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FLEXIBLE FUZZY SOFT M- STRUCTURES UNDER THE EXTENSIONS OF MOLODTSOV'S SOFT SETS THEORY

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ABSTRACT

In this paper, we introduce flexible fuzzy soft M-group structures by using Molodtsov's definition of soft sets and investigate their related properties with respect to α-inclusion of soft sets.

Keywords: *Soft set, flexible fuzzy soft set, flexible soft M-group ,flexible fuzzy soft M-group structure ,α-inclusion, pre-image and inverse image.*

SECTION-1: INTRODUCTION

Soft set theory was introduced by Molodtsov [26] for modeling vagueness and uncertainty and it has been received much attentionin the field of set theory. Maji *et.al* [23, 24] explains the applications of soft sets in decision making problems. Ali *et.al* [2] defined some new operations in soft set theory and Sezgin and Atagun [31] introduced and studied operations of soft sets. Soft set theory has also potential applications especially in decision making as in [31]. This theory has started to progress in the mean of algebraic structures, since Aktas and Cagman [3] defined and studied soft groups. Since then, soft substructures of rings, fields and modules [4], union soft substructures of near-rings and near-ring modules [32], normalistic soft groups [25] are defined and studied in detailed. The theory of G-modules originated in the 20th century. Representation theory was developed on the basis of embedding a group G in to a linear group GL(V).In 1999, Molodtsov's [26] proposed an approach for Modeling, Vagueness and uncertainty, called soft set theory, since its inception, works on soft set theory have been progressing rapidly with a wide range applications especially in the mean of algebraic structures as in [2-12]. The structures of soft sets , operations of soft sets and some related concepts have been studied by [14-19]. The theory of soft set continues to experience tremendous growth and diversification in the mean of soft decision making as in the following studies [20-23] as well. Atagun and Sezgin defined soft N-subgroups and soft N-ideals of an N-group, they studied their properties with respect to soft set operators in more detail. In this paper, we introduce flexible fuzzy soft M-Group by using Molodtsov's definition of soft sets and investigate their related properties with respect to α-inclusion of soft sets.

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SECTION-2: PRELIMINARIES

Definition 2.1: Let $(\Gamma,+)$ be a group and μ: M x $\Gamma\to\Gamma(m,\nu)\to m\nu$, (Γ,μ) is called an M-group if x, y$\in$ M and $\forall\nu\in\Gamma$,

(i) $x(y\,\nu)=(xy)\,\nu$ and
(ii) $(x+y)\,\nu = x\,\nu + y\,\nu$. It is denoted by N^{Γ}.

Clearly M itself is an M-group by natural operation. A subgroup H of $\Gamma$with MH$\subseteq$ H is said to be an M-subgroup of Γ. Let $\Gamma$and ψ be two M- groups. Then f:$\Gamma\to\psi$ is called an M-homomorphism if $\forall\nu$, H $\in\Gamma$, $\forall$ m$\in$M

(i) $f(\nu+H) = f(\nu)+f(H)$ and
(ii) $f(m\nu) = mf(\nu)$

For all undefined concepts and notations, we refer to [27]. From now on U refers to initial universe, E is a set of parameters, 2^U is the power set of U and A, B, C $\subseteq$ E

Definition 2.2: Let U be any Universal set, E set of parameters and A$\subseteq$ E. Then a pair (GD, A) is called soft set over U, where GD is a mapping from A to 2^U , the power set of U.

Example 2.3: 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 (GD,A) ={GD(e_1) ={c_1,c_2,c_3},GD(e_2) = {c_1,c_2} } is the crisp soft set over X.

Definition 2.4 [Moltdosov]: Let U be an initial universe. Let P (U) be the power set of U, E be the set of all parameters and A$\subseteq$ 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$\in$ E, $f_A\in$ P (U)} where f_A : E $\to$ P (U) such that f_A (e) = ϕ if e $\notin$A. Heref_A is called an approximate function of the soft set.

