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On Nano $\lambda\psi g$-Irresolute Functions in Nano Topological Spaces

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Abstract: In this paper we introduce Nano $\lambda\psi g$-irresolute functions and discussed some of their properties. Also we investigate the relationships between the other existing Nano irresolute functions.

Key Words: $N\lambda\psi g$-closed sets, $N\lambda\psi g$-irresolute function.

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§1. Introduction

In 1991, Balachandran [1] et.al, introduced and studied the notations of generalized continuous functions. Different types of generalizations of continuous functions were studied by various authors in the recent development of topology. Continous function is one of the main functions in topology. Lellis Thivagar [4] introduced Nano topological space with respect to a subset X of a universe which is defined in terms of lower and upper approximations of X. The elements of Nano topological space are called Nano open sets. He has also defined Nano closed sets, Nano-interior and Nano closure of a set. He also introduced the weak forms of Nano open sets, namely Nano-open sets, Nano semi open sets and Nano preopen sets. He also defined Nano continuous functions, Nano open mapping, Nano closed mapping and Nano Homeomorphism. M.K.R.S.Veerakumar [10] was introduced the notion of ψ closed sets in topological spaces. Maki [6] introduced the notion of Λ-sets in topological spaces in 1986. Λ-set is a set A which is equal to its kernel, i.e., to the intersection of all open supersets of A. N.R.Santhi Maheswari and P.Subbulakshmi [7], [8], [10] introduced Nano $\Lambda_\psi(A)$ sets, nano Λ_ψ^*(A) sets, nano Λ_ψ-set and nano Λ_ψ^*-set in nano topological spaces and we also introduce Nano (Λ,ψ)-closed sets , Nano (Λ,ψ)-Open sets and Nano $\lambda\psi$ generalized Closed sets and Nano $\lambda\psi g$-continuous functions in nano topological spaces. In this paper we introduce Nano $\lambda\psi g$-irresolute functions and discussed some of their properties. Also we investigate the relationships between the other existing Nano irresolute functions.

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§2. Preliminaries

Definition 2.1([7]) *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 in discernible with one another. The 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 it is denoted by $L_R(X)$. That is $L_R(X) = U_{x \in U}\{R(X) : R(X) \subseteq X\}$, where $R(X)$ denotes the equivalence class determined by $X \in U$;*

(2) *The upper 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 $U_R(X)$.That is $U_R(X) = U_{x \in U}\{R(X) : R(X) \cap X = \phi\}$;*

(3) *The boundary of the 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 $B_R(X) = U_R(X) - L_R(X)$.*

Lemma 2.2([4]) *If (U, R) is an approximation space and $X, Y \subseteq U$, then*

(1) $L_R(X) \subseteq X \subseteq U_R(X)$;
(2) $L_R(\phi) = U_R(\phi) = \phi$;
(3) $L_R(U) = U_R(U) = U$;
(4) $U_R(X \cup Y) = U_R(X) \cup U_R(Y)$;
(5) $U_R(X \cap Y) \subseteq U_R(X) \cap U_R(Y)$;
(6) $L_R(X \cup Y) \supseteq L_R(X) \cup L_R(Y)$;
(7) $L_R(X \cap Y) = L_R(X) \cap L_R(Y)$;
(8) $L_R(X) \subseteq L_R(Y) and\, U_R(X) \subseteq U_R(Y)$ *whenever* $X \subseteq Y$;
(9) $U_R(X^c) = [L_R(X)]^c$ *and* $L_R(X^c) = [U_R(X)]^c$;
(10) $U_R(U_R(X)) = L_R(U_R(X)) = U_R(X)$;
(11) $L_R(L_R(X)) = U_R(L_R(X)) = L_R(X)$

Definition 2.3([4]) *Let U be the Universe and R be an equivalence relation on U and $\tau_R(X) = \{U, \phi, L_R(X), U_R(X), B_R(X)\}$ where $X \subseteq U$. $\tau_R(X)$ satisfies the following axioms:*

(1) *U and $\phi \in \tau_R(X)$;*
(2) *The union of elements of any subcollection of $\tau_R(X)$ is in $\tau_R(X)$;*
(3) *The intersection of the elements of any finite subcollection of $\tau_R(X)$ is in $\tau_R(X)$.*

We call $(U, \tau_R(X))$ is a Nano topological space. The elements of $\tau_R(X)$ are called a open sets and the complement of a Nano open set is called Nano closed sets.

