



On Micro_Z Continuity in Micro_Z Topological Space

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Abstract

In this paper, we investigate Micro_Z Continuous functions and examine their relationships with various classes of Micro_Z -Continuity. In particular, we introduce several types of Continuity, including μ_Z Semi Continuity, μ_Z -pre-Continuity, μ_Z - α Continuity, μ_Z -regular Continuity, and μ_Z - β Continuity. Furthermore, we study a number of fundamental properties of Micro_Z -Continuous functions. The main results are established through rigorous theorems and supported by illustrative examples.

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1. Introduction

In 2013 [1] introduced On Nano Continuity, 2014 [2] introduced a nano-topological space with respect to subset x of a universe which is defined in terms of lower approximation and upper approximation and boundary region. In 2015[9] studied on nano generalized continuous function in nano topological space. In 2017 [8] study on nano semi-continuity and nano pre-continuity. In 2021[4] studied Micro open sets of Micro topological space and introduced Micro-Continuous functions. In 2023[5] introduced Nano-Z-topological space by defining open sets for nano-Z-topological space. In this paper we study Micro_Z -Continuity functions and inverse functions, and we studied We studied the relationship with some types of Micro_Z Continuity. We also discuss some properties of Micro_Z -Continuity functions, we explained it through theorems and examples.

2. Preliminary

Definition 1. [2]

Let U be a non- empty finite set of elements called the universe set and $U \neq \emptyset$. Then the equivalence relation R on U dubbed a indiscernibility relation. The elements that belong to the same equivalence class are said to be 'indistinguishable with one another. The ordered pair (U, R) is said to be the approximation space, let $X \subseteq U$.

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 is defined by

$L_R(X) = \sqcup \{R(X) : R(X) \subseteq X\}$. 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 is defined by

$U_R(X) = \sqcup \{R(X) : R(X) \cap X \neq \emptyset\}$

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 is defined by

$$B_R(X) = [U_R(X) - L_R(X)]$$

Definition 2 . [2]

Let U be a comprehensive set with equivalence relation R on U and $\tau_R(X) = \{\emptyset, U, L_R(X), U_R(X), B_R(X)\}$, where $X \subseteq U$. $(U, \tau_R(X))$ is called a Nano – Topological' space w. r. to 'X'. The objects of $\tau_R(X)$ are called Nano – Open set. Let $A \subseteq U$, then Nano- Interior of A, $Nint(A)$ is a biggest Nano– Open subset of A. Nano- Closure of A $Ncl(A)$ is a tiniest Nano- Closed set including A.

Definition 3. [3]:

Let $(U, \tau_R(X))$ is a nano topological space here $\mu_R(X) = \{N\mu, N\mu\}$; $N, \check{N} \in \tau_R(X)$ and called it Micro topological of $\tau_R(X)$ by μ Where $\mu \notin \tau_R(X)$.

Definition 4. [3]

The Micro closure of a set A is symbolize by $\mu ic-cl(A)$ and is describe as

$$\mu ic-cl(A) = \cap \{B : B \text{ is } \mu\text{-closed and } A \subseteq B\}.$$

The Micro interior of a set A is symbolize by $\mu ic-int(A)$ and is describe as

$$\mu ic-int(A) = \cup \{B : B \text{ is } \mu ic\text{-open and } A \supseteq B\}.$$

Definition 5. [3]

Let $(U, \tau_R(X), \mu_R(X))$. be a micro topological space and $A \setminus c \subseteq U$. Then A is said to be micro-pre-open if $A \subseteq \text{Mic-int}(\text{Mic-cl}(A))$ and micro- pre-closed set if $\text{Mic-cl}(\text{Mic-int}(A)) \subseteq A$.

Definition 6.[6]:

Let $(U, \tau_R(X), \mu_R(X))$ be a Micro – topological space, Then B subset of U is called μ_Z -open set if B satisfies the following condition :-

1- $\forall b \in B, \exists \text{ Micro – open } G \text{ such that } b \in G \subseteq \text{Micro – cl}(B)$.