Example 2.5: Let U = {u_1, u_2, u_3, u_4} be a set of four shirts and E = {white(e_1),red(e_2), blue (e_3)} be a set of parameters. If A = {e_1 ,e_2} $\subseteq$ E. Let $f_A(e_1)$ = {u_1, u_2 ,u_3, u_4} and $f_A(e_2)$= {u_1,u_2,u_3}. Then we write the soft set (f_A , E)= {(e_1, {u_1, u_2 ,u_3, u_4}), (e_2,{ u_1,u_2,u_3})} over U which describe the "colour of the shirts" which Mr. X is going to buy. We may represent the soft set in the following form:

U	e_1	e_2	e_3
u_1	1	1	0
u_2	1	1	0
u_3	1	1	0
u_4	1	0	0

Definition 2.6: Let U be the universal set, E set of parameters and A$\subset$ E. Let GD(X) denote the set of all fuzzy subsets of U. Then a pair (GD,A) is called fuzzy soft set over U, where GD is a mapping from A to GD(U).

Example 2.7: 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. Then (GD,A) = {GD(e_1) ={c_1/0.6,c_2/0.4,c_3/0.3}, GD(e_2) = {c_1/0.5,c_2/0.7,c_3/0.8}} is the fuzzy soft set over U denoted by F_A.

Definition 2.8: Let GD_A be a fuzzy soft set over U and α be a subset of U. Then upper α - inclusion of GD_A denoted by GD^{α}_A = {x$\in$A /GD(x) $\geq\alpha$ }.

Similarly GD^{α}_A = {x$\in$ A / GD(x) $\leq\alpha$ } is called lower α-inclusion of GD_A.

Definition 2.9: Let GD_A and G_B be fuzzy soft sets over the common universe U and ψ: A $\to$ B be a function. Then fuzzy soft image of GD_A under ψ over U denoted by $\psi(GD_A)$ is a set-valued function, where $\psi(GD_A)$: B$\to 2^U$ defined by $\psi(GD_A)$ (b)={$\cup${GD(a) / a$\in$A and ψ (a)=b} , if $\psi^{-1}(b)\neq\varphi$} for all b$\in$B, the soft pre-image of G_B under ψ over U denoted by $\psi^{-1}(G_B)$ is a set-valued function, where $\psi^{-1(}G_B)$: A $\to$ 2^U defined by $\psi^{-1}(G_B)(b) = G(\psi(a))$ for all a $\in$ A. Then fuzzy soft anti-image of GD_A under ψ over U denoted by $\psi(GD_A$ is a set-valued function, where $\psi(GD_A)$:B $\to 2^U$ defined by $\psi^{-1}(GD_A)(b)$={$\cap${GD(a) / a$\in$A and ψ (a)=b}, if $\psi^{-1}(b)\neq\varphi$ }for all b $\in$B.

Definition 2.10[Subbiah et.al]: Let X be a set. Then a mapping μ: X$\to$ $M^*([0, 1])$ is called flexible subset of X, where $M^*([0, 1])$ denotes the set of all non empty subset of [0, 1]

Definition 2.11 [Subbiah et.al]: Let X be a non empty set .Let μ and λ be two flexible fuzzy subsets of X. Then the intersection of μ and λ denoted by $\mu\cap\lambda$ and defined by $\mu\cap\lambda=\{\min\{a, b\}/ a\in\mu(x), b\in\lambda(x)\}$ for all $x\in X$. The union of μ and λ and denoted by $\mu\cup\lambda$ and defined by $\mu\cup\lambda=\{\max\{a,b\}/ a\in\mu(x), b\in\lambda(x)\}$ for all $x\in X$.

Definition 2.12 [Naim Cagman]: Let U be an initial universe, E be the set of all parameters and $A\subseteq E$. A pair (F, A) is called a flexible fuzzy soft set over U where F: $A \rightarrow \tilde{P}(U)$ is a mapping from A into $\tilde{P}(U)$, where $\tilde{P}(U)$ denotes the collection of all subsets of U.

Example 2.13: Consider the example 2.5, here we cannot express with only two real numbers 0 and 1, we can characterized it by a membership function instead of crisp numbers 0 and 1, which associate with each element a real number in the interval [0,1].Then

$(f_A, E) = \{f_A(e_1) = \{(u_1, 0.7), (u_2, 0.5), (u_3, 0.4), (u_4, 0.2)\},$
$f_A(e_2) = \{(u_1, 0.5), (u_2, 0.1), (u_3, 0.5)\}\}$

is the fuzzy soft set representing the "colour of the shirts" which Mr. X is going to buy.

