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MULTI GRANULATION ON NANO SOFT TOPOLOGICAL SPACE

S.P.R. PRIYALATHA[1] AND WADEI. F. AL-OMERI

ABSTRACT. In this paper, we explore a nano soft topological space with a multi granulation is known as "Multi-Nano Soft Topological Space (MNSTS)". We study the characterization and properties of soft approximation space in MNSTS. Further, we define multi-nano soft interior and multi-nano soft closure an investigation is done on properties with a model.

1. INTRODUCTION

Molodtsov [5], in 1999, introduced the concept of soft set theory as a mathematical model for handling ambiguities that a known mathematical model can't hold. He has indicated a few applications of soft set theory for discovering answers for some practical problems, for example, financial matters, sociology, designing, clinical science, and so forth. In 1998, Lin [4] considered granular computing utilizing neighbourhood frameworks for the understanding of granules. Lellis Thivagar et.al [3] introduced a nano topological space. The notion of soft topological space which was formulated by Shabir and Naz [7], which is defined over an initial universe with a fixed set of parameters. Recently, the author has studied the soft set and nano topology [2]. The soft set relation was developed by Babitha.et.al. [1] and authors are studied and developed by the concept [8]. This paper we define nano soft topological space using a soft

[1]*corresponding author*

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set based on multi granulation. We also derive the soft approximation space $(\mathcal{U}, F_A)$ in multi-nano soft topological space. The properties of multi-soft lower and multi-soft upper approximations are discussed with an example. Further, we discuss the properties of multi-nano soft interior and multi-nano soft closure based on MNSTS with examples are given.

2. PRELIMINARIES

In the current section, we recollect the some basic definitions of nano topology and soft set.

Definition 2.1. *[5], [6] A soft set (F, A) denoted by F_A on the universe $\mathcal{U}$ is defined by the set of ordered pairs $F_A = \{(e, F(e)) : e \in E, F(e) \in P(\mathcal{U})\}$, where $F : E \to P(\mathcal{U})$ such that $F(e) = \emptyset$ if $e \notin A$. Here, F is called an approximate function of the soft set F_A.The set F(e) is called e-approximate value set or e-approximate set which consists of related objects of the parameter $e \in E$.*

Definition 2.2. *[1] Let F_A and G_B be two soft sets over $\mathcal{U}$,then the Cartesian product ofF_A and G_B is defined as,$F_A \times G_B = (H, A \times B)$,where $H : A \times B \to P(\mathcal{U}\times\mathcal{U})$ and $H(a, b) = F(a)\times G(b)$,where $\forall(a, b) \in A\times B$,i.e., $H(a, b) = \{(h_i, h_j) : h_i \in F(a)$ and $h_j \in G(b)\}$.*

Definition 2.3. *[8] Let R be a soft equivalence relation on F_A,then*

- (i) *soft reflexive if $F(a) \times F(a) \in R, \forall a \in A$.*
- (ii) *soft symmetric if $F(a) \times F(b) \in R \Rightarrow F(b) \times F(a) \in R, \forall a, b \in A$.*
- (iii) *soft transitive if $F(a) \times F(b) \in R, F(b) \times F(c) \in R \Rightarrow F(a) \times F(c) \in R, \forall a, b, c \in A$.*

Definition 2.4. *[1], [8] Let F_A be a soft set, then soft equivalence class of $F(a)$ denoted by $[F(a)]$ is defined as $[F(a)] = \{F(b) : F(a) \times F(b) \in R, \forall a, b \in A\}$.*

Definition 2.5. *[3] Let $\mathcal{U}$ be a non-empty finite set of objects called the universe, $\mathcal{R}$ be an equivalence relation on $\mathcal{U}$ named as the indiscerniblity relation. Elements belonging to the same equivalence class are said to be indiscernible with one another. The pair $(\mathcal{U}, R)$ is said to be approximation space. Let $X \subseteq \mathcal{U}$.*

(1) *The Lower approximation of X with respect to R is the set of all objects, which can be for certain classified as X with respect to R and it is denoted by*

$L_R(X)$. That is, $L_R(X) = \left\{ \bigcup_{x \in \mathcal{U}} \{R(x) : R(x) \subseteq X\} \right\}$, where R(x) denotes the equivalence class determined by x.

