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Nano δG-Continuous Functions and Nano δG-Irresolute Functions in Nano Topological Spaces

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Abstract— In this paper we presented Nano δG-continuous functions and discussed some of their properties. Also we investigate the relationships between the other existing Nano continuous functions .Further, we define and study the concept of Nano δG-irresolute functions in Nano topological spaces and studied some of their characterizations.

Keywords— Nano δ closed sets, Nano δG closed sets, Nano δG-continuous functions and Nano δG-irresolute functions

I. INTRODUCTION

The concept of Nano topology was introduced by Lellis Thivagar [6]which was defined in terms of approximations and boundary region of a subset of an universe using an equivalence relation on it. Nano generalized closed sets introduced by K. Bhuvaneswari[1] et.al.,LellisThivagar introduced Nano continuous functions in Nano topological spaces. In this paper we presented Nano δG-continuous functions and discussed some of their properties. Also we investigate the relationships between the other existing Nano continuous functions .Further, we define and study the concept of Nano δG-irresolute functions in Nano topological spaces and studied some of their characterizations.

II. PRELIMINARIES

Definition 2.1 [6]:
Let U be a non-empty finite set of objects called the universe and R be an equivalence relation on U named as the indiscernibility relation. Then U is divided into disjoint equivalence classes. Elements belonging to the same equivalence class are said to be indiscernible with one another. The pair (U, R) is said to be the approximation space. Let $X \subseteq U$.

(i) 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 $L_R(X) = \bigcup_{x\in U}\{R(x): R(x) \subseteq X\}$. Where R(x) denotes the equivalence class determined by $x \in U$.
(ii) 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 $U_R(X) = \bigcup_{x\in U}\{R(x): R(x) \cap X \neq \phi\}$
(iii) 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 $B_R(X)$. That is $B_R(X) = U_R(X) - L_R(X)$.

Property 2.2 [6]
If (U, R) is an approximation space and $X, Y \subseteq U$, then
i) $L_R(X) \subseteq X \subseteq U_R(X)$
ii) $L_R(\phi) = U_R(\phi) = \phi$
iii) $L_R(U) = U_R(U) = U$
iv) $U_R(X \cup Y) = U_R(X) \cup U_R(Y)$
v) $U_R(X \cap Y) \subseteq U_R(X) \cup U_R(Y)$
vi) $L_R(X \cup Y) \supseteq L_R(X) \cup L_R(Y)$
vii) $L_R(X \cap Y) = L_R(X) \cap L_R(Y)$
viii) $L_R(X) \subseteq L_R(Y)$ and $U_R(X) \subseteq U_R(Y)$ whenever $X \subseteq Y$.
ix) $U_R(X^C) = [L_R(X)]^C$ and $L_R(X^C) = [U_R(X)]^C$
x) $U_R(U_R(X)) = L_R(U_R(X)) = U_R(X)$
xi) $L_R(L_R(X)) = U_R(L_R(X)) = L_R(X)$

Definition 2.3 [6]
Let U be a non-empty, finite universe of objects and R be an equivalence relation on U. Let $X \subseteq U$.

Let $\tau_R(X) = N\tau = \{U, \phi, L_R(X), U_R(X), B_R(X)\}$.
Then $\tau_R(X)$ is a topology on U , called as the Nano topology with respect to X.
Elements of the Nano topology are known as the Nano open sets in U and (U, Nτ) is called the Nano topological space. $[N\tau]^C$ is called as the dual Nano topology of Nτ. Elements of $[N\tau]^C$ are called as Nano closed sets. `

Definition 2.4
Let (U, Nτ) be a Nano topological space with respect to X where X ⊆ U and if A ⊆U,then A is said to be
(i) .Nano semi-open set[6] if A ⊆ Ncl(Nint(A)).
(ii). Nano-regular open set [6]if A=Ncl(Nint(A)).
(iii).Nano Pre-open set if [6]A⊆N int(Ncl(A))
(iv).Nano α-open set [6]if A⊆Nint(Ncl(Nint(A))
(v).The finite union of Nano regular open sets is said to be [8]Nano π-open

