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FUZZY VERSION OF SOFT INT G-MODULES

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ABSTRACT

In this paper, we introduce fuzzy version of soft int-G-modules of a vector space with respect to soft structures, which are fuzzy soft int-G-modules (IFSG-module) .These new concepts show that how a soft set effects on a G-module of a vector space in the mean of intersection, union and inclusion of sets and thus, they can be regarded as a bridge among classical sets, fuzzy soft sets and vector spaces. We then investigate their related properties with respect to soft set operations, soft image, soft pre-image, soft anti image, α-inclusion of fuzzy soft sets and linear transformations of the vector spaces. Furthermore, we give the applications of these new G-modules on vector spaces.

Index terms: *Soft set, IFSG-module, fuzzy soft image, fuzzy soft anti image, trivial, whole.*

1. INTRODUCTION

The concept of soft set theory is introduced by Molodtsov [1] to overcome uncertainties which cannot be dealt with by classical methods in many areas such as engineering, economics, medical science and social science. At present, work on the soft set theory is progressing rapidly. P.K.Maji *et al.* [2] defined basic properties of soft set theory. Aktaş and Çağman [3] compared to soft sets to the related concepts of fuzzy sets and rough sets and introduced soft group and derived their basic properties. Afterward, soft algebraic structures have been studied by some researchers, such as soft ring, soft field and soft modules [5], soft int-groups [4].Soft linear spaces and soft norm on soft linear spaces are given and some of their properties are studied by Samanta, Das ve P. Majumdar [7]. In [8] Q. Sun, Z. Zang and J. Liu, introduced the definition of soft modules and constructed some basic properties of soft modules, Many important results could be proved only for representations over algebraically closed fields. Module theoretic approach is better suited to deal with deeper results in representation theory. This is the subject matter of representation theory [9, 10, 11]. Soon after the introduction of fuzzy set theory by L.A. Zadeh [12] in 1965, Rosenfield [13] initiated the fuzzification of algebraic structures. Recently, some researchers studied G-modules on fuzzy sets.

As a continuation of these works S. Fernandez [14] introduced fuzzy parallels of the notions of G-modules, group representations, reducibility, irreducibility and completely reducibility and observe, some of their basic properties. In [15] A.K.Sinho and K. Dewangan studied isomorphism theorems for fuzzy submodules of G-modules. Recently, many authors have studied some algebraic structures of soft set theory. [16, 17, 18, 19, 20] Some interesting results in the theory of soft modules are still being explored currently. However the theory of soft modules has not yet been studied. M.Shabir [21] gave some new notions such as the restricted intersection, the restricted union, the restricted difference and the extended intersection of two soft sets along with a new notion of complement of a soft set. The work of this paper is organized as follows. In the second section as preliminaries, we give basic concepts of soft sets and fuzzy soft G-modules. In Section 3, we introduce IFSG-modules and study their characteristic properties. In Section 4, we give the applications of IFSG-modules.

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2. PRELIMINARIES

In this section as a beginning, the concepts of G-module [22] soft sets introduced by Molodsov [1] and the notions of fuzzy soft set introduced by Maji *et al.* [23] have been presented.

2.1 Definition (Molodtsov[1]): Let U be an initial universe, P (U) be the power set of U, E be the set of all parameters and A⊆ E. A soft set (f_A, E) on the universe U is defined by the set of order pairs

(f_A, E) = {(e, f_A (e)): e∈ E, f_A ∈ P (U)} where f_A: E → P (U) such that f_A (e) = ϕ if e ∉ A.

Here f_A is called an approximate function of the soft set.

Example: Let U = {u_1,u_2,u_3,u_4} be a set of four shirts and E = { yellow(p_1), green(p_2),black (p_3)} be a set of parameters.

If A = {p_1, p_2} ⊆ E, f_A (p_1) = {u_1,u_2,u_3,u_4} and f_A(p_2)= {u_1,u_2,u_3}, then we write the soft set (f_A, E) = {(p_1 u_1, u_2, u_3, u_4}), (p_2,{u_1, u_2, u_3})} over U which describe the "colour of the shirts" which Mr. X is going to buy.