(2) *The Upper approximation of X with respect to R is the set of all objects, which can be possibly classified as X with respect to R and it is denoted by $U_R(X) = \left\{ \bigcup_{X \in \mathcal{U}} \{R(x) : R(x) \cap X \neq \emptyset\} \right\}$.*

(3) *The Boundary region of X with respect to R is the set of all objects which can be classified neither as X nor as not -X with respect to R and it is denoted by $B_R(X) = U_R(X) - L_R(X)$.*

Definition 2.6. *[3] Let $\mathcal{U}$ be the universe, R be an equivalence relation on $\mathcal{U}$ and $\tau_R(X) = \{\mathcal{U}, \emptyset, L_R(X), U_R(X), B_R(X)\}$ where $X \subseteq \mathcal{U}$. $\tau_R(X)$ satisfies the following axioms:*

(1) *$\mathcal{U}$ and $\emptyset \in \tau_R(X)$*
(2) *The union of elements of any sub collection of $\tau_R(X)$ is in $\tau_R(X)$.*
(3) *The intersection of the elements of any finite sub collection of $\tau_R(X)$ is in $\tau_R(X)$.*

That is, $\tau_R(X)$ forms a topology on $\mathcal{U}$ called as the nano topology on $\mathcal{U}$ with respect to X. We call $\{\mathcal{U}, \tau_R(X)\}$ as the nano topological space.

3. Bi-Granularity Soft Approximation Space Based On Nano soft Topology

In this section, we define the nano soft topological space induced by multi-granulation is said to be "Multi-Nano Soft Topological Space(MNSTS)" and their characterization are investigated.

Definition 3.1. *Let $\mathcal{U}$ be non-empty finite universe, F_A be a soft set over $\mathcal{U}$.Let M, N be a soft equivalence relation on $F_A \subseteq F_E$. Elements belonging to the soft equivalence class of $F(a)$ denoted by $[F(a)]$ are said to be soft indiscernible with one another. The ordered pair $(\mathcal{U}, F_A)$ is said to be soft approximation space .Let $G_B \subseteq F_A$.*

(i) *If $\mathcal{L}_{\mathcal{M}+\mathcal{N}}(G_B) = \bigcup_{a \in A} \{[F(a)] : [F(a)]_M \subseteq G_B$ or $[F(a)]_N \subseteq G_B\}$ is a multi-soft lower approximation of F_A with respect to G_B.*

(ii) *If* $\mathcal{U}_{\mathcal{M}+\mathcal{N}}(G_B) = \bigcup_{a \in A} \{[F(a)] : [F(a)]_M \cap G_B \neq \tilde{\emptyset}\}$ *and* $[F(a)]_N \cap G_B \neq \tilde{\emptyset}\}$ *is a multi-soft upper approximation of* F_A *with respect to* G_B*.*

(iii) *If* $\mathcal{B}_{\mathcal{M}+\mathcal{N}}(G_B) = \mathcal{U}_{\mathcal{M}+\mathcal{N}}(G_B) - \mathcal{L}_{\mathcal{M}+\mathcal{N}}(G_B)$ *is a multi-soft boundary region of* F_A *with respect to* G_B*.*

Definition 3.2. *Let* $\mathcal{U}$ *be a non empty finite set of objects called the universe,* $F_A \subseteq F_E$ *is an soft set over* $\mathcal{U}$*. Then* $(\mathcal{U}, F_A)$ *is an ordered pair of soft approximation space and* $\tilde{\tau}_{M+N}(G_B) = \{\tilde{\mathcal{U}}, \tilde{\phi}, \mathcal{L}_{\mathcal{M}+\mathcal{N}}(G_B), \mathcal{U}_{\mathcal{M}+\mathcal{N}}(G_B), \mathcal{B}_{\mathcal{M}+\mathcal{N}}(G_B)\})$*, where* $G_B \subseteq F_A$*.That is,* $\tilde{\tau}_{M+N}(G_B)$ *forms a multi-nano soft topology on* $\mathcal{U}$ *having the at most five elements of soft set and triple ordered pair of* $(\mathcal{U}, \tilde{\tau}_{M+N}, E)$ *is called a multi-nano soft topological space over* $\mathcal{U}$ *with respect to* G_B*, then the members of* $\tilde{\tau}_{M+N}$ *are said to be multi-nano soft open sets in* $\mathcal{U}$*.*