Throughout this paper $(U, \tau_R(X))$ is a nano topological space with respect to X where $X \subseteq U$, R is an equivalence relation on U, U/R denotes the family of equivalence classes of U by R.

Definition 2.4([4]) *If $(U, \tau_R(X))$ is a nano topological space with respect to X. Where $X \subseteq G$ and if $A \subseteq G$, then*

(1) *The Nano interior of the set A is defined as the union of all Nano open subsets contained in A and is denoted by $Nint(A)$, $Nint(A)$ is the largest Nano open subset of A;*

(2) *The Nano closure of the set A is defined as the intersection of all Nano closed sets containing A and is denoted by $Ncl(A)$. $Ncl(A)$ is the smallest Nano closed set containing A.*

Definition 2.5([4]) *Let $(U, \tau_R(X))$ be a Nano topological space and $A \subseteq G$. Then, A is said to be*

(i) *Nano semi-open (briefly Ns-open) if $A \subseteq Ncl(Nint(A)$;*

(ii) *Nano α-open (briefly $N\alpha$-open) if $A \subseteq Nint(Ncl(Nint(A))$;*

(iii) *Nano regular-open (briefly Nr-open) if $A = Nint(Ncl(A)$.*

The complements of the above mentioned open sets are called their respective closed sets.

Definition 2.6([8]) *Let A be a subset of a Nano topological space $(U, \tau_R(X))$. A subset $N\Lambda_\psi(A)$ is defined as $N\Lambda_\psi(A) = \cap\{H/A \subseteq H$ and $H \in N\psi O(U, \tau_R(X)\}$.*

Definition 2.7([8]) *A subset A of a Nano topological space $(U, \tau_R(X))$ is called a $N\Lambda_\psi$-set if $A = N\Lambda_\psi(A)$. The set of all $N\Lambda_\psi$ -sets is denoted by $N\Lambda_\psi(U, \tau_R(X))$.*

Definition 2.8([9]) *Let A be a subset of a Nano topological space $(U, \tau_R(X))$. A subset $N(\Lambda, \psi)$ closed if $A = B \cap C$, where B is $N\Lambda_\psi$ set and C is a $N\psi$ closed set.*

Definition 2.9 *Let $(U, \tau_R(X))$ be a Nano topological space and $A \subseteq G$. Then A is said to be*

(1) *Nano sg-closed (briefly Nsg-closed) [2] if $Nscl(A) \subseteq G$ whenever $A \subseteq G$ and G is Nano-semi open in U;*

(2) *Nano ψ-closed (briefly $N\psi$-closed) [10] if $Nscl(A) \subseteq G$ whenever $A \subseteq G$ and G is Nano-sg open in U;*

(3) *Nano $\lambda\psi$ generalized closed (briefly $N\lambda\psi g$-closed) [8] if $N\psi cl(A) \subseteq G$, whenever $A \subseteq G$ and G is $N(\Lambda, \psi)$- open in U.*

Remark 2.10([9]) We have known the conclusions following:

(1) Every Nano closed set is $N\lambda\psi g$-closed;

(2) Every Ns-closed set is $N\lambda\psi g$-closed;

(3) Every Nr-closed set is $N\lambda\psi g$-closed;

(4) Every $N\alpha$-closed set is $N\lambda\psi g$-closed;

(5) Every $N\psi$-closed set is $N\lambda\psi g$-closed.