2.2 Definition (P.K.Maji [23]): Let U be an initial universe, E be the set of all parameters and A⊆ E. 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), where P (U) denotes the collection of all fuzzy subsets of U.

Example: Consider the above example, here we cannot express with only two real numbers 0 and 1, we can characterized it by a membership function instead of crisp number 0 and 1, which associate with each element a real number in the interval [0,1]. Then (f_A , E) = {{f_A (p_1) = {(u_1, 0.7), (u_2 , 0.5), (u_3, 0.4), (u_4,0.2)}, f_A (p_2) = {(u_1, 0.5), (u_2, 0.1), (u_3, 0.5)} is the fuzzy soft set representing the "colour of the shirts" which Mr. X is going to buy.

2.3 Definition (Curties[9]): Fuzzy soft class, Let U be an initial Universe set and E be the 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.

Definition 2.4 (Ali al[21]): Let F_A and G_B be two soft sets over U such that A∩B ≠ ϕ. The restricted intersection of F_A and G_B is denoted by $F_A \Cap G_B$, and is defined as $F_A \Cap G_B$ =(H,C), where C = A∩B and for all c ∈ C, H(c) = F(c)∩G(c).

2.5 Definition (Shery Fernandez[22]): Let M and M* be G-modules. A mapping ϕ : M→M* is a G-module homomorphism if

1. ϕ (k_1 m_1 + $k_2$$m_2$) = k_1 ϕ (m_1) + k_2 ϕ (m_2)
2. ϕ (gm) = g ϕ (m), k_1, k_2 ∈ K, m, m_1,m_2 ∈ M & g ∈ G.

2.6 Definition (A˘gman al[26]): Let F_A and G_B be soft sets over the common universe U and ψbe a function from A to B. Then we can define the soft set ψ (F_A) over U, where ψ (F_A): B→P(U) is a set valued function defined by

ψ (F_A)(b) =∪{F(a) | a ∈ A and ψ (a) = b},

If ψ^{-1}(b) ≠ ϕ, = 0 otherwise for all b ∈ B. Here, ψ (F_A) is called the soft image of F_A under ψ. Moreover we can define a soft set ψ^{-1}(G_B) over U, where ψ^{-1}(G_B): A → P(U) is a set-valued function defined by ψ^{-1} (G_B)(a) = G(ψ (a)) for all a ∈ A. Then, ψ^{-1}(G_B) is called the soft pre image (or inverse image) of G_B under ψ.

2.1. Theorem (A˘gman al[25]): Let F_H and T_K be soft sets over U, F^r_H, T^r_K be their relative soft sets, respectively and ψ be a function from H to K. then,

i) $\psi^{-1}(T^r_K) = (\psi^{-1}(T_K))^r$,
ii) $\psi (F^r_H) = (\psi^\star(F_H))^r$ and $\psi^\star(F^r_H) = (\psi (F_H))^r$.

3. IFSG-MODULES

In this section, we first define intersection fuzzy soft G-modules of a vector space, abbreviated as IFSG-modules.

We then investigate its related properties with respect to soft set operations.

Let G be a non-empty set. A fuzzy subset μ on G is defined by μ : G → [0,1] for all x ∈G.

3.1. Definition: Let G be a group. Let M be a G-module of V and A_M be a fuzzy soft set over V. Then A_M is called Intersection Fuzzy Soft G-module of V (IFSG-m), denoted by $A_M \lessapprox_i V$ if the following properties are satisfied

(IFSG-m_1) A(ax + by) ≥ A(x) ∩ A(y)
(IFSG-m_2) A(αx) ≥ A(x), for all x, y∈ M, a, b, α ∈ F.

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Example: Let G = {1,-1}, M = R^4 over R. Then M is a G-module.

Define A on M by,

$$A(x) = \begin{cases} 1, & \text{if } x_i = 0 \ \forall i. \\ 0.5, & \text{if atleast } x_i \neq 0. \end{cases}$$

Where x={x_1, x_2, x_3, x_4}; $x_i \in$ R. Then A is a fuzzy soft G-Module.