Definition 2.14: Let H be an M-subgroup of Γ and Ꞷ be a flexible fuzzy soft over Γ. If for all x, $y\in$ H and $m\in M$,

(i) $\max\{\text{Ꞷ}(x-y), \varphi\} \leq \min\{\text{Ꞷ}(x) \cup \text{Ꞷ}(y), \theta\}$ and
(ii) $\max\{\text{Ꞷ}(mx), \varphi\} \leq \min\{\text{Ꞷ}(x), \theta\}$, then the flexible fuzzy soft set Ꞷ is called a threshold flexible fuzzy soft M-subgroup of Γ and denoted by $\text{Ꞷ}<_M\Gamma$

Example 2.15: Consider M={0,1,2,3} be a group with operation +

+	0	1	2	3
0	0	1	2	3
1	1	2	3	0
2	2	3	0	1
3	3	0	1	2

If we define a flexible fuzzy soft set G over Γ by

$G(x) = \{y \in\Gamma/ 3x=y\}$ for all $x \in H$.

Then G(0)={0} and G(2)={2} since $G(2-2)=G(0) \neq G(2)$,G is not a threshold flexible fuzzy soft M-subgroup of Γ.

Definition 2.16: The relative complement of the flexible fuzzy soft set Ꞷ_A over U is denoted by Ꞷ^r_A where Ꞷ^r_A $:A\rightarrow 2^U$ is a mapping given as $\text{Ꞷ}^r_A(x) = U/\text{Ꞷ}_A(x)$,for all $x \in A$.

SECTION-3: Characterization's of threshold flexible fuzzy soft M-group structures

In this section, we characterize the flexible fuzzy soft set through M-group structures.

Proposition 3.1: Let Ꞷ_A be a flexible fuzzy soft set over Γ and α be a subset of Γ. If Ꞷ_A is a flexible fuzzy soft M-subset of Γ, then upper α- inclusion of Ꞷ_A is an M-subgroup of Γ.

Proof: Since Ꞷ_A is flexible fuzzy soft M-subgroup of Γ. Assume x ,$y\in\text{Ꞷ}_A^\alpha$ and $m\in M$, then $\text{Ꞷ}(x)\geq\alpha$ and $\text{Ꞷ}(y) \geq\alpha$. We need to show that $x-y\in\text{Ꞷ}_A^\alpha$and $m\in\text{Ꞷ}_A^\alpha$.Since Ꞷ_A is flexible fuzzy soft M-subgroup of Γ, it follows that $\max\{\text{Ꞷ}(x-y), \varphi\} \leq \min\{(\text{Ꞷ}(x),\text{Ꞷ}(y)), \theta\}= \min\{(\alpha,\alpha), \theta\}\geq\alpha$ and $\max\{\text{Ꞷ}(mx), \varphi\}\leq \min\{\alpha, \theta\} = \alpha$ which completes the proof.

Proposition 3.2: Let Ꞷ_A be a flexible fuzzy soft set over Γ. Then Ꞷ_A is a threshold flexible fuzzy soft M-subgroup of Γ if $\text{Ꞷ}_A{}^r$ is threshold flexible anti fuzzy soft M-subgroup of Γ.

Proof: Let Ꞷ_A be a threshold flexible fuzzy soft M-subgroup of Γ.Then for all x, $y \in$ A and $m\in M$.

$$\begin{aligned}\max\{\text{Ꞷ}_A{}^r(x-y), \varphi\} &= \Gamma / \max\{\text{Ꞷ}_A(x-y), \varphi\}\\ &\geq \Gamma/ \min\{\text{Ꞷ}_A(x),\text{Ꞷ}_A(y), \theta\}\\ &= \min\{\Gamma / \text{Ꞷ}_A(x), \Gamma/ \text{Ꞷ}_A(y), \theta\}\\ &= \min\{\text{Ꞷ}_A{}^r(x), \text{Ꞷ}_A{}^r(y), \theta\}\end{aligned}$$

$$\begin{aligned}\max\{\text{Ꞷ}_A{}^r(mx), \varphi\} &= \Gamma / \max\{\text{Ꞷ}_A(mx), \varphi\}\\ &\geq \Gamma / \min\{\text{Ꞷ}_A(x), \theta\}\end{aligned}$$

$$\max\{\text{Ꞷ}_A{}^r(mx), \varphi\}= \min\{\text{Ꞷ}_A{}^r(x), \theta\}.$$

Hence $\text{Ꞷ}_A{}^r$ is threshold flexible anti fuzzy soft M-subgroup of Γ.