Definition 2.11 *The function $f : (U, \tau_R(X)) \to (V, \tau'_R(Y))$ is said to be*

(1) *Nr-continuous [3] if the inverse image of every Nano closed set in $(V, \tau'_R(Y))$ is Nr-closed in $(U, \tau_R(X))$;*

(2) *Nano-continuous [5] if the inverse image of every Nano closed set in $(V, \tau'_R(Y))$ is Nano closed in $(U, \tau_R(X))$;*

(3) *Ns-continuous [2] if the inverse image of every nano closed set in $(V, \tau'_R(Y))$ is Ns-closed in $(U, \tau_R(X))$;*

(4) *$N\alpha$-continuous [3] if the inverse image of every Nano closed set in $(V, \tau'_R(Y))$ is $N\alpha$-closed in $(U, \tau_R(X))$;*

(5) *$N\psi$-continuous [9] if the inverse image of every Nano closed set in $(V, \tau'_R(Y))$ is $N\psi$-closed in $(U, \tau_R(X))$;*

(6) *$N\lambda\psi g$-continuous [8] if the inverse image of every Nano closed set in $(V, \tau'_R(Y))$ is $N\lambda\psi g$-closed in $(U, \tau_R(X))$.*

Definition 2.12 *The function $f : (U, \tau_R(X)) \to (V, \tau'_R(Y))$ is said to be*

(1) *Nr-irresolute [3] if the inverse image of every Nr-closed set in $(V, \tau'_R(Y))$ is Nr-closed in $(U, \tau_R(X))$;*

(2) *Ns-irresolute [2] if the inverse image of every Ns-closed set in $(V, \tau'_R(Y))$ is Ns-closed in $(U, \tau_R(X))$;*

(3) *$N\alpha$-irresolute [3] if the inverse image of every $N\alpha$-closed set in $(V, \tau'_R(Y))$ is $N\alpha$-closed in $(U, \tau_R(X))$;*

(4) *$N\psi$-irresolute [2] if the inverse image of every $N\psi$-closed set in $(V, \tau'_R(Y))$ is $N\psi$-closed in $(U, \tau_R(X))$.*

§3. $N\lambda\psi g$ -Irresolute Functions

In this section, we introduce and study a new concept of $N\lambda\psi g$-irresolute functions in Nano topological spaces.

Definition 3.1 *A function $f : (U, \tau_R(X)) \to (V, \tau'_R(Y))$ is said to be $N\lambda\psi g$-irresolute if $f^{-1}(G)$ is a $N\lambda\psi g$-open set in $(U, \tau_R(X))$ for every $N\lambda\psi g$-open set G in $(V, \tau'_R(Y))$.*

Example 3.2 Let $U = \{a, b, c, d\}$ with $U/R = \{\{a\}, \{b, c, d\}\}$ and $X = \{b, c\}$.Then $\tau_R(X) = \{U, \phi, \{b, c, d\}\}$. Let $V = \{a, b, c, d\}$ with $V/R' = \{\{b\}, \{d\}, \{a, c\}\}$ and $Y = \{a, b\}$. Then $\tau'_R(Y) = \{V, \phi, \{b\}, \{a, c\}, \{a, b, c\}\}$. Define a mapping $f : (U, \tau_R(X)) \to (V, \tau'_R(Y))$ as, $f(a) = a$, $f(b) = b$, $f(c) = d$, $f(d) = c$. Here the inverse image of every $N\lambda\psi g$- closed set in $(V, \tau'_R(Y))$ is $N\lambda\psi g$-closed set in $(U, \tau_R(X))$. Hence $f : (U, \tau_R(X)) \to (V, \tau'_R(Y))$ is $N\lambda\psi g$-irresolute.