3.1. Proposition: If $A_M \lesssim_i$ V, then A(0v) ⊇ A(x) for all x ∈ M.

Proof: Since A_M is an IFSG-module of V, then A(ax+by) ⊇ A(x) ∩ A(y) for all x, y∈ M and since (M,+) is a group, if we take ay=-ax then, for all x ∈ M, A(ax-ax) =A(0_V) ⊇ A(x) ∩ A(x) = A(x).

3.2. Proposition: If $A_{M_1} \lesssim_i$ V and $B_{M_2} \lesssim_i$ V, then $A_{M_1} \cap B_{M_2} \lesssim_i$ V.

Proof: Since M_1 and M_2 are G-modules of V, then $M_1 \cap M_2$ is a G-module of V. By definition 2.6, let

$A_{M_1} \cap B_{M_2}$ = (A, M_1) ∩ (B, M_2) = (T, $M_1 \cap M_2$),

Where, T(x) = A(x) ∩ B(x) for all x∈ $M_1 \cap M_2 \neq \phi$. Then for all x, y∈ $M_1 \cap M_2$ and $\alpha \in$ F.

(IFSG-m_1) T(ax+by) = A(ax+by) ∩ B(ax+by) ⊇ (A(x) ∩ A(y)) ∩ (B(x) ∩ B(y))
= (A(x) ∩ B(x)) ∩ (A(y) ∩ B(y)) = T(x) ∩ T(y),

(IFSG-m_2) T(αx) = A(αx) ∩ B(αx) ⊇ A(x) ∩ B(x) = T(x).

There fore $A_{M_1} \cap B_{M_2} = T_{M_1 \cap M_2} \lesssim_i$ V.

3.2. Definition: Let (A, M_1) and (B, M_2) be two IFSG-modules of V_1 and V_2 respectively, the product of IFSG-modules (A, M_1) and (B, M_2) is defined as (A, M_1) × (B, M_2) = (Q, $M_1 \times M_2$), where Q(x,y) = A(x) × B(y) for all (x, y) ∈ $M_1 \times M_2$.

3.1. Theorem: If $A_{M_1} \lesssim_i$ V and $B_{M_2} \lesssim_i$ V, then $A_{M_1} \times B_{M_2} \lesssim_i V_1 \times V_2$.

Proof: Since M_1 and M_2 are G-modules of V_1 and V_2 respectively, then $M_1 \times M_2$ is a G-module of $V_1 \times V_2$. By definition3.2, let

$A_{M_1} \times B_{M_2}$ = (A, M_1) × (B, M_2)
= (Q, $M_1 \times M_2$),

where Q(x, y) = A(x) × B(y) for all (x,y) ∈ $M_1 \times M_2$.

Then for all (x_1, y_1), (x_2, y_2) ∈ $M_1 \times M_2$ and (α_1, α_2) ∈ F×F,

(IFSG-m_1) Q {(ax_1, by_1) + (ax_2, by_2)} = Q ($ax_1 + ax_2$, $by_1 + by_2$)
= A ($ax_1 + ax_2$) × B($by_1 + by_2$)
⊇ (A (x_1) ∩ A (x_2)) × (B (y_1)∩ B (y_2))
= Q(x_1, y_1) ∩ Q(x_2, y_2)

(IFSG-m_2) Q ((α_1, α_2)(x_1, y_1)) = Q ($\alpha_1 x_1$ + $\alpha_2 y_1$)
= A ($\alpha_1 x_1$) × B ($\alpha_2 y_2$) ⊇ A (x_1) ∩ B (y_2) = Q(x_1, y_1).

Hence $A_{M_1} \times B_{M_2} = Q_{M_1 \times M_2} \lesssim_i V_1 \times V_2$.

3.3. Definition: Let A_{M_1} and B_{M_2} be two IFSG-module's of V. If $M_1 \cap M_2$ = {0_V}, then the sum of IFSG-module's A_{M_1} and B_{M_2} is defined as $A_{M_1} + B_{M_2} = T_{M_1 + M_2}$ where T(ax+by) = A(x)+B(y) for all ax+by ∈ $M_1 + M_2$.