Example 1. *Let* $\mathcal{U} = \{k_1, k_2, k_3, k_4, k_5, k_6\}$ *be the universe,* $E = \{d_1, d_2, d_3, d_4, d_5\}$ *and* $A = \{d_1, d_2, d_3, d_4\}$ *be a set of parameters. Also, let* $F_A = \{(d_1, \{k_1, k_2\}), (d_2, \{k_2, k_3\}), (d_3, \{k_2, k_3\}), (d_4, \{k_4, k_5\})\}$ *and* $G_B \subseteq F_A$*, where* $G_B = \{(d_1, \{k_1, k_2\}), (d_2, \{k_3\}), (d_3, \{k_2, k_3\})\}$ *such that* $F(d_1) = \{k_1, k_2\}, F(d_2) = \{k_3\}, F(d_3) = \{k_2, k_4\}, F(d_4) = \{k_4, k_5\}$ *is a soft set over* $\mathcal{U}$ *and* $M = \{F(d_1) \times F(d_1), F(d_2) \times F(d_2), F(d_3) \times F(d_3), F(d_4) \times F(d_4), F(d_1) \times F(d_2), F(d_2) \times F(d_1)\}$ *and* $N = \{F(d_1) \times F(d_1), F(d_2) \times F(d_2), F(d_3) \times F(d_3), F(d_4) \times F(d_4), F(d_2) \times F(d_3), F(d_3) \times F(d_2)\}$ *is a two soft equivalence relation.*

Then $[F(d_1)]_M = \{F(d_1), F(d_2)\}$*,* $[F(d_2)]_M = \{F(d_1), F(d_2)\}$*,* $[F(d_3)]_M = \{F(d_3)\}$*,* $[F(d_4)]_M = \{F(d_4)\}$ *and* $[F(d_1)]_N = \{F(d_1)\}$*,* $[F(d_2)]_N = \{F(d_2), F(d_3)\}$*,* $[F(d_3)]_N = \{F(d_2), F(d_3)\}$*,* $[F(d_4)]_N = \{F(d_4)\}$*.*

So, we have $\mathcal{L}_{\mathcal{M}+\mathcal{N}}(G_B) = \{(d_1, \{k_1, k_2\}), (d_2, \{k_2, k_3\})\}$ *and* $\mathcal{U}_{\mathcal{M}+\mathcal{N}}(G_B) = \{\{(d_1, \{k_1, k_2\}), (d_2, \{k_2, k_3\})\}, \{(d_1, \{k_1, k_2\}), (d_2, \{k_2, k_3\}), (d_3, \{k_2, k_3\})\}, \{(d_2, \{k_2, k_3\}), (d_3, \{k_2, k_3\})\}$ *and* $\mathcal{B}_{\mathcal{R}}(G_B) = \{(d_1, \{k_1, k_2\}), (d_2, \{k_2, k_3\}), (d_3, \{k_2, k_3\})\}, \{(d_2, \{k_2, k_3\}), (d_3, \{k_2, k_3\})\}$*. Hence*

$$\begin{aligned}\tilde{\tau}_{M+N}(G_B) = \{&\tilde{\mathcal{U}}, \tilde{\phi}, \{(d_1, \{k_1, k_2\}), (d_2, \{k_2, k_3\})\}, \{\{(d_1, \{k_1, k_2\}), (d_2, \{k_2, k_3\})\},\\ &\{(d_1, \{k_1, k_2\}), (d_2, \{k_2, k_3\}), (d_3, \{k_2, k_3\})\}, \{(d_2, \{k_2, k_3\}),\\ &(d_3, \{k_2, k_3\})\}, \{(d_1, \{k_1, k_2\}), (d_2, \{k_2, k_3\}), (d_3, \{k_2, k_3\})\},\\ &\{(d_2, \{k_2, k_3\}), (d_3, \{k_2, k_3\})\}\}\end{aligned}$$

is a multi-nano soft topological space.