2- $G=U$ iff $B = U$, every set in $\mu_{RZ}(X)$ is μ_Z – open set and complement of μ_Z – open set is μ_Z – closed set and denoted by $\mu_{RZ}(X)$, the $(U, \mu_R(X), \mu_{RZ}(X))$ is called Micro_Z topological space.

Example 7:-Let $U = \{m, n, o, p\}$, with U/R

$= \{\{m\}, \{o\}, \{n, p\}\}, X = \{n, p\} \subseteq U, \tau_R(X) = \{U, \emptyset, \{n, p\}\}$ and then $\mu = \{n\}$.

$$\mu_R(X) = \{U, \emptyset, \{n\}, \{n, p\}\}$$

$$\text{Micro-closed set} = \{U, \emptyset, \{m, o, p\}, \{m, o\}\}.$$

$$\mu_{RZ}(X) = \{U, \emptyset, \{n\}, \{p\}, \{n, p\}\}.$$

Theorem 8.[6]:-

Every μ_Z -open set is a μ_Z -pre open.

Proof. Let go B be μ_Z -open .Then $B \subseteq \mu_Z -int(\mu_Z -int B)$. Since $\mu_Z -int(\mu_Z -int B) \subseteq \mu_Z -int(\mu_Z -cl B)$, therefore $B \subseteq \mu_Z -int(\mu_Z -cl B)$. Hence B is μ_Z -pre open.

Theorem 9. [6].

a. Arbitrary union of μ_Z -pre open sets is μ_Z -pre open.

b. " Arbitrary intersection of μ_Z -pre closed sets is μ_Z -pre closed..

Proof:

a. Let $\{B_\alpha | \alpha \in I\}$ form the family of μ_Z -pre open sete in X. By definition 3.5. for each $\alpha, B_\alpha \subseteq \mu_Z -int(\mu_Z cl(B_\alpha))$, this implies that

$$\cup B_\alpha \subseteq \cup (\mu_Z int(\mu_Z cl(B_\alpha))) . \text{ Since } \cup$$

$$(\mu_Z int(\mu_Z cl(B_\alpha))) \subseteq \mu_Z int(\cup \mu_Z cl(B_\alpha)) \text{ and } \mu_Z -$$

$$int(\cup \mu_Z - cl(B_\alpha)) = \mu_Z - int(\cup$$

$B_\alpha)$, this implies that $\cup B_\alpha \subseteq \mu_Z - int(\mu_Z - (\cup B_\alpha))$. Hence $\cup B_\alpha$ is $\mu_Z - pre$ open.

b. Let $\{C_\alpha | \alpha \in I\}$ to be part a family of μ_Z -per closed sets in X. Let $B_\alpha = C_\alpha^c$, then $\{B_\alpha | \alpha \in I\}$ is a family of $\mu_Z - pre$ open

sets. By (a), $\cup B_\alpha = (\cup C_\alpha)^c$ is $\mu_Z -$

pre open. As a result $(C_\alpha)^c$ is μ_Z -pre open. Hence $(\cap C_\alpha)$ is μ_Z -pre closed.

Theorem 10.[6].

a." every μ_Z – Open set is a μ_Z – Semi Open set.

b. every μ_Z – Closed set is a μ_Z – Semi Closed set

Proof. a. If B is μ_Z – open set then by then , $B \subseteq \mu_Z -int(\mu_Z - int(B))$. Since $\mu_Z int(\mu_Z - int(B)) \subseteq \mu_Z -cl(\mu_Z - int(B))$. $B \subseteq \mu_Z - cl(\mu_Z - int(B))$. Hence B is μ_Z – Semi open".

b. "If B is μ_Z –

closed set" therefore by Theorem 4[] , "we have $\mu_Z - cl(\mu_Z - cl(B)) \subseteq B$. Since $\mu_Z - int(\mu_Z - cl(B)) \subseteq \mu_Z - cl(\mu_Z - cl(B))$. $\mu_Z - int(\mu_Z - cl(B)) \subseteq B$. Hence B is μ_Z – semi closed.

Remark 11.[6]:-Every μ_Z – Open set is a $\mu_Z - \alpha$ Open set

Remark 12.[6]:-Every μ_Z – Open set is a $\mu_Z - \beta$ Open set.