3.2. Theorem: If $A_{M_1} \lesssim_i$ V and $B_{M_2} \lesssim_i$ V where $M_1 \cap M_2$ = {0_V}, then $A_{M_1} + B_{M_2} \lesssim_i$ V.

Proof: Since M_1& M_2 are G-modules of V, then $M_1 + M_2$ is a G-modules of V. By definition: 3.3,

Let $A_{M_1} + B_{M_2}$ = (A, M_1) + (B, M_2) = (T, $M_1 + M_2$), where T(ax+by) = A(x)+B(y) for all ax+by ∈ $M_1 + M_2$. It is obvious that since $M_1 \cap M_2$ = {0_V}, then the sum is well defined. Then for all $ax_1 + by_1, ax_2 + by_2 \in M_1 + M_2$ and α ∈F,

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$$\begin{aligned} T((ax_1+by_1)+(ax_2+by_2)) &= T((ax_1+ax_2)+(by_1+by_2)) \\ &= A(a(x_1+x_2))+B(b(y_1+y_2)) \\ &\supseteq (A(x_1)\cap A(x_2))+(B(y_1)\cap B(y_2)) \\ &= (A(x_1)+B(y_1))\cap(A(x_2)+B(y_2)) \\ &= T(ax_1+by_1)\cap T(ax_2+by_2) \end{aligned}$$

$$\begin{aligned} T(\alpha(x_1+y_1)) &= T(\alpha x_1+\alpha y_1) \\ &= A(\alpha x_1)+B(\alpha y_1) \supseteq A(x_1)+B(y_1) \\ &= T(x_1+y_1) \end{aligned}$$

Thus, $A_{M_1}+B_{M_2} \lessapprox_i V$.

3.4. Definition: Let A_M be an IFSG-module of V. Then,

(i) A_M is said to be trivial if $A(x) = \{0_V\}$ for all x∈M.

(ii) A_M is said to be whole if $A(x) = V$ for all x∈M.

3.3. Proposition: Let A_{M_1} and B_{M_2} be two IFSG-modules of V, then

(i) If A_{M_1} and B_{M_2} are trivial IFSG-modules of V, then $A_{M_1} \cap B_{M_2}$ is a trivial IFSG -module of V.

(ii) If A_{M_1} and B_{M_2} are whole IFSG-modules of V, then $A_{M_1} \cap B_{M_2}$ is a whole IFSG -module of V.

(iii) If A_{M_1} is a trivial IFSG-module of V and B_{M_2} is a whole IFSG-modules of V, then $A_{M_1} \cap B_{M_2}$ is a trivial IFSG -module of V.

(iv) If A_{M_1} and B_{M_2} are trivial IFSG-modules of V where $M_1 \cap M_2=\{0_V\}$, then $A_{M_1}+B_{M_2}$ is a trivial IFSG-module of V.

(v) If A_{M_1} and B_{M_2} are whole IFSG-modules of V where $M_1 \cap M_2=\{0_V\}$, then $A_{M_1}+B_{M_2}$ is a whole IFSG-module of V.

(vi) If A_{M_1} is a trivial IFSG-module of V and B_{M_2} is a whole IFSG-modules of V where $M_1 \cap M_2=\{0_V\}$, then $A_{M_1}+B_{M_2}$ is a whole IFSG-module of V.

Proof: The proof is easily seen by definition 2.4, definition3.3, definition3.4 and theorem 3.1.

3.4. Proposition: Let A_{M_1} and B_{M_2} be two IFSG-modules of V_1 and V_2 respectively. Then

(i) If A_{M_1} and B_{M_2} are trivial IFSG-modules of V_1 and V_2 respectively, then $A_{M_1} \times B_{M_2}$ is a trivial IFSG -module of $V_1 \times V_2$.

(ii) If A_{M_1} and B_{M_2} are whole IFSG-modules of V_1 and V_2 respectively, then $A_{M_1} \times B_{M_2}$ is a whole IFSG -module of $V_1 \times V_2$.