Proposition 3.3: Let $\mho_A$: $X \rightarrow X^1$ be a soft homomorphism of M-subgroups. If $\mho_A$ is threshold flexible fuzzy soft M-subgroup of X, then $\mho_A$ is threshold flexible fuzzy soft M-subgroup of X^1.

Proof: Suppose $\mho_A$ is threshold flexible fuzzy soft M-subgroup of X^1, then

(i) Let x^1, $y^1 \in X^1$, then exists x , y $\in$X such that
$f(x) = x^1$ and $f(y)=y^1$, we have
$$\max\{\mho_A(x^1-y^1), \varphi\} = \min\{\mho_A(f(x)-f(y)), \theta\}$$
$$\leq \min\{\mho_A(f(x)),\mho_A(f(y)), \theta\}$$
$$\max\{\mho_A(x^1-y^1), \varphi\} = \min\{\mho_A{}^1(x),\mho_A{}^1(y), \theta\}$$

(ii) $\max\{\mho_A(mx^1),\varphi\} = \min\{\mho_A(mf(x)), \theta\} \leq \min\{\mho_A{}^f(x), \theta\}$
$\max\{\mho_A(mx^1), \varphi\} = \min\{\mho_A{}^f(x), \theta\}$.
.: $\mho_A$ is threshold flexible fuzzy soft M-subgroupX .

Proposition 3.4: Let $\mho_A$ be threshold flexible soft M-sub group of X and $\mho_A{}^\alpha$ be a flexible fuzzy soft set in X given by $\mho_A{}^\alpha(x)=\mho_A(x)+1-\mho(1)$ for all x $\in$X. Then $\mho_A{}^\alpha$ is threshold flexible fuzzy soft M-subgroup of X and $\mho_A \subseteq \mho_A{}^\alpha$.

Proof: Since $\mho_A$ is threshold flexible fuzzy soft M-subgroup of X and $\mho_A{}^\alpha(x)=\mho_A(x)+1- \mho_A(1)$ for x $\in$X. For any x, y $\in$ X, we have $\mho_A(1)=\mho_A(1)+1-\mho_A(1)=1>\mho_A{}^\alpha(x)$ and for all x ,y $\in$ X, we have
$$\max\{\mho_A{}^\alpha (x-y), \varphi\} = \max\{\mho_A(x-y)+1-\mho_A(1), \varphi\}$$
$$\leq \min\{(\mho_A(x),\mho_A(y))+1-\mho_A(1), \theta\}$$
$$= \min\{\mho_A(x)+1-\mho_A(1),\mho_A(y)+1-\mho_A(1),\theta\}$$
$$= \min\{\mho_A{}^\alpha(x),\mho_A{}^\alpha(y), \theta\}$$

$$\max\{\mho_A{}^\alpha(mx), \varphi\} = \max\{\mho_A(mx)+1-\mho_A(1), \varphi\}$$
$$= \min\{\mho_A(x)+1-\mho_A(1), \theta\}$$
$$= \min\{\mho_A{}^\alpha(x), \theta\}$$
Hence $\mho_A{}^\alpha$ is threshold flexible fuzzy soft M-subgroup of X and $\mho_A \subseteq \mho_A{}^\alpha$.

Proposition 3.5: Let $\mho_A$ and G_B two flexible fuzzy soft sets over Γ, where A and B are M- groups of Γ and ø: A $\rightarrow$ B is an M-homomorphism. If $\mho_A$ is threshold flexible fuzzy soft M- subgroup of Γ, then so is ø ($\mho_A$).

Proof: Let α_1, $\alpha_2 \in$ B such ø is surjective, there exists $a_1,a_2 \in$A such that $ø(a_1)=\alpha_1$ and $ø(a_2)=\alpha_2$.Thus
$$\max\{ (ø\, \mho_A)(\alpha_1 - \alpha_2), \varphi \} = \max\{\mho(a)/A \in A,\ ø(A)=\alpha_1- \alpha_{2,\varphi}\}$$
$$= \max\{\mho(a)/A\in A,A=ø^{-1}(\alpha_1 - \alpha_2), \varphi\}$$
$$= \max\{\mho(a)/A\in A,A=ø^{-1}(ø(a_1- a_2))= A_1 - A_2, \varphi\}$$
$$= \max\{\mho(a_1 - a_2)/\alpha_1,\alpha_2\in B,\ ø(a_i)= \alpha_i ,i =1,2, \varphi\}$$
$$= \min\{\max\{\mho(a_1)/\alpha_1\in B,ø(a_1) = \alpha_1,\theta\}, \max\{\mho(a_2)/\alpha_2\in B,ø(a_2)=\alpha_2, \theta\}\}$$
$$= \min\{ø(\mho_A)(\alpha_1),ø(\mho_A)(\alpha_2), \theta\}$$

