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The Generalized Matrix Representation of Vague Soft Set Theory (SST)

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ABSTRACT

In this paper, soft set, fuzzy soft set, Vague soft set and their properties are initiated by P.K.Majia,B.Ahmad and A.Kharal and R.Biswas these are continued and developed a generalized Matrix representation of vague soft set theory.

Keywords **–**Soft Set, Fuzzy Soft Set, Vague Soft Set.

1. INTRODUCTION

In many complicated problems arising in the fields of engineering, social science, economics, medical science etc involving uncertainties, classical methods are found to be inadequate in recent times. Molodtsov [1] pointed out that the important existing theories viz. Probability Theory, Fuzzy Set Theory, Intuitionistic Fuzzy Set Theory, Rough Set Theory etc. which can be considered as mathematical tools for dealing with uncertainties, have their own difficulties. He further pointed out that the reason for these difficulties is, possibly, the inadequacy of the parameterization tool of the theory. In 1999 he initiated the novel concept of Soft Set as a new mathematical tool for dealing with uncertainties. Soft Set Theory, initiated by Molodtsov [2], is free of the difficulties present in these theories. In 2011, Neog and Sut [9] put forward a new notion of complement of a soft set and accordingly some important results have been studied in their work. In recent times, researches have contributed a lot towards fuzziflcation of Soft Set Theory. Maji et al. [6] introduced the concept of Fuzzy Soft Set and some properties regarding fuzzy soft union, intersection, complement of a fuzzy soft set, De Morgan Law etc. These results were further revised and improved by Ahmad and Khara! [1]. Recently, Neog and Sut [8] have studied the notions of fuzzy soft union, fuzzy soft intersection, complement of a fuzzy soft set and several other properties of fuzzy soft sets along with examples and proofs of certain results. In this paper, we have studied some operations and results available in the literature of fuzzy soft sets. Instead of taking the notion of complement of a fuzzy soft set put forward by Maji et al. [6] , throughout our work, we have taken the notion of complement of a fuzzy soft set put forward by Neog and Sut [7].

2. PRELIMINARIES

In this section, we first recall the basic definitions related to soft sets and fuzzy soft sets also vague soft set theory which would be used in the sequel.

2.1. Soft Set [2]

A pair *(F, E)* is called a soft set (over *U)* if and only if *F* is a mapping of *E* into the set of all subsets of the set *U.*

In other words, the soft set is a parameterized family of subsets of the set *U.* Every set $F(\varepsilon), \varepsilon \in E$, from this family may be considered as the set of ε - elements of the soft set *(F, E),* or as the set of ε - approximate elements of the soft set.

2.2 Soft Null Set [5]

A soft set *(F, A)* over *U* is said to be null soft set denoted by φ if $\forall$ ε *A, F(s) = (p*
(Null set)

2.3 Soft Absolute Set [5]

A soft set (F, A) over U is said to be absolute soft set denoted by A if $\forall \varepsilon \in A, F($
$\varepsilon) = U$.

2.4 Soft Subset [5]

For two soft sets (F.A.) and (G,B) over the universe U, we say that (F.A) is a soft subset of (G, B), if

(i) $A \subset$ B ,

(ii) $\forall \varepsilon \in A, F(\varepsilon)$ and G(ε) are identical approximations and is written as (F, A) $\subseteq$(G.B).

Pei and Miao [4] modified this definition of soft subset in the following way –

2.5. Soft Subset Redefined [4]

For two soft sets (F,A) and (G,B) over the universe U, we say that (F,A) is a soft subset of (G,B), if

(i) $A \not\subset$ B,

(ii) $\forall \varepsilon \in A, F(\varepsilon) \subseteq$ G(ε) and is written as

(F, A) $\subseteq (G, B)$

(F,A) is said to be soft superset of (G,B) if (G,B) is a soft subset of (F, A) and we write (F,A) $\supseteq (g, B)$.