Theorem 3.3 *Let $(U, \tau_R(X))$, $(V, \tau'_R(Y))$ and $(W, \tau'_R(Z))$ be Nano topological spaces. If $f : (U, \tau_R(X)) \to (V, \tau'_R(Y))$ and $g : (V, \tau'_R(Y)) \to (W, \tau'_R(Z))$ are two functions. If f is $N\lambda\psi g$-irresolute and g is $N\lambda\psi g$-continuous then $g \circ f$ is $N\lambda\psi g$-continuous.*

Proof Let G be a Nano closed set in $(W, \tau'_R(Z))$. Since g is $N\lambda\psi g$-continuous, $g^{-1}(G)$ is a $N\lambda\psi g$-closed set in $(V, \tau'_R(Y))$. Since f is $N\lambda\psi g$-irresolute, $f^{-1}(g^{-1}(G))$ is a $N\lambda\psi g$-closed set in $(U, \tau_R(X))$. Thus $(g \circ f)^{-1}(G)$ is $N\lambda\psi g$-closed in U, for every $N\lambda\psi g$ closed set G in $(W, \tau'_R(Z))$. Hence the composition $g \circ f : (U, \tau_R(X)) \to (W, \tau'_R(Z))$ is $N\lambda\psi g$-continuous. □

Theorem 3.4 *Let $f : (U, \tau_R(X)) \to (V, \tau'_R(Y))$ and $g : (V, \tau'_R(Y)) \to (W, \tau''_R(Z))$ be two maps. If f and g are both $N\lambda\psi g$-irresolute then $g \circ f$ is $N\lambda\psi g$-continuous.*

Proof Let G be Nano closed in $(W, \tau''_R(Z))$. Since every Nano closed sets is $N\lambda\psi g$-closed. Since g is $N\lambda\psi g$-irresolute, $g^{-1}(G)$ is $N\lambda\psi g$-open in $N\lambda\psi g$-closed $(W, \tau''_R(Z))$. Since f is

$N\lambda\psi g$-irresolute, $f^{-1}(g^{-1}(G))$ is $N\lambda\psi g$-closed in U. Thus $(g\circ f)^{-1}(G) = f^{-1}(g^{-1}(G))$ is a $N\lambda\psi g$-closed set in $(U, \tau_R(X))$, for every Nano closed set G in $(W, \tau''_R Z))$. Hence $g\circ f$ is $N\lambda\psi g$ - continuous. □

Theorem 3.5 *Let $(U, \tau_R(X))$, $(V, \tau'_R(Y))$ and $(W, \tau"_R(Z))$ be Nano topological spaces. If $f : (U, \tau_R(X)) \to (V, \tau'_R(Y))$ and $g : (V, \tau'_R(Y)) \to (W, \tau''_R(Z))$ be two functions. If f and g are both $N\lambda\psi g$-irresolute then $g\circ f$ is $N\lambda\psi g$ - irresolute.*

Proof Let G be $N\lambda\psi g$-closed in $(W, \tau''_R Z))$. Since g is $N\lambda\psi g$-irresolute, $g^{-1}(G)$ is $N\lambda\psi g$-closed in $(W, \tau''_R(Z))$. Since f is $N\lambda\psi g$-irresolute, $f^{-1}(g^{-1}(G))$ is $N\lambda\psi g$-closed in $(U, \tau_R(X))$. Thus $(g\circ f)^{-1}(G) = f^{-1}(g^{-1}(G))$ is $N\lambda\psi g$-closed set in $(U, \tau_R(X))$, for every $N\lambda\psi g$-closed set in $(W, \tau''_R(Z))$. Hence $g\circ f$ is $N\lambda\psi g$-irresolute. □

Theorem 3.6 *A function $f : (U, \tau_R(X)) \to (V, \tau'_R(Y))$ is $N\lambda\psi g$-irresolute if and only if the inverse image $f^{-1}(G)$ is $N\lambda\psi g$-closed set in $(U, \tau_R(X))$, for every $N\lambda\psi g$-closed set in $(V, \tau'_R(Y))$.*

Proof Let G be $N\lambda\psi g$-closed in $(V, \tau'_R(Y))$. Then $V-G$ is $N\lambda\psi g$-open in $(V, \tau'_R(Y))$. Since f is $N\lambda\psi g$-irresolute, $f^{-1}(V-G)$ is $N\lambda\psi g$-open in $(U, \tau_R(X))$. But $f^{-1}(V-G) = U - f^{-1}(G)$. Hence $f^{-1}(G)$ is $N\lambda\psi g$-closed in $(U, \tau_R(X))$.