Proof: The proof is easily seen by definition 3.2 and definition 3.4

Applications of IFSG modules: In this section, we give the applications of soft image, soft pre image, upper α-inclusion of fuzzy soft sets and linear transformation of vector spaces on vector space with respect to IFSG-modules.

4.1. Theorem: If $A_M \lessapprox_i V$, then $M_G = \{x∈M / A(x) = A(0_V)\}$ is a G-module of M .

Proof: It is obvious that $0_V \in M_G$ and $\phi \neq M_G \subseteq M$. We need to show that ax+by ∈ M_G and αx ∈ M_G for all x, y∈ M_G and α ∈ F, which means that $A(ax+by) = A(0_V)$ and $A(\alpha x) = A(0_V)$ have to be satisfied. Since x, y∈ M_G and A_M is an IFSG-Module of V, then $A(x) = A(y) = A(0_V)$, $A(ax+by) \supseteq A(x) \cap A(y) = A(0_V)$, $A(\alpha x) \supseteq A(x) = A(0_V)$ for all x, y∈ M_G and α ∈ F. Moreover, by Proposition3.1, $A(0_V) \supseteq A(ax+by)$ and $A(0_V) \supseteq A(\alpha x)$ which completes the proof.

4.2. Theorem: Let A_M be a fuzzy soft set over V and α be a subset of V such that $A(0_V) \supseteq \alpha$. If A_M is an IFSG-module of V, then $A_M^{\supseteq\alpha}$ is a G-module of V.

Proof: Since $A(0_V) \supseteq \alpha$, then $0_V \in A_M^{\supseteq\alpha}$ and $\emptyset \neq A_M^{\supseteq\alpha} \subseteq V$. Let x, y ∈ $A_M^{\supseteq\alpha}$, then $A(x) \supseteq \alpha$ and $A(y) \supseteq \alpha$. We need to show that x + y ∈ $A_M^{\supseteq\alpha}$ nx∈ $A_M^{\supseteq\alpha}$ for all x, y ∈ $A_M^{\supseteq\alpha}$ and n∈F. Since A_M is an IFSG-module of V, it follows that $A(ax+by) \supseteq A(x) \cap A(y) \supseteq \alpha \cap \alpha = \alpha$.

Furthermore, $A(nx) \supseteq A(x) \supseteq \alpha$, which completes the proof.

4.3. Theorem: Let A_M and T_W be fuzzy soft sets over V, where M and W are G-modules of γ and Ψ be a linear isomorphism from M to W. If A_M is an IFSG-Module of V, then so is $\Psi(A_M)$.

Proof: Let $w_1, w_2 \in W$. Since Ψ is a subjective linear transformation. Then there exists $m_1, m_2 \in M$ such that $\Psi(m_1) = w_1$, $\Psi(m_2) = w_2$. Then

$$
\begin{aligned}
(\Psi(A_M))(aw_1 + bw_2) &= \cup\{A(m): m \in M,\ \Psi(m) = aw_1 + bw_2\} \\
&= \cup\{A(m): m \in M,\ m = \Psi^{-1}(aw_1 + bw_2)\} \\
&= \cup\{A(m): m \in M,\ m = \Psi^{-1}(\Psi(aw_1 + bw_2)) = am_1 + bm_2\} \\
&= \cup\{A(am_1 + bm_2) : m_i \in M, \Psi(m_i) = w_i, i = 1,2\} \\
&\supseteq \cup\{A(m_1) \cap A(m_2) : m_i \in M, \Psi(m_i) = w_i, i = 1,2\} \\
&= (\cup A(m_1): m_1 \in M, \Psi(m_1) = w_1) \cap (\cup A(m_2): m_2 \in M, \Psi(m_2) = w_2) \\
&= (\Psi(A_M))(w_1) \cap (\Psi(A_M))(w_2)
\end{aligned}
$$

Now let $\alpha \in F$ and $w \in W$. Since Ψ is a surjective linear transformation, there exits $\tilde{m} \in M$ such that $\Psi(\tilde{m}) = w$. Then

$$
\begin{aligned}
(\Psi(A_M))(\alpha w) &= \cup\{A(m): m \in M, \Psi(m) = \alpha w\} \\
&= \cup\{A(m): m \in M, m = \Psi^{-1}(\alpha w)\} \\
&= \cup\{A(m): m \in M, m = \Psi^{-1}(\Psi(\alpha\tilde{m})) = \alpha\tilde{m}\} \\
&= \cup\{A(\alpha\tilde{m}): \alpha\tilde{m} \in M, \Psi(\tilde{m}) = w\} \\
&= (\Psi(A_M))(w)
\end{aligned}
$$

Hence, $\Psi(A_M)$ is an IFSG –module of V.