2.6 Union of Soft Sets [5]

Union of two soft sets (F,A) and (G,B) over a common universe U, is the soft set (H, C), where C = $A \cup \mathrm{B}$ and $\forall \varepsilon \in C$,

$$H(\varepsilon) = \begin{cases} \mathrm{F}(\varepsilon), & \text{if } \varepsilon \in \mathrm{A - B} \\ \mathrm{G}(\varepsilon), & \text{if } \varepsilon \in \mathrm{B - A} \\ \mathrm{F}(\varepsilon) \cup \mathrm{G}(\varepsilon) & \text{if } \varepsilon \in \mathrm{A} \cap \mathrm{B} \end{cases}$$

and is written as $(F, A) \cup (G, B) = (H, C)$.

2.7 Intersection of Soft Sets [5]

Intersection of two soft sets *(F,A) and (G,B)* over a common universe *U*, is the soft set *(H,C),* where C = $A \cap B$ and $\forall \varepsilon \in \mathrm{C}$, $\mathrm{H}(\varepsilon) = F(\varepsilon)$ or $\mathrm{G}(\varepsilon)$ (as both are same set) and is written as $(F, A) \cap (G, B) = (H, C)$.

Pie and Miao [4] pointed out that generally F(ϵ) or G(ϵ) may not be identical. Moreover in order to avoid the degenerate case, Ahmad and Kharal [1] proposed that $A \cap B$ must be non-empty and thus revised the above definition as follows.

2.8 Intersection of Soft Sets Redefined [1]

Let *(F,A) and (G,B)* be two soft sets over a common universe *U* with $A \cap \mathrm{B} \neq \phi$. Then Intersection of two soft sets *(F,A) and (G,B)* is a soft set *(H, C)* where $C = A \cap \mathrm{B}$ and $\forall \varepsilon \in \mathrm{C}$, $\mathrm{H}(\varepsilon) = F(\varepsilon) \cap G(\varepsilon)$.

2.9 AND Operation of Soft Sets [5]

If *(F,A) and (G,B)* be two soft sets, then "(F,A) AND (G, B)" is a soft set denoted by (F,A) $\wedge (G, B) = (H, AxB, where$
$\mathrm{H}(\alpha, \beta) = F(\alpha) \cap G(\beta), \forall \alpha \in A$ and $\forall \beta \in \mathrm{B}$, where $\cap$ is the operation intersection of two sets.

2.10 OR Operation of Soft Sets [5]

If *(F,A) and (G,B)* be two soft sets, then "(F,A) OR (G, B)" is a soft set denoted by (F,A) $\vee (G, B)$ and is defined by (F,A) $\vee (G, B)$ = (K, A Xb), where
$K(\alpha, \beta) = F(\alpha) \cup G(\beta), \forall \alpha \in A$ and $\forall \beta \in \mathrm{B}$, where $\cup$ is the operation union of two sets.

3. Complement of a Soft Set [9]

The complement of a soft set *(F,A)* is denoted by $(F, A)^C$ and is defined by $(F,A)^C$ and is defined by $(F,A)^C = (F^C, A)$, where F^C A→ P(U) is a mapping given by $F^C(\epsilon) = [F(\epsilon)]^C$ for all $\epsilon \in A$.

3.1 Fuzzy Soft Set [6]

A pair *(F, A)* is called a fuzzy soft set over *U* where *F: A→ P (U)* is a mapping from *A* into *P(U)*.

3.2 Fuzzy Soft Class [1]

Let *U* be a universe and *E* a set of attributes. Then the pair *(U,E)* denotes the collection of all fuzzy soft sets on *U* with attributes from *E* and is called a fuzzy soft class.

3.3 Fuzzy Soft Null Set [6]

A soft set *(F,A)* over *U* is said to be null fuzzy soft set denoted by ϕ if $\forall \varepsilon \in \mathrm{A}, \mathrm{F}(\varepsilon)$ is the null fuzzy set 0 of U where 0 (x) = 0 $\forall x \in U$

3.4 Fuzzy Soft Absolute Set [6]

A soft set (F,A) over U is said to be absolute fuzzy soft set denoted by A if $\forall \varepsilon \in A, F(\varepsilon)$ is the absolute fuzzy set 1 of U where 1(x) = 1 $\forall x \in \mathrm{U}$

3.5 Fuzzy Soft Subset [6]

For two fuzzy soft sets *(F,A)* and (G,B) in a fuzzy soft class *(U,E)*, we say that (F,A) is a fuzzy soft subset of (G,B), if

(i) $A \subseteq \mathrm{B}$

(ii) For all $\varepsilon \in A, F(\varepsilon) \subseteq G(\varepsilon)$ and is written as $(\mathrm{F,A}) \subseteq (\mathrm{G,B})$.