Definition 2.5
Let (U, Nτ) be a Nano topological space with respect to X where X ⊆ U and if A ⊆U, then A is said to be
(i).Nano g-closed [1]if Nano cl(A)⊆Q whenever A⊆Q and Q is Nano open.
(ii)Nano gp-closed[2] if Nano pcl(A)⊆Qwhenever A⊆Q and Q is Nano open.
(iii)Nano πgp-closed[9] if Nano pcl(A)⊆Q whenever A⊆Q and Q is Nano π -open
(iv)Nano πgs-closed [10]if Nano scl(A)⊆Q whenever A⊆Q and Q is Nano π -open
(v)Nano gα-closed set [11]if Nano αcl(A)⊆Q whenever A⊆Q and Q is Nano α open .

Definition 2.6
Let (U, Nτ) be a Nano topological space with respect to X where X ⊆ U and if A ⊆U, then A is said to be
(i).Nano δ-closed if A=$Ncl_\delta(A)$, where

$Ncl_\delta(A)=\{x\in U:Nint(Ncl(Q))\cap A \neq\phi, Q\in N\tau \text{ and } x\in Q\}$.
(ii).Nano δG-closed set if Nδcl(A)⊆Q whenever A⊆Q,Q is Nano open in (U, Nτ).
(iii).Nano Gδ-closed set if Ncl(A)⊆Q whenever A⊆Q , Q is Nδ-open in (U,Nτ).

III. ON NANO δ GENERALIZED CONTINUOUS

In this section we Introduce new forms of continuity namely, Nano δG-continuous in nano topological spaces and study some of their properties.

Definition 3.1
A function f : (U, Nτ)→ (V, Nσ) is said to be Nano δG-continuous if the inverse image of every Nano open set in (V, Nσ) is Nano δG-open in (U, Nτ).
Example 3.2
Let U= $\{a_1, a_2, a_3,a_4\}$ with U/R= $\{\{a_1\},\{a_3\},\{a_2,a_4\}\}$
Let X=$\{a_1, a_2\}$⊆ U.
Then Nτ =$\{U, \phi ,\{a_1\},\{a_2, a_4\},\{a_1, a_2,a_4\}\}$.
Let V= $\{b_1, b_2, b_3,b_4\}$ with V/R= $\{\{b_1, b_2\},\{b_3,b_4\}\}$
Let X=$\{b_1, b_2\}$⊆ V.
Then Nσ =$\{U, \phi ,\{b_1, b_2\}\}$.
Let f : (U, Nτ)→ (V, Nσ) be defined by $f(a_1)= b_1$, $f(a_2)= b_2$, $f(a_3)= b_3$, $f(a_4)= b_3$. Then f is δG-continuous

Definition 3.3
A function f : (U, Nτ)→ (V, Nσ) is said to be
(i). Nano δ-continuous if the inverse image of every Nano open set in (V, Nσ) is Nano δ-open in (U,Nτ).
(ii). Nano g-continuous if the inverse image of every Nano open set in (V, Nσ) is Nano g-open in (U,Nτ)
(iii). Nano Gδ-continuous if the inverse image of every Nano open set in (V, Nσ) is Nano Gδ -open in (U, Nτ).
(iv). Nano gp-continuous if the inverse image of every Nano open set in (V, Nσ) is Nano gp-open in (U,Nτ).
(v). Nano πgp-continuous if the inverse image of every Nano open set in (V, Nσ) is Nano πgp -open in (U, Nτ).
(vi). Nano πgs -continuous if the inverse image of every Nano open set in (V, Nσ) is Nano πgs-open in (U, Nτ).

