,a_4\}$. But by *Theorem 1*, any set containing a reduction set is a reduct set and hence the whole set A is a reduct set. Thus, we remove the redundancy, we modify the reduct definition for multi soft set as follows.

Definition 6. Let M_A be a multi soft set over U representing multi soft set (F,A_m). A set of attributes B of A is a reduct for A if B is a minimal subset of A such that $C_{\underset{b\in B}{AND} M_b}=C_{\underset{a\in A}{AND} M_a}$.

Example 3. Consider the multi soft set as in *Example 4.1*. Here $\{a_1, a_2, a_3\}$ and $\{a_3, a_4\}$ are reductions of (F, A_m) but $\{a_1, a_3, a_4\}$ and $\{a_2, a_3, a_4\}$ are not reductions of (F, A_m).

5| Conclusion

In this paper, we have presented a new decision making approach for the soft set over the universe with partition of objects using the certainty and coverage of a parameter. Also, we have pointed out the misconception of the reduct definition given by Herawan et al. [20].

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