3.6 Union of Fuzzy Soft Sets [6]

Union of two fuzzy soft sets *(F,A)* and *(G.B)* in a soft class *(U, E)* is a fuzzy soft set (H, C) where C = $\mathrm{A} \cup B$ and $\forall \varepsilon \in C$,

$$H(\varepsilon) = \begin{cases} \mathrm{F}(\varepsilon), & \text{if } \varepsilon \in \mathrm{A - B} \\ \mathrm{G}(\varepsilon), & \text{if } \varepsilon \in \mathrm{B - A} \\ \mathrm{F}(\varepsilon) \cup \mathrm{G}(\varepsilon) & \text{if } \varepsilon \in \mathrm{A} \cap \mathrm{B} \end{cases}$$

And is written as (F,A) $\cup$ (G,B) = (H,C).

3.7 Intersection of Fuzzy Soft Sets [6]

Intersection of two fuzzy soft sets *(F,A)* and *(G,B)* in a soft class (U.E) is a fuzzy soft set (H.C) where C= $\mathrm{A} \cup B$ and $\forall \varepsilon \in C, \mathrm{H}(\varepsilon) = F(\varepsilon)$ or $\mathrm{G}(\varepsilon)$ (as both are same fuzzy set) and is written as (F,A) $\cap$ (G,B) = (H,C).

Ahmad and Kharal [1] pointed out that generally $F(\varepsilon)$ or $\mathrm{G}(\varepsilon)$ may not be identical moreover in order to avoid the degenerate case, he prposed that $\mathrm{A} \cap B$ must be non-empty and thus revised the above definition as follows.

3.8 Intersection of Fuzzy Soft Sets Redefined [1]

Let *(F,A)* and *(G,B)* be two fuzzy soft sets in a soft class *(U,E)* and $\mathrm{A} \cap B \neq \phi$. Then Intersection of two fuzzy soft sets *(F, A)* and *(G,B)* in a soft class *(U,E)* is a fuzzy soft set *(H,C)* where C = $\mathrm{A} \cap B$ and $\forall \varepsilon \in C$, (H(ϵ) = F (ϵ) $\cap G(\varepsilon)$. We write (F,A) $\cap$(G,B) = (H.C.).

3.9 Complement of a Fuzzy Soft Set [7]

The complement of a fuzzy soft set (F,A) is denoted by $(F,A)^C$ and is defined by $(F,A)^C=(F^C A)$ where F^C:A→ P(U) is a mapping given by $F^C\ (\alpha)=\{F(\alpha)\}, \forall \alpha \in$ A.

3.10 AND Operation of Fuzzy Soft Sets [6]

If *(F,A)* and *(G,B)* be two fuzzy soft sets, then "(F,A) AND (G, B)" is a fuzzy soft set denoted by (F,A) $\wedge(G,B)$ and is defined by (F,A) $\wedge(G,B)=(H,AxB)$, where $H(\alpha,\beta)=F(\alpha)\cap G(\beta)\forall \alpha \in A$ and $\forall \beta \in$ B, where $\cap$ is the operation intersection of two fuzzy sets.

4. Soft sets and Fuzzy soft sets

Definition 4.1 [8]

Let *U* be a universal set, *E* a set of parameters and $A \subset E$. Then a pair (F,A) is called soft set over U, where F is a mapping from *A to* 2^U, the power set *U*.

Example

Let X = {c_1, c_2, c_3} be the set of three cars and E = {costly (e_1), metallic colour (e_2) cheap (e_3)} be the set of parameters, where $A=\{e_1 e_2\}\subset E$. Then (F,A) = $\{F(e_1)=\{c_1,c_2,c_3\}F(e_2)=\{c_1,c_3\}\}$ is the crisp soft set over X which describes the "Attractiveness of the cars" which Mr. S (say) is going to buy.

Definition 4.2 [6]

Let *U* be universal set, *E* a set of parameters and $A \subset E$. Let F(X) denotes the set of all fuzzy subsets of *U*. Then a pair *(F,A)* is called fuzzy soft set over *U*, where F is a mapping from *A* to *F (U*).