4.4. Theorem: Let A_M and T_W be fuzzy soft sets over V, where M and W are G-modules of γ and Ψ be a linear isomorphism from M to W. If T_W is an IFSG-Module of V, then so is $\Psi^{-1}(T_W)$.

Proof: Let $m_1, m_2 \in M$. Then

$$
\begin{aligned}
\Psi^{-1}(T_W)(am_1+bm_2) &= T(\Psi(am_1+bm_2)) \\
&= T(\Psi(am_1) + \Psi(bm_2)) \\
&\supseteq T(\Psi(m_1)) \cap T(\Psi(m_2)) \\
&= (\Psi^{-1}(T_W))(m_1) \cap (\Psi^{-1}(T_W))(m_2)
\end{aligned}
$$

Now let $\alpha \in F$ and $m \in M$. Then,

$$
\begin{aligned}
\Psi^{-1}(T_W)(\alpha m) &= T(\Psi(\alpha m)) \\
&= T(\alpha\Psi(m)) \\
&\supseteq T(\Psi(m)) = \Psi^{-1}(T_W)(m)
\end{aligned}
$$

Hence $\Psi^{-1}(T_W)$ is an IFSG –module of V.

4.5. Theorem: Let V_1 and V_2 be two vector spaces and $(A_1, M_1) \tilde{<}_i V_1$, $(A_2, M_2) \tilde{<}_i V_2$. If $f: M_1 \to M_2$ is a linear transformation of vector spaces, then

(i) f is surjective, then $(A_1, f^{-1}(M_2)) \tilde{<}_i V_1$,
(ii) $(A_2, f(M_1)) \tilde{<}_i V_2$,
(iii) $(A_1, \text{kerl} f) \tilde{<}_i V_1$.

Proof:

(i) Since $M_1 < V_1$, $M_2 < V_2$ and $f : M_1 \to M_2$ is a surjective linear transformation, then it is clear that $f^{-1}(M_2) < V_1$. Since$(A_1, M_1) \tilde{<}_i V_1$ and $f^{-1}(M_2) < M_1$, $A_1(ax+by) \supseteq A(x) \cap A(y)$ and $A_1(\alpha x) \supseteq A(x)$ for all $x, y \in f^{-1}(M_2)$ and $\alpha \in F$. Hence $(A_1, f^{-1}(M_2)) \tilde{<}_i V_1$.
(ii) Since $M_1 < V_1$, $M_2 < V_2$ and $f: M_1 \to M_2$ is a vector space linear transformation, then $f(M_1) < V_2$. Since $f(M_1) \subseteq M_2$, the result is obvious by definition3.1.
(iii) Since kerl $f < V_1$ and kerl $f \subseteq M_1$, the rest of the proof is clear by definition3.1.

4.1. Corollary: Let $(A_1, M_1) \tilde{<}_i V_1$, $(A_2, M_2) \tilde{<}_i V_2$. If $f: M_1 \to M_2$ is a linear transformation, then $(A_2, \{0M_2\}) \tilde{<}_i V_2$.

Proof: By theorem: 4.5, (iii) $(A_1, \text{kerl} f) \tilde{<}_i V_1$, then $(A_2, f(\text{kerl} f)) = (A_2, \{oM_2\}) \tilde{<}_i V_2$, By theorem 4.5 (ii).

CONCLUSION

Throughout this paper, we have dealt with IFSG-modules of a vector space. We have investigated their related properties with respect to soft set operations Furthermore; we have derived some applications of IFSG-modules with respect to soft image, soft pre image, soft anti image, Further study could be done for fuzzy soft sub structures of different algebras.

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