Theorem.3.4
Every Nano δ-continuous function is Nano δG-continuous
Proof:
Assume f is a Nano δ-continuous function. Let H be any Nano open set in (V, Nσ).Then $f^{-1}(H)$ is δG-open in (U, Nτ). Since every Nano δ-open set is Nano δG-open, $f^{-1}(H)$ is Nano δG-open in (U, Nτ).Therefore f is Nano δG-continuous.
Example 3.5
Let U= $\{a_1, a_2, a_3,a_4, a_5\}$ with U/R= $\{\{a_1\},\{a_2\}, \{a_3,a_4, a_5\}\}$
Let X=$\{a_1, a_3\}$⊆ U.
Then Nτ =$\{U, \phi,\{a_1\},\{a_3,a_4, a_5\}\{a_1, a_3,a_4, a_5\}\}$.
Let V= $\{b_1, b_2, b_3, b_4, b_5\}$ with V/R=$\{\{b_1\}, \{b_2 ,b_3\},\{b_4, b_5\}\}$
Let X=$\{b_4, b_5\}$⊆V.
Then Nσ=$\{U, \phi,\{b_4, b_5\}\}$.
Let f : (U, Nτ)→ (V, Nσ) be defined by $f(a_1)=b_1$, $f(a_2)=b_2$, $f(a_3)=b_3$, $f(a_4)=b_4$, $f(a_5)=b_5$ Then f is δG-continuous .
$f^{-1}\{\{b_1,b_2 ,b_3\}\}=\{a_1,a_2, a_3\}$ is Nano Gδ-continuous but not Nano δ continuous

Theorem 3.6
Every Nano δG-continuous function is Nano Gδ-continuous
Proof:
Assume f is a Nano δG-continuous function. Let H be any Nano open set in(V, Nσ). Then $f^{-1}(H)$ is Nano δG-open in (U, Nτ). Since every Nano δG-open set is Nano Gδ-open, $f^{-1}(H)$ is Nano Gδ-open in (U, Nτ). Therefore f is Nano Gδ-continuous.

The converse of the above theorem need not be true as seen from the following example.

Example 3.7

Let $U=\{a_1, a_2, a_3\}$ with $U/R=\{\{a_1\},\{a_2,a_3\}\}$

Let $X=\{a_1\}\subseteq U$.

Then $N\tau=\{U, \phi, \{a_1\}\}$.

Let $V=\{b_1, b_2, b_3\}$ with $V/R=\{\{b_1\},\{b_2,b_3\}\}$

Let $X=\{b_2, b_3\}\subseteq V$.

Then $N\sigma=\{U, \phi, \{b_2, b_3\}\}$.

Let $f:(U, N\tau)\rightarrow(V, N\sigma)$ be defined by $f(a_1)=b_1$, $f(a_2)=b_2$, $f(a_3)=b_3$.

Then f is Nano Gδ-continuous but not Nano δG-continuous, since $f^{-1}(\{b_1\})=\{a_1\}$ is not Nano δG -closed set in $(U, N\tau)$.

Theorem 3.8

Every Nano δG-continuous function is Nano πgp-continuous

Proof:

Assume f is a Nano δG-continuous function. Let H be any Nano open set in $(V, N\sigma)$. Then $f^{-1}(H)$ is Nano δG-open in $(U, N\tau)$.Since every Nano δG-open set is Nano πgp-open, $f^{-1}(H)$ is Nano πgp-open in $(U, N\tau)$. Therefore f is Nano πgp -continuous.

The converse of the above theorem need not be true as seen from the following example.

Example 3.9

Let $U=\{a_1, a_2, a_3\}$ with $U/R=\{\{a_1,a_2\},\{a_3\}\}$

Let $X=\{a_3\}\subseteq U$.

Then $N\tau=\{U, \phi, \{a_3\}\}$.

Let $V=\{b_1, b_2, b_3\}$ with $V/R=\{\{b_1,b_2\},\{b_3\}\}$

Let $X=\{b_1, b_2\}\subseteq V$.