Example

Let U = Let X = {c_1, c_2, c_3} be the set of three cars and E = {costly (e_1), metallic colour (e_2) cheap (e_3)} be the set of parameters, where $A=\{e_1 e_2\}\subset E$.
Then (F,A)= $\{F(e_1)=\{c_1/,6,c_2/,4,c_3/3\},F(e_2)=\{c_1/5,c_2/,7,c_3/,8\}\}$ is the fuzzy soft set overr U describes the "attractiveness of the cars" which Mr. S(say) is going to buy 2.2. Uague sets and vague soft sets.

Definition 4.3 [11]

Let *U* be an initial universe set, U = $\{u_1,u_2,...u_0\}$. A vague set over *U* is characterized by truth-membership function t_v and a false-membership function f_v tv *U* $\rightarrow[0,1]$, F_v : U $\rightarrow[0,1]$, where t_v (u_i) is a lower bound on the on the grade of membership of u_i derived from the evidence for u_i $f\ (u_i)$ is a lower bound on the negation of u_i derived from the evidence against u_i, and $t_v(u_i)$ + $f_v(u_i) \leq 1$. The grade of membership of u_i in the vague set is bound to a subinterval [t, (u_i), 1-$f_v(u_i)$] of [0,1]. The vague value [t,(u), 1-f_v(u)] indicates that the exact grade of membership $\mu_v(u_i)$ of u_i may be unknown, but it is bounded by $t_i(u_i) \leq \mu_v(u_i) \leq 1 - f_v(u_i)$, where $t_v(u_i) + f_v(u_i) \leq 1$.

Definition 4.4 [12]

Let *U* be universe, *E* a set of parameters, *V(U)* the power set of vague sets on U, and $A \subset E$. . *A* pair *(F,A)* is called a vague soft set over *U*, where *F* is a mapping giving by F:A $\rightarrow$ V *(U)*.

Example

Let U = {c_1, c_2, c_3} be the set of three cars and E = {costly (e_1), metallic colour (e_2) cheap (e_3)} be the set of parameters, where $A = \{e_1 e_2\} \subset E$. Suppose that $\{F(e_1) = \{[6,7]/c_1, [.4,.6]/c_2, [3,.5]/c_3\}, F(e_2) = \{[.5,.7]/c_1, \}[.7,.8]/c_2, [.8,1]/c_3\}$ then the vague soft sets (F,A) is a parameterized family $\{F(e_1), F(e_2)\}$ of vague sets on *U* describes the "attractiveness of the cars" which Mr. S(say) is going to buy.

4.5 Application of vague soft set in students' evaluation

In this section, we present an application of vague soft set (VSST) theory in students' answer scripts evaluation following Biswas approach [4]. Assume that there are five satisfaction levels to evaluate the students' answer scripts regarding a question of an examination i.e. excellent *(g_1)*, very good *(g_2)*, good *(g_3)* satisfactory *(g_4)* and unsatisfactory *(g_5)*, Let X be a set of satisfaction level, X = {excellent *(g_1)*, very good *(g_2)*, good *(g_3)* satisfactory *(g_4)* and unsatisfactory *(g_5)*, and again let S= {0%. 20%, 40%, 60%, 80%, 100%} be the degree of satisfaction of the evaluator for a particular question of the student's answer script. Suppose *S* is a set of questions for a particular paper of 100 marks. We first assume *X* as a universal set and S the set of parameters. Then a VSST is constructed over the *X*, where *F* is a mapping *F.S* → V(X) and V(X) is the power set of vague sets on X. This VSST given a relation matrix, say, R, called expert students evaluation matrix. We refer to the matrix R as "Soft Evaluation Knowledge".