Definition 3.3. *Let $F_A \subseteq F_E$ be a soft set over $\mathcal{U}$ and $(\mathcal{U}, F_A)$ be a soft approximation space and $G_B \subseteq F_A$. We define the characterization of five basic types of multi-nano soft topological space as follows as:*

(i) *If $\mathcal{L}_{\mathcal{M}+\mathcal{N}}(G_B) = \tilde{\phi}$ and $\mathcal{U}_{\mathcal{M}+\mathcal{N}}(G_B) = \tilde{\mathcal{U}}$, then $\tilde{\tau}_{M+N}(G_B) = \{\tilde{\mathcal{U}}, \tilde{\phi}\}$ is called as multi-nano indiscrete soft topology on $\mathcal{U}$.*

(ii) *If $\mathcal{L}_{\mathcal{M}+\mathcal{N}}(G_B) = \mathcal{U}_{\mathcal{M}+\mathcal{N}}(G_B) = \tilde{\mathcal{U}}$, then the multi-nano soft topology ,$\tilde{\tau}_{M+N}(G_B) = \{\tilde{\mathcal{U}}, \tilde{\phi}, \mathcal{L}_{\mathcal{M}+\mathcal{N}}(G_B)\}$.*

(iii) *If $\mathcal{L}_{\mathcal{M}+\mathcal{N}}(G_B) = \tilde{\phi}$ and $\mathcal{U}_{\mathcal{M}+\mathcal{N}}(G_B) \neq \tilde{\mathcal{U}}$, then multi-nano soft topology ,$\tilde{\tau}_{M+N}(G_B) = \{\tilde{\mathcal{U}}, \tilde{\emptyset}, \mathcal{U}_{\mathcal{M}+\mathcal{N}}(G_B)\}$.*

(iv) *If $\mathcal{L}_{\mathcal{M}+\mathcal{N}}(G_B) \neq \tilde{\emptyset}$ and $\mathcal{U}_{\mathcal{M}+\mathcal{N}}(G_B) = \tilde{\mathcal{U}}$, then multi-nano soft topology $\tilde{\tau}_{M+N}(G_B) = \{\tilde{\mathcal{U}}, \tilde{\emptyset}, \mathcal{L}_{\mathcal{M}+\mathcal{N}}(G_B), \mathcal{B}_{\mathcal{M}+\mathcal{N}}(G_B)\}$.*

(v) *If $\mathcal{L}_{\mathcal{M}+\mathcal{N}}(G_B) \neq \mathcal{U}_{\mathcal{M}+\mathcal{N}}(G_B)$, where $\mathcal{L}_{\mathcal{M}+\mathcal{N}}(G_B) \neq \tilde{\emptyset}$ and $\mathcal{U}_{\mathcal{M}+\mathcal{N}}(G_B) \neq \tilde{\mathcal{U}}$, then multi-nano discrete soft topology on $\tilde{\tau}_{M+N}(G_B) = \{\tilde{\mathcal{U}}, \tilde{\emptyset}, \mathcal{L}_{\mathcal{M}+\mathcal{N}}(G_B), \mathcal{U}_{\mathcal{M}+\mathcal{N}}(G_B), \mathcal{B}_{\mathcal{M}+\mathcal{N}}(G_B)\}$.*

Proposition 3.1. *Let $(\mathcal{U}, F_A)$ be a soft approximation space and let $G_B, H_C \in F_A$ and $M, N \in R$.Then*

(i) $\mathcal{L}_{\mathcal{M}+\mathcal{N}}(F_\phi) = F_\phi$ *and* $\mathcal{U}_{\mathcal{M}+\mathcal{N}}(F_\phi) = F_\phi$.

(ii) $\mathcal{L}_{\mathcal{M}+\mathcal{N}}(F_A) = F_A$ *and* $\mathcal{U}_{\mathcal{M}+\mathcal{N}}(F_A) = F_A$.

(iii) *If* $G_B \subseteq H_C$ *then* $\mathcal{L}_{\mathcal{M}+\mathcal{N}}(G_B) \subseteq \mathcal{L}_{\mathcal{M}+\mathcal{N}}(H_C)$ *and* $\mathcal{U}_{\mathcal{M}+\mathcal{N}}(G_B) \subseteq \mathcal{U}_{\mathcal{M}+\mathcal{N}}(H_C)$.