Then $N\sigma=\{U, \phi, \{b_1, b_2\}\}$.

Let $f:(U, N\tau)\rightarrow(V, N\sigma)$ be defined by $f(a_1)=b_1$, $f(a_2)=b_2$, $f(a_3)=b_3$.

.Then f is Nano πgp-continuous but not Nano δG-continuous, since $f^{-1}(\{b_3\})=\{a_3\}$ is not a Nano δG-closed set in $(U, N\tau)$.

Theorem 3.10

Every Nano δG-continuous function is Nano πgs -continuous

Proof:

Assume f is a Nano δG-continuous function. Let H be any Nano open set in $(V, N\sigma)$.Then $f^{-1}(H)$ is Nano δG-open in $(U, N\tau)$. Since every Nano δG-open set is Nano πgs -open,
$f^{-1}(H)$ is Nano πgs -open in $(U, N\tau)$. Therefore f is Nano πgs -continuous.

The converse of the above theorem need not be true as seen from the following example.

Example 3.11

Let $U=\{a_1, a_2, a_3\}$ with $U/R=\{\{a_1,a_3\},\{a_2\}\}$

Let $X=\{a_1,a_3\}\subseteq U$.

Then $N\tau=\{U, \phi, \{a_1,a_3\}\}$.

Let $V=\{b_1, b_2, b_3\}$ with $V/R=\{\{b_1,b_2\},\{b_3\}\}$

Let $X=\{b_1, b_2\}\subseteq V$.Then $N\sigma=\{U, \phi, \{b_1, b_2\}\}$.

Let $f:(U, N\tau)\rightarrow(V, N\sigma)$ be defined by $f(a_1)=b_1$, $f(a_2)=b_2$, $f(a_3)=b_3$.

Then f is Nano πgs-continuous but not Nano δG-continuous, since $f^{-1}(\{b_3\})=\{a_3\}$ is not a Nano δG -closed set in $(U, N\tau)$.

Theorem 3.12

Every Nano δG-continuous function is Nano gp-continuous

Proof:

Assume f is Nano δG-continuous function. Let H be any Nano open set in $(V, N\sigma)$.Then $f^{-1}(H)$ is Nano δG-open in $(U, N\tau)$. Since every Nano δG-open set is Nano gp-open,$f^{-1}(H)$ is Nano gp -open in $(U, N\tau)$. Therefore f is Nano gp-continuous.

The converse of the above theorem need not be true as seen from the following example.

Example 3.13

Let $U=\{a_1, a_2, a_3,a_4\}$ with $U/R=\{\{a_1, a_2\},\{a_3,a_4\}\}$

Let $X=\{a_1, a_2\}\subseteq U$.

Then $N\tau=\{U, \phi, \{a_1, a_2\}\}$.

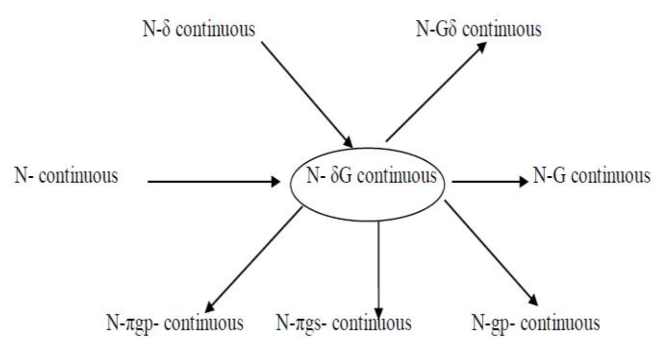
Let $V=\{b_1, b_2, b_3,b_4\}$ with $V/R=\{\{b_1, b_3,b_4\},\{b_2\}\}$

Let $X=\{b_1, b_3,b_4\}\subseteq V$. Then $N\sigma=\{U, \phi, \{b_1, b_3,b_4\}\}$.