Again we construct another VSST, (F_1,X) over *S*, where F_1 is a mapping given by *$F_1X \rightarrow V(S)$* and *V(S)* is the power set of vague sets on *S*. This VSST gives a relation matrix R_1, called examination knowledge matrix. Then, we obtain a new relation.
$T = R_1 \, o \, R$ called satisfaction question matrix in which the membership values are given by

$$t_T(S_i, S_k) = \text{V}\{t_{R_1}(S_i, g_j) \wedge t_R(g_j, S_k)\}$$
$$(1 - f_T)(1_i, S_k) = \vee\{(1 - f_{R_1})(S_i, g_j) \wedge (1 - f_R)(g_j, S_k)\}, \text{ where } \vee = \max \text{ and } \wedge = \min.$$

Then compute the matrix S_T where S_T = $\lfloor (1-\lambda) x t_{\theta} + \lambda x (1 - f_{ij} \rfloor$, where $\lambda \in [0,1]$ is the degree of optimism of the evaluator determined by the evaluator for evaluating students' answer script of $\lfloor t_{ij} 1 - f_{ij} \rfloor$ of the matrix *T*.

Corresponding to each question S_i of the paper for the matrix *T* we take the highest value $0, x_i = (1-\lambda) x t_{ij} + \lambda x (1 - f_{ij})$(say) which indicates that the degree of satisfaction of the question S_i is $100x_i$%. Then the highest score of the question S_i *is* $H(S_i)$ = $100x_i$%. If M S_i is the mark allotted to the question Q_i then the total score of the student is calculated by the formula = $\frac{1}{100} \sum \{H(S_i) x M(S_i)\}$.

4.6 Algorithm:

- Input the VSST (F,S) over the set X of satisfaction levels, where *S* is the set of degree of satisfaction of the particular question paper and also write the soft evaluation knowledge R representing the relation matrix of the VSST (F,S).
- Input the VSST (F_1X) over the set *S* of questions of the paper and write its relation matrix R_1.
- Compute the relation matrix T = R_1 o R
- Compute S_T from the matrix T.
- Compute the highest score for each question for the matrix T.
- Calculate the total score for the student for each paper.

4.7 Case Study:

Consider a candidate answer scripts to paper of 100 marks. Assume that in total there were four questions to be answered. Let X be a set of satisfaction level and let X = $\{g_1, g_2, g_3, g_4, g_5\}$ where $g_1, g_2, g_3, g_4,$ and g_5 represents excellent, very good, good, satisfactory and unsatisfactory respectively. Suppose an evaluator is using vague soft grade sheet. Consider X be as the universal set and *S={0%, 20%, 40%, 60%, 80% 100%}* be the set of degree of satisfaction of the evaluator's as the set of parameters. Suppose that

$$F(0\%) = \{[0,.2]/g_1, [0,.2]/g_2, [0,.2]/g_3, [2,.5]/g_4, [2,2]/g_s\}$$
$$F(20\%) = \{[1,1]/g_1, [1,.1]/g_2, [2,.2]/g_3, [3,.5]/g_4, [2,2]/g_s\}$$
$$F(40\%) = \{[.3,.3]/g_1, [.4,.5]/g_2, [.5,.6]/g_3, [.3,.5]/g_4, [.3,5]/g_s\}$$
$$F(60\%) = \{[.5,.9]/g_1, [.9,.9]/g_2, [.6,.9]/g_3, [.6,.5]/g_4, [3,53]/g_s\}$$
$$F(80\%) = \{[2,.2]/g_1, [.5,.5]/g_2, [.3,.5]/g_3, [.3,.6]/g_4, [1,1]/g_s\}$$
$$F(100\%) = \{[2,.2]/g_1, [.2,.9]/g_2, [.2,.6]/g_3, [.1,.1]/g_4, [2,2]/g_s\}$$

Than the VSST (F,S) is a parameterized family *{F(0%), F(20%), F(40%), F(60%), F(80%) F(100%)}* of vague soft sets over the set *X* and are determined from expert student evaluation documentation. Thus the *VSST (F,S)* gives an approximate description of the vague soft examination knowledge of the four questions and questions and their level of satisfaction. This *VSST (F,S)* is represented by matrix R, called expert students, evaluation matrix and is given by