Definition 13.[7]:- Continuity in general it is $F:(X, \tau) \rightarrow (Y, \tau')$ is Continuous iff $f^{-1}(V) \in \tau \forall V \in \tau'$.

Definition 14.[3] :- Let $(U, \tau_R(X), \mu_R(X))$ and $(V, \tau_R(Y), \mu_R(Y))$ be two Micro-topological spaces. A function $f : U \rightarrow V$ is called Micro-continuous function if $f^{-1}(H)$ is Micro-open in U for every Micro-open set H in V.

3. Continuous Functions in Micro_Z-Topological Spaces

Definition 3.1:-

Let $(H, \mu_{RZ}(X))$ and $(K, \mu_{RZ}(Y))$ be Micro_Z-Topological Spaces. With respect X and Y respectively. A function $f: H \rightarrow K$ is

Micro_Z

– Continuous on H if he inverse image of every μ_Z

– open set in

K is μ_Z – open set in H .

Example 3.2:- Let $H = \{r, s, t\}$, $R/H = \{\{r\}, \{s, t\}\}$ with

$$X = \{s, t\}, \tau_R(X) = \{H, \emptyset, \{s, t\}\}$$

$$\mu = \{r\} \text{ then } \mu_R(X) = \{H, \emptyset, \{r\}, \{s, t\}\}, \mu_{RZ}(X) =$$

$$\{H, \emptyset, \{r\}, \{s\}, \{t\}, \{s, t\}\} \text{ and Let } K = \{1, 2, 3\}, R/K = \{\{r\}, \{s, t\}\}$$

$$\text{with } Y = \{2, 3\}, \tau_R(Y) = \{K, \emptyset, \{2, 3\}\}, \mu = \{1\}$$

$$\text{Then } \mu_R(Y) = \{K, \emptyset, \{1\}, \{2, 3\}\}, \mu_{RZ}(Y) =$$

$$\{K, \emptyset, \{1\}, \{2\}, \{3\}, \{2, 3\}\}. \text{ Define the } f: H \rightarrow K \text{ as } f(r) =$$

$$1, f(s) = 2, f(t) = 3, f^{-1}\{2\} = \{s\}, f^{-1}\{3\} = \{t\},$$

$$f^{-1}\{2, 3\} = \{s, t\}. \text{ Then } f \text{ is } \mu_Z -$$

Continuous mapping on H .

Definition 3.3:-

Let $(H, \mu_R(X), \mu_{RZ}(X))$ and $((K, \mu_R(Y), \mu_{RZ}(Y)))$ be the two Micro_Z-topological spaces. A function $f: H \rightarrow K$ is called Micro_Z-continuous at a point $a \in H$ if for every Micro_Z-open set H containing $f(a)$ in K , there exist a Micro_Z-open set G containing a in H , such that $f(G) \subset H$.

Theorem 3.4:- $f: H \rightarrow K$ is Micro_Z-continuous if and only if f is Micro_Z-continuous at each point of H .

Proof:- Let $f: H \rightarrow K$ be Micro_Z-continuous. Let $a \in H$, and Y be a Micro_Z-open set in K containing $f(a)$. Since f is Micro_Z-continuous, $f^{-1}(Y)$ is Micro_Z-open in H containing a . Let $G = f^{-1}(Y)$, then $f(G) \subset Y$, and $f(a) \in G$. Hence f is continuous at a .

Conversely, suppose f is Micro_Z-continuous at each point of H . Let Y be Micro_Z-open set in K . If $f^{-1}(Y) = \emptyset$, then it is Micro_Z-open set. So let $f^{-1}(Y) \neq \emptyset$. Take any $a \in f^{-1}(Y)$, then $f(a) \in Y$. Since f is Micro_Z-continuous at each point there exist a Micro_Z-open set \hat{G} containing a , such that $f(\hat{G}) \subset Y$. Let $G = (\hat{G} | a \in f^{-1}(Y))$. Claim: $G = f^{-1}(Y)$. If $x \in f^{-1}(Y)$ then $x \in \hat{G} \subset G$.