Let $f:(U, N\tau)\rightarrow(V, N\sigma)$ be defined by $f(a_1)=b_1$, $f(a_2)=b_2$, $f(a_3)=b_3$, $f(a_4)=b_4$, Then f is Nano gp-continuous but not Nano δG-continuous, since $f^{-1}(\{b_2\})=\{a_2\}$ is not a Nano δG-closed set in $(U, N\tau)$.

Diagram-I

Here the following diagram shows the relationships of Nano δG continuous sets with other sets.



Theorem 3.14

A function $f:(U, N\tau)\rightarrow(V, N\sigma)$ is Nano δG-continuous if and only if the inverse image of every nano closed set in V is Nano δG-closed in U.

Proof:

Assume that f is Nano δG-continuous. Let K be a nano closed set in V. Then F^C is nano open in V. Since f is Nano δG-continuous, $f^{-1}(F^C)=U\backslash f^{-1}(K)$ is Nano δG-open in $(U,N\tau)$ .Hence f (K) is Nano δG-closed in $(U, N\tau)$.

Conversely assume that the inverse image of every Nano closed set in V is Nano δG-closed in U. Let H be an Nano open set in V, then V^C is Nano closed in V. By assumption $f^{-1}(V^C)$ is Nano δG-closed in U. But $f^{-1}(V^C)=U\backslash f^{-1}(H)$ and so $f^{-1}(H)$ is Nano δG-open in U . Thus f is Nano δG-continuous.

IV.NANO δ GENERALIZED IRRESOLUTE FUNCTIONS

In this section, we Introduce new forms of irresolute functions namely, Nano δG- irresolute functions in nano topological spaces and study some of their properties.

Definition 4.1
A function f : (U, Nτ)→(V, Nσ) is called Nano δG-irresolute if f^{-1} (H) is Nano δG-closed in (U, Nτ) for every Nano δG closed set H of (V, Nσ).

Example: 4.2
Let U= {a_1, a_2, a_3,a_4} with U/R= {{a_1, a_2},{ a_3,a_4} }
Let X={a_1, a_2}⊆ U.
Then Nτ={U, ϕ ,{ a_1, a_2}}.
Nano δG-closed set ={ U, ϕ,{a_3},{a_4}, {a_1, a_3},{a_1, a_4}, {a_2, a_3},{a_2, a_4},{a_3, a_4},{a_1, a_2,a_3}, {a_1, a_3,a_4}, {a_1, a_2,a_4},{a_2, a_3,a_4}}
Let V={b_1, b_2, b_3,b_4} with V/R={{b_1}, {b_2,b_4},{b_3}}
Let X={ b_1, b_3,b_4}⊆ V.
Then Nσ ={U, ϕ,{b_1},{b_2,b_4},{ b_1,b_2,b_4}}.
Nano δG-closed set ={U, ϕ,{b_3},{b_1,b_3},{ b_3,b_4}, { b_1,b_2,b_3}, { b_1,b_3,b_4},{b_2,b_3,b_4}}.
Let f : (U, Nτ)→ (V, Nσ) be defined by f(a_1)=b_1, f(a_2)=b_2, f(a_3)=b_3, f(a_4)=b_4,
Then f is Nano δG-irresolute.

Theorem 4.3
Let A be a subset of (U, Nτ) and x∈U. Then x∈N-δGCl(A) if and only if H∩A ≠ϕ for every Nano δG-open set H containing x.

Proof:
Let A be a subset of (U, Nτ)and x∈N-δGCl(A). Suppose that there exists a Nano δG-open set H containing x such that H∩A=ϕ. Then A⊆U\H,N-δGCl(A)⊆U\H and then x ∉N-δGCl(A), a contradiction.
Conversely, suppose that x ∉ N-δGCl(A). Then there exists a Nano δG-closed set K contains A such that x ∉ K. Since x ∈ U\K andU\K is N-δG-open,(U\K)∩A=ϕ, a Contradiction.