Suppose an evaluator is using vague soft grade sheet. Suppose there are four questions S_1, S_2, S_3 *and* S_4 in the question paper and we consider the set $\{S = S_1, S_2, S_3, S_4,\}$ as universal set and $S = \{g_1, g_2, g_3, g_4,\}$ as the set of parameters respectively. The evaluator's satisfaction level for the student for question with respect to parameters is respectively

$$F_1(g_1) = \{[.1,.1]/S_1, [2,2]/S_2, [.3,.5]/S_3, [.5,.6]/s_4\}$$
$$F_1(g_2) = \{[.6,.6]/S_1, [.7,9]/S_2, [.8,.7]/S_3, [.3,.5]/S_4\}$$
$$F_1(g_3) = \{[.4,.7]/S_1, [.4,.6]/S_2, [.4,.8]/S_3, [.2,.3]/S_4\}$$
$$F_1(g_4) = \{[.1,.1]/S_1, [.1,.1]/S_2, [.3,.5]/S_3, [.1,.1]/S_4\}$$
$$F_1(g_5) = \{[.1,.1]/S_1, [.1,.1]/S_2, [.1,.1]/S_3, [.4,.6]/S_4\}$$

Then the VSST *(F₁X)* is a parameterized family $\{F_1(g_1), \mathrm{F}_1(g_2), F_1(g_3), F_1(g_4), F_1(g_5)\}$ of all vague set over the set *S* and are determined from evaluated satisfaction for a particular student. This VSST *(F_1,X)* gives approximate description of the vague soft examination knowledge of the four question and their level of satisfaction. This VSST *(F_1, X)* is represented by relation matrix R_1 called examination knowledge matrix and given by

$$R_1 = \begin{matrix} S_1 \\ S_2 \\ S_3 \\ S_4 \end{matrix} \begin{bmatrix} \overset{e_1}{[.5,.7]} & \overset{e_2}{[.8,.8]} & \overset{e_3}{[.6,.7]} & \overset{e_4}{[0,0]} & \overset{e_5}{[0,0]} \\ [1,1] & [.8,.9] & [.4,.5] & [0,0] & [0,0] \\ [.5,.7] & [.6,.7] & [.4,.5] & [.2,.3] & [0,0] \\ [.8,.9] & [.5,.7] & [.1,.3] & [0,0] & [.5,.6] \end{bmatrix}$$

Then combining the relation matrices

$$T = R_1 R = \begin{matrix} S_1 \\ S_2 \\ S_3 \\ S_4 \end{matrix} \begin{bmatrix} \overset{\%}{[0,.1]} & \overset{20\%}{[.1,2]} & \overset{40\%}{[.5,.6]} & \overset{60\%}{[8,8]} & \overset{80\%}{[.8,8]} & \overset{100\%}{[.8,8]} \\ [0,1] & [.1,.2] & [.6,.6] & [.8,9] & [1,1] & [1,1] \\ [2,.3] & [.2,.3] & [.5,.6] & [.6,.7] & [.6,7] & [.6,7] \\ [5,.6] & [.5,.6] & [.6,.6] & [.8,9] & [.8,.9] & [.8,.9] \end{bmatrix}$$

Suppose that the index of optimism λ determined by the evaluator is 0.60 $\in [0,1]$ then $\mathrm{S_r}$ can be calculated in the following way, i.e.

$$S_T = \begin{matrix} S_1 \\ S_2 \\ S_3 \\ S_4 \end{matrix} \begin{bmatrix} \overset{\%}{..06} & \overset{20\%}{.16} & \overset{40\%}{.68} & \overset{60\%}{.8} & \overset{80\%}{.8} & \overset{100\%}{.8} \\ .06 & .16 & .6 & .86 & 1 & 1 \\ .26 & 26 & .66 & .66 & .66 & .66 \\ .56 & .56 & .86 & .86 & .86 & .86 \end{bmatrix}$$

Hence the highest score for S_1 is .8 i.e. it indicates that the degree of satisfaction of the question S_1 of the student's answer script evaluation by the evaluator is 80%. Similarly for S_2 is 100%. S_3 is 66% and S_4 is 86%. Therefore $H(S_1) = 80,$ $H(S_2) = 86,$ $H(S_3) = 66,$ and $H(S_4) = 86.$ Again suppose that S_1 carries 20 marks, S_2 carries 30 marks, S_3 carries 25 marks and S_4 carries 25 marks.

Therefore the total score of the student

$= \frac{1}{100}\sum T(S_1)\ \text{x}\ \text{m}(S_1)$

= 1/100 {80 x 20 + 100 x 30 + 66 + 86 x 25}

= 1/100 {1600 + 3000 + 1650 + 2150}

= 84.

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