(iv) $\mathcal{L}_{\mathcal{M}+\mathcal{N}}(G_B) \subseteq [\mathcal{U}_{\mathcal{M}+\mathcal{N}}(H_C)^c]^c$.

(v) $\mathcal{U}_{\mathcal{M}+\mathcal{N}}(G_B) \subseteq [\mathcal{L}_{\mathcal{M}+\mathcal{N}}(H_C)^c]^c$.

(vi) $\mathcal{L}_{\mathcal{M}+\mathcal{N}}(G_B \cap H_C) = \mathcal{L}_{\mathcal{M}+\mathcal{N}}(G_B) \cap \mathcal{L}_{\mathcal{M}+\mathcal{N}}(H_C)$.

(vii) $\mathcal{L}_{\mathcal{M}+\mathcal{N}}(G_B) \cup \mathcal{L}_{\mathcal{M}+\mathcal{N}}(H_C) \subseteq \mathcal{L}_{\mathcal{M}+\mathcal{N}}(G_B \cup H_C)$.

$(viii)$ $\mathcal{U}_{\mathcal{M}+\mathcal{N}}(G_B \cup H_C) = \mathcal{U}_{\mathcal{M}+\mathcal{N}}(G_B) \cup \mathcal{U}_{\mathcal{M}+\mathcal{N}}(H_C)$.

(ix) $\mathcal{U}_{\mathcal{M}+\mathcal{N}}(G_B \cap H_C) \subseteq \mathcal{U}_{\mathcal{M}+\mathcal{N}}(G_B) \cap \mathcal{U}_{\mathcal{M}+\mathcal{N}}(H_C)$.

Proposition 3.2. *Let $(\mathcal{U}, \tilde{\tau}_{M+N}, E)$ be a multi-nano soft topological space and let $G_B \in F_A$ and $M, N \in R$.Then*

(i) $G_B \subseteq \mathcal{U}_{\mathcal{M}+\mathcal{N}}(G_B)$

(ii) $\mathcal{L}_{\mathcal{M}+\mathcal{N}}(G_B) \subseteq G_B$

(iii) $\mathcal{U}_{\mathcal{M}+\mathcal{N}}(\mathcal{L}_{\mathcal{M}+\mathcal{N}})(G_B) \subseteq G_B$.

(iv) $G_B \subseteq \mathcal{L}_{\mathcal{M}+\mathcal{N}}(\mathcal{U}_{\mathcal{M}+\mathcal{N}}(G_B))$.

(v) $\mathcal{U}_{\mathcal{M}+\mathcal{N}}(\mathcal{U}_{\mathcal{M}+\mathcal{N}}(G_B)) \subseteq \mathcal{U}_{\mathcal{M}+\mathcal{N}}(G_B)$.

(vi) $\mathcal{L}_{\mathcal{M}+\mathcal{N}}(G_B) \subseteq \mathcal{L}_{\mathcal{M}+\mathcal{N}}(\mathcal{L}_{\mathcal{M}+\mathcal{N}}(G_B))$

Definition 3.4. *Let $(\mathcal{U}, \tilde{\tau}_{M+N}, E)$ be a multi- nano soft topological space over $\mathcal{U}$. Then multi-nano soft interior of soft set $H_C \subseteq F_A$ over $\mathcal{U}$ is denoted by H_C°. Thus H_C° is the largest multi nano soft open set contained in H_C and is defined as the union of all multi-nano soft open sets contained in H_C.*

Example 2. *From Example 3.4 Let $H_C = \{(d_3, \{k_2, k_3\})\}$, then multi-nano soft interior $H_C^\circ = \{(d_3, \{k_2, k_3\}), (d_2, \{k_2, k_3\})\}$.*

Theorem 3.1. *Let $(\mathcal{U}, \tau_{\tilde{M+N}}, E)$ be a multi-nano soft topological space over $\mathcal{U}$ and $H_C \subseteq F_A$ and H_C is an multi-nano soft open set if and only if $H_C = H_C^\circ$.*