Theorem 4.4
(a). The following statements are equivalent
(i).f is Nano δG-continuous
(ii).The inverse image of every Nano open set in V is Nano δG-open in U.
(b). If f:(U, Nτ)→(V, Nσ) is Nano Gδ-continuous, then f(NδGCl(A)) ⊆Ncl(f(A)) for every subset A of U
(c). The following statements are equivalent
(i).For each x∈U and each Nano open set H containing f(x) there exist a Nano δG-open set G containing x such that f(G)⊆H
(ii).For every subset A of U,f(NδGCl(A))⊆Ncl(f(A))

Proof:
(i)⇔(ii) is obvious.
(b).Let A⊆U.Since f is NanoGδ-continuous and A⊆f^{-1}(N-cl(f(A))),N-δGcl(A) ⊆ f(N-cl(f(A))) and hence f(N-δGcl(A))⊆Ncl(f(A)
(i)⇔(ii) Let y ∈ f(N-δGCl(A)) and let H be any Nano open neighbourhood of y .Then there exist a x∈U and a Nano δG-open set G such that f(x)=y, x∈G, x∈N-δGCl (A) and f(G)⊆H By theorem 3.14, G∩A≠ϕ and hence f(A)∩H ≠ ϕ. Hence y = f(x)∈N-cl(f(A)).
(ii) ⇔(i) Let x ∈U and H be any Nano open set containing f(x). Let A = f^{-1}(V\H).Since f(NδGCl(A))⊆Ncl(f(A))⊆V\H, NδGCl(A)=A. Since x∉ NδGCl(A), there exists a N-δG-open set G containing x such that G ∩ A=ϕ and hence f(G)⊆f(U\A)⊆H .

Theorem 4.5
Let f : (U, Nτ) → (V, Nσ) and g : (V, Nσ) → (Z, Nρ) be any two functions. Then
(i).g o f is Nano δG-continuous, if g is Nano continuous and f is Nano δG-continuous.
(ii).g o f is Nano δG-irresolute, if g is Nano δG-irresolute and f is Nano δG-irresolute.
(iii).g o f is Nano δG-continuous, if g is Nano δG-continuous and f is Nano δG-irresolute.

Proof
(i). Let H be Nano closed in (Z, Nρ). Then g^{-1}(H) is Nano closed in (V, Nσ), since g is Nano continuous. Nano δG-continuity of f implies that f^{-1}(g^{-1}(H)) is Nano δG-closed in (U,Nτ) . Hence gof is Nano δG-continuous.
(ii).Let H be Nano δG-closed in (Z, Nρ). Since g is Nano δG-irresolute. Then g^{-1}(H) is Nano δG-closed in (V, Nσ). Since f is N-δG-irresolute,f^{-1}(g^{-1}(H)) is Nano δG-closed in (U, Nτ). Hence g o f is Nano δG-irresolute.
(iii).Let H be Nano closed in (Z, Nρ). Since g is N-δG-continuous, g^{-1}(H) is N-δG-closed in (V, Nσ). As f is N-δG-irresolute f^{-1}(g^{-1}(H)) is N-δG-closed in (U, Nτ). Hence gof is N-δG-continuous.

V. CONCLUSIONS

Many different forms of continuous functions have been introduced over the years. Various interesting problems arise when one considers openness. Its importance is significant in various areas of mathematics and related sciences, In this paper we presented Nano δG-continuous functions and discussed some of their properties. Also we investigate the relationships between the other existing Nano continuous functions. This shall be extended in the future Research with some applications

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R. Vijayalakshmi worked as Assistant professor in Department of Mathematics in Annamalai University from 2006 to 2017. She is currently working as Assistant Professor in PG & Research Department of Mathematics in Arignar Anna Government Arts College, Namakkal (DT), from 2017.She has published more than 15 research papers in reputed international journals. Her main research work focuses on Generalized topology, Nano topology, Fuzzy topology and Netrosophic topology. She has 13 years of teaching experience and 10 years of research experience.