Hence $f^{-1}(Y) \subset G$. On the other hand, On the other hand, suppose $y \in G$ then $y \in \hat{G}$ for some x and $y \in f^{-1}(Y)$. Hence $H = f^{-1}(Y)$. Since \hat{G} is μ_Z open by definition 2.5 G is μ_Z -open and hence $G = f^{-1}(Y)$ is μ_Z -open for every μ_Z -open set Y in K . Hence f is Micro_Z-continuous.

Theorem 3.5:- Let $(H, \mu_R(X), \mu_{RZ}(X))$ and $((K, \mu_R(Y), \mu_{RZ}(Y)))$ be two Micro_Z-topological spaces. Then $f: H \rightarrow K$ is Micro_Z-continuous function if and only if $f^{-1}(Y)$

is μ_Z -closed set in H , whenever Y is μ_Z -closed set in K .

Proof. Let $f: H \rightarrow K$ is Micro_Z-continuous function and Y be μ_Z -closed set in K . Then $(Y)^c$ is μ_Z -open set in K . By hypothesis $f^{-1}((Y)^c)$ is μ_Z -open set in H , i.e. $(f^{-1}(Y))^c$ is μ_Z -open set in H .

μ_Z -open in H . Hence $f^{-1}(Y)$ is μ_Z -closed in H whenever Y is μ_Z -closed in K . **Conversely**, suppose $f^{-1}(Y)$ is μ_Z -closed in H whenever Y is μ_Z -closed in K . Let G is μ_Z -open in K , then $(G)^c$ is μ_Z -closed in K . By assumption $f^{-1}((G)^c)$ is μ_Z -closed in H , i.e. $(f^{-1}(Y))^c$ is μ -closed in K . Then $f^{-1}(G)$ is μ_Z -open in H . Hence f is Micro_Z-continuous.

Theorem 3.6:-

Let $(H, \mu_R(X), \mu_{RZ}(X))$ and $((K, \mu_R(Y), \mu_{RZ}(Y)))$ be two Micro_Z-topological space. Then $f: H \rightarrow K$ is Micro_Z-continuous function if and only if $f(\text{Micro}_Z\text{-cl}A) \subset \text{Micro}_Z\text{-cl}(f(A))$.

Proof:-

Suppose $f: H \rightarrow K$ is Micro_Z-continuous and $\mu_Z\text{-cl}(f(A))$ is μ_Z -closed in K . Then by $f^{-1}(\mu_Z\text{-cl}(f(A)))$ is μ_Z -closed in H . Consequently, $\mu_Z\text{-cl}(f^{-1}(\mu_Z\text{-cl}(f(A)))) = f^{-1}(\mu_Z\text{-cl}(f(A)))$. Since $f(A) \subset \mu_Z\text{-cl}(f(A))$, $A \subset f^{-1}(\mu_Z\text{-cl}(f(A)))$ and $\mu_Z\text{-cl}(A) \subset \mu_Z\text{-cl}(f^{-1}(\mu_Z\text{-cl}(f(A)))) = f^{-1}(\mu_Z\text{-cl}(f(A)))$. Hence $f(\mu_Z\text{-cl}(A)) \subset \mu_Z\text{-cl}(f(A))$. **Conversely**, if $f(\mu_Z\text{-cl}(A)) \subset \mu_Z\text{-cl}(f(A))$ for all $A \subset H$. Let E be μ_Z -closed set in K , so that $\mu_Z\text{-cl}(E) = E$... (1) By hypothesis, $f(\mu_Z\text{-cl}(f^{-1}(E))) \subset \mu_Z\text{-cl}(f(f^{-1}(E))) \subset \mu_Z\text{-cl}(E)$, then by (1), $\mu_Z\text{-cl}(f^{-1}(E)) \subset E$. It follows that $\mu_Z\text{-cl}(f^{-1}(E)) \subset f^{-1}(E)$. But always $f^{-1}(E) \subset \mu_Z\text{-cl}(f^{-1}(E))$, so that $\mu_Z\text{-cl}(f^{-1}(E)) = f^{-1}(E)$. Hence $f^{-1}(E)$ is μ_Z closed in H and f is continuous by Theorem 2.5.