Proof. If H_C is an multi-nano soft open set,then the largest multi-nano soft open set that is contained by H_C is equal to H_C.Therefore $H_C = H_C^\circ$.Conversely,It is know that H_C° is a multi-nano soft open set,and if $H_C^\circ = H_C$,then H_C is an multi-nano soft open set. □

Theorem 3.2. *Let $(\mathcal{U}, \tau_{\tilde{M+N}}, E)$ be a multi-nano soft topological space and $H_C, I_D \subseteq F_A$.Then*

(a) $[H_C^\circ]^\circ = H_C^\circ$.
(b) $H_C \subseteq I_D \Rightarrow H_C^\circ \subseteq I_D^\circ$.
(c) $H_C^\circ \cap I_D^\circ = [H_C \cap I_D]^\circ$.
(d) $H_C^\circ \cup I_D^\circ \subseteq [H_C \cap I_D]^\circ$.

Definition 3.5. *Let $(\mathcal{U}, \tau_{\tilde{M+N}}, E)$ be a multi-nano soft topological space over $\mathcal{U}$.Then multi-nano soft closure of soft set $H_C \subseteq F_A$ over $\mathcal{U}$ is denoted by $\overline{H}_C$.Thus $\overline{H}_C$ is the smallest multi-nano soft closed set which containing H_C and is defined as the intersection of all multi-nano soft closed supersets of H_C.*

Example 3. *By example 3.4 and the complement of multi-nano soft topological space*

$$\begin{aligned}[\tilde{\tau}_{M+N}(G_B)]^c = \{&\tilde{\mathcal{U}}, \tilde{\phi}, \{(d_1, \{k_3, k_4, k_5, k_6\}), (d_2, \{k_1, k_4, k_5, k_6\})\},\\ &\{\{(d_1, \{k_3, k_4, k_5, k_6\}), (d_2, \{k_1, k_4, k_5, k_6\})\}, \{(d_1, \{k_3, k_4, k_5, k_6\}),\\ &(d_2, \{k_1, k_4, k_5, k_6\}), (d_3, \{k_1, k_4, k_5, k_6\})\}, \{(d_2, \{k_1, k_4, k_5, k_6\}),\\ &(d_3, \{k_1, k_4, k_5, k_6\})\}, \{(d_1, \{k_3, k_4, k_5, k_6\}), (d_2, \{k_1, k_4, k_5, k_6\}),\\ &(d_3, \{k_1, k_4, k_5, k_6\})\}, \{(d_2, \{k_1, k_4, k_5, k_6\}), (d_3, \{k_1, k_4, k_5, k_6\})\}\}\end{aligned}$$

Let $H_C = \{(d_2, \{k_1, k_4, k_5, k_6\})\}$ is a nano multi-soft closed set,then multi-nano soft closure $\overline{H_C} = \{(d_2, \{k_1, k_4, k_5, k_6\})\} = H_C$.

Theorem 3.3. *Let* $(\mathcal{U}, \tau_{\tilde{M+N}}, E)$ *be a multi-nano soft topological space over* $\mathcal{U}$*,* $H_C, I_D \subseteq F_A$ *.Then*

(a) $\overline{\phi} = \phi$ *and* $\overline{\mathcal{U}} = \mathcal{U}$.
(b) $H_C \subseteq \overline{H_C}$.
(c) H_C *is a multi-nano soft closed set if and only if* $H_C = \overline{H_C}$.
(d) $\overline{\overline{H_C}} = \overline{H_C}$.
(e) $I_D \subseteq H_C \Rightarrow \overline{I}_D \subseteq \overline{H}_C$.
(f) $\overline{H}_C \cap \overline{I}_D \subseteq \overline{[H_C \cap I_D]}$.
(g) $\overline{H}_C \cup \overline{I}_D = \overline{[H_C \cup I_D]}$.

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DEPARTMENT OF MATHEMATICS
KONGUNADU ARTS AND SCIENCE COLLEGE
COIMBATORE-641 029,TAMIL NADU,INDIA.
Email address: spr.priyalatha@gmail.com

MATHEMATICS DEPARTMENT,FACULTY OF SCIENCE
AL-BALQA APPLIED UNIVERSITY
SALT 19117, JORDAN.
Email address: wadeialomeri@bau.edu.jo