Now let m$\in$M and $\alpha\in$ B. Since ø surjective, then exists $\bar{A}\in$A such that $ø(\bar{A})=0$. We have
$$\max \{ø(\mho_A)(m\alpha), \varphi\} = \max\{\mho(A)/A\in A,\ ø (A)=m\alpha, \varphi\}$$
$$= \max\{\mho(A)/A\in A,A=ø^{-1}(m\alpha), \varphi\}$$
$$= \max\{\mho(A)/A\in A,A=ø^{-1}(mø(\bar{A})), \varphi\}$$
$$= \max\{\mho(A)/A\in A,A=ø^{-1}(ø(mA))=m\bar{A}, \varphi\}$$
$$= \max\{\mho(m\bar{A})/\bar{A}\in A ,ø(\bar{A})=\alpha, \varphi\}$$
$$= \min\{\mho(\bar{A})/\bar{A}\in A ,ø(\bar{A})=\alpha, \theta\}$$
$$= \min\{ø(\mho_A)(\alpha), \theta \}.$$ Hence
Hence Ø($\mho_A$) is threshold flexible fuzzy soft M-subgroup of Γ.

Proposition 3.6: Let $\mho_A$:X$\rightarrow$Y be a soft homomorphism of M-subgroups. If $\mho_A$ is threshold flexible fuzzy soft M-subgroup of Y, then $\mho_A{}^f$ is threshold flexible fuzzy soft M-subgroup of X.

Proof: Suppose $\mho_A$ is threshold flexible fuzzy soft M-subgroup of Y, then

i) For all x ,y $\in$ X ,we have
$$\max \{\mho_A (x- y), \varphi \} = \max\{\mho_A(f(x- y), \varphi\}$$
$$= \max\{\mho_A (f(x)-f(y), \varphi\}$$
$$= \min\{\mho_A(f(x)),\mho_A(f(y)), \theta\}$$
$$= \min\{\mho_A{}^f(x),\mho_A{}^f(y), \theta\}$$

ii) $\max\{Ꙍ_A^f(mx), \varphi\} = \max\{Ꙍ_A(f(mx)), \varphi\} \leq \min\{Ꙍ_A(f(x)), \theta\}$
$= \min\{Ꙍ_A^f(x), \theta\}$.

Therefore $Ꙍ_A^f$ is threshold flexible fuzzy soft M- subgroup of X.

Proposition 3.7: Let $Ꙍ_A$ and G_B be flexible fuzzy soft sets over Γ, where A and B are M-subgroups of Γ. Let Ø be on M-homomorphism from A to B. If G_B is a threshold flexible fuzzy soft M-subgroup of Γ, then so is $Ø^{-1}(G_B)$.

Proof: Let $a_1, a_2 \in A$. Then

$$\max\{(Ø^{-1}(G_B))(a_1\text{-}a_2), \varphi\} = \max\{G(Ø(a_1\text{-}a_2)), \varphi\}$$
$$\geq \min\{G(Ø(a_1), Ø(a_2), \theta\}$$
$$= \min\{(Ø^{-1}(G_B)(a_1), Ø^{-1}(G_B)(a_2), \theta\}$$

Now let $m \in M$ and $A \in A$, then

$$\max\{(Ø^{-1}(G_B))(m_A), \varphi\} = \max\{G(Ø(m_A)), \varphi\}$$
$$= \min\{G(mØ(A)), \theta\}$$
$$= \min\{G(Ø(A)), \theta\}$$
$$= \min\{(Ø^{-1}(G_B))(A), \theta\}.$$

Hence $Ø^{-1}(G_B)$ is a flexible fuzzy soft M-subgroup of Γ.

CONCLUSION

This paper summarized the basic concepts of flexible soft sets. By using these concepts we studied the algebraic properties of flexible fuzzy soft M-groups. This work focused on flexible fuzzy soft pre-image, flexible fuzzy soft image, flexible fuzzy soft anti image. To extend this work one could study the properties of flexible fuzzy soft M-groups in other algebraic structures such as rough set and vague set.

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