Theorem 3.7:-

Let $((H, \mu_R(X), \mu_{RZ}(X)), ((K, \mu_R(Y), \mu_{RZ}(Y)))$ and $((L, \mu_R(W), \mu_{RZ}(W)))$ be three Micro_Z-topological spaces. If $f: H \rightarrow K$ and $g: K \rightarrow L$ are Micro_Z-continuous mappings then $\text{gof}: H \rightarrow L$ is also Micro_Z-continuous.

Proof :-

Let G be a μ_Z -open set in L . Since by g is Micro_Z-continuous, $g^{-1}(G)$ is μ_Z -open set in K . Now, $(\text{gof})^{-1}G = (f^{-1} \circ g^{-1})G = f^{-1}(g^{-1}(G))$. Take $f^{-1}(G) = H$ which is μ_Z -open in K , then $f^{-1}(y)$ is μ_Z -open in H , since by f is Micro_Zcontinuous. Hence $\text{gof}: H \rightarrow L$ is Micro_Z-continuous function.

Definition 3.8:-

Let $(H, \mu_R(X), \mu_{RZ}(X))$ and $(K, \mu_R(Y), \mu_{RZ}(Y))$ be μ_{RZ} -topological Spaces with respect to X and Y respectively and $f: (H, \mu_R(X), \mu_{RZ}(X)) \rightarrow (K, \mu_R(Y), \mu_{RZ}(Y))$ be a function then f be called :

a) μ_Z –Semi-Continuous (μ_Z S Con.) if the inverse image of

- every μ_Z -open set in K is μ_Z SO set in H .
- b)** μ_Z -pre-Continuous (μ_Z P Con.) if the inverse image of every μ_Z -open set in K is μ_Z PO set in H .
- c)** μ_Z - α -Continuous (μ_Z α Con.) if the inverse image of every μ_Z -open set in K is μ_Z α O set in H .
- d)** μ_Z -Reg.-Continuous (μ_Z R Con.) if the inverse image of every μ_Z -open set in K is μ_Z RO set in H .
- e)** μ_Z - β Continuous (μ_Z β Con.) if the inverse image of every μ_Z -open set in K is μ_Z β O set in H .

Example 3.9:- Let $H = \{r, s, t\}$, $R/H = \{\{r\}, \{s, t\}\}$ with $X = \{s, t\}$, $\tau_R(X) = \{H, \emptyset, \{s, t\}\}$
 $\mu = \{r\}$ then $\mu_R(X) = \{H, \emptyset, \{r\}, \{s, t\}\}$, $\mu_{RZ}(X) = \{H, \emptyset, \{r\}, \{s\}, \{t\}, \{s, t\}\}$ and Let $K = \{1, 2, 3\}$
 $\mu_R/K = \{\{r\}, \{s, t\}\}$ with $Y = \{2, 3\}$, $\tau_R(Y) = \{K, \emptyset, \{2, 3\}\}$, $\mu = \{1\}$

Then $\mu_R(Y) = \{K, \emptyset, \{1\}, \{2, 3\}\}$, $\mu_{RZ}(Y) = \{K, \emptyset, \{1\}, \{2\}, \{3\}, \{2, 3\}\}$. Define the $f: H \rightarrow K$ as $f(r) = 1, f(s) = 2, f(t) = 3, f^{-1}\{2\} = \{s\}, f^{-1}\{3\} = \{t\}, f^{-1}\{2, 3\} = \{s, t\}$. Then

- μ_Z SO(H, X) = $\{H, \emptyset, \{r\}, \{s\}, \{t\}, \{r, s\}, \{r, t\}, \{s, t\}\}$
- μ_Z PO(H, X) = $\{H, \emptyset, \{r\}, \{s\}, \{t\}, \{r, s\}, \{r, t\}, \{s, t\}\}$
- μ_Z RO(H, X) = $\{H, \emptyset, \{r\}, \{s\}, \{t\}, \{s, t\}\}$
- μ_Z α O(H, X) = $\{H, \emptyset, \{r\}, \{s\}, \{t\}, \{s, t\}\}$
- μ_Z β O(H, X) = $\{H, \emptyset, \{r\}, \{s\}, \{t\}, \{r, s\}, \{r, t\}, \{s, t\}\}$.

Theorem 3.10:-

Every μ_Z -continuous function is μ_Z -pre continuous.

Proof:-

Let $f: H \rightarrow K$ be μ_Z -continuous. i.e., $f^{-1}(y)$ is μ_Z -open in H , whenever y is μ_Z -open in K . By Theorem 8, every μ_Z -open set is μ_Z -pre open, and hence $f^{-1}(Y)$ is μ_Z -pre open in H , whenever Y is μ_Z -open in K . Hence $f: H \rightarrow K$ be μ_Z -pre continuous. But the converse of this theorem is not true.

Example 3.11:-

From example 2.9 the set $\{r, t\}$ is μ_Z -pre open set. Then $f^{-1}(\{r, t\}) = \{1, 3\}$ is not μ_Z -open. Therefore is μ_Z -pre continuous but it is not μ_Z -continuous.

Theorem 3.12:-

Every μ_Z -continuous function is μ_Z -semi continuous.

Proof:-

Let $f: H \rightarrow K$ be μ_Z -continuous. i.e., $f^{-1}(Y)$ is μ_Z -open in H , whenever Y is μ_Z -open in K . By Theorem 10 (a), every μ_Z -open set is μ_Z -semi open. This implies that $f^{-1}(Y)$ is μ_Z -semi open in H whenever Y is open in K . Hence $f: H \rightarrow K$ be μ_Z -semi continuous. But the converse of this theorem is not true.

Example 3.13:-

From example 2.9 the set $\{r, s\}$ is μ_Z -semi open set. Then $f^{-1}(\{r, s\}) = \{1, 2\}$ is not μ_Z -open. Therefore is μ_Z -semi continuous but it is not μ_Z -continuous.

Theorem 3.14:-

Every μ_Z -continuous function is μ_Z - α continuous.

Proof:-

Let $f: H \rightarrow K$ be μ_Z -continuous. i.e., $f^{-1}(y)$ is μ_Z -open set in H , whenever Y is μ_Z -open set in K . By remark 11. This implies that $f^{-1}(Y)$ is μ_Z - α open set in H whenever Y is open set in K . Hence $f: H \rightarrow K$ be μ_Z - α continuous. But the converse of this theorem is not true.

Example 2.15:-

From example 2.11 the set $\{t\}$ is μ_Z - α open set. Then $f^{-1}(\{t\}) = \{3\}$ is not μ_Z -open. Therefore is μ_Z -semi continuous but it is not μ_Z -continuous.

Theorem 2.16:-

Every μ_Z -continuous function is μ_Z - β continuous.

Proof:-

Let $f: H \rightarrow K$ be μ_Z -continuous. i.e., $f^{-1}(y)$ is μ_Z -open in H , whenever y is μ_Z -open in K . By remark 8[3]. This implies that $f^{-1}(y)$ is μ_Z - β open in H whenever y is open in K . Hence $f: H \rightarrow K$ be μ_Z - β continuous. But the converse of this theorem is not true.

Example 2.17:-

From example 2.9 the set $\{r, s\}$ is μ_Z - β open but not μ_Z -open set. Then $f^{-1}(\{1, 2\}) = \{r, s\}$ is μ_Z - β continuous but it is not μ_Z -continuous.

Figure 1. represents the relationship between the sets studied in the paper.

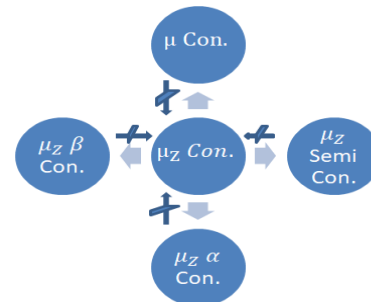


Figure 1. The relationship between the sets studied in the paper.

Conclusion

This study establishes a comprehensive framework for Micro_z-continuous functions by defining and analyzing various continuity classes (semi, pre, α , regular, and β). Through rigorous theorems and examples, the research clarifies their fundamental properties and interrelationships, contributing a robust theoretical foundation to the field of micro-topological spaces.

Conflict of interest

None.

Reference.

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