Conversely, assume that inverse image $f^{-1}(G)$ is $N\lambda\psi g$-closed in $(U, \tau_R(X))$, for every $N\lambda\psi g$-closed set G in $(V, \tau'_R(Y))$. Let F be $N\lambda\psi g$-open in $(V, \tau'_R(Y))$. Then $V - F$ is $N\lambda\psi g$-closed in $(V, \tau'_R(Y))$. By assumption, $f^{-1}(V - F)$ is $N\lambda\psi g$-closed in $(U, \tau_R(X))$. But $f^{-1}(V - F) = U - f^{-1}(F)$. Then $f^{-1}(F)$ is $N\lambda\psi g$-open in $(U, \tau_R(X))$. Hence f is $N\lambda\psi g$ - irresolute.□

Theorem 3.7 *A function $f : (U, \tau_R(X)) \to (V, \tau'_R(Y))$ is $N\lambda\psi g$-irresolute if and only if $f(N\lambda\psi gcl(F)) \subseteq N\lambda\psi gcl(f(F))$ for every subset F of $(U, \tau_R(X))$.*

Proof Suppose f is $N\lambda\psi g$-irresolute. Let $F \subseteq U$. Then $f(F) \subseteq V$. Hence $N\lambda\psi gcl(f(F))$ is $N\lambda\psi g$-closed in V. Since f is $N\lambda\psi g$-irresolute, $f^{-1}(N\lambda\psi gcl(f(F)))$ is $N\lambda\psi g$-closed in $(U, \tau_R(X))$. Since $f(F) \subseteq N\lambda\psi gcl(f(F))$, which implies $F \subseteq f^{-1}(N\lambda\psi gcl(f(F)))$. Since $N\lambda\psi gcl(F)$ is the smallest $N\lambda\psi g$-closed set containing F, $N\lambda\psi gcl(F) \subseteq f^{-1}(N\lambda\psi gcl(f(F)))$. Hence $f(N\lambda\psi gcl(F)) \subseteq N\lambda\psi gcl(f(F))$.

Conversely, assume that $f(N\lambda\psi gcl(F)) \subseteq N\lambda\psi gcl(f(F))$, for every subset F of U. Let G be $N\lambda\psi g$-closed in V. Now, $f^{-1}(G) \subseteq U$. Hence $f(N\lambda\psi gcl(f^{-1}(G))) \subseteq N\lambda\psi gcl(f(f^{-1}(G))) = N\lambda\psi gcl(G)$, which implies $N\lambda\psi gcl(f^{-1}(G)) \subseteq f^{-1}(N\lambda\psi gcl(G)) = f^{-1}(G)$ that implies $f^{-1}(G)$ is $N\lambda\psi g$-closed in U, for every $N\lambda\psi g$-closed set G in V. Hence f is $N\lambda\psi g$-irresolute. □

Theorem 3.8 *A function $f : (U, \tau_R(X)) \to (V, \tau'_R(Y))$ is $N\lambda\psi g$-irresolute if and only if $f^{-1}(N\lambda\psi gint(G)) \subseteq N\lambda\psi gint(f^{-1}(G))$, for every subset G of $(V, \tau'_R(Y))$.*

Proof Let f be $N\lambda\psi g$-irresolute. Let $G \subseteq V$. Then $N\lambda\psi gint(G)$ is $N\lambda\psi g$-open in V. Since f is $N\lambda\psi g$-irresolute, $f^{-1}(N\lambda\psi gint(G))$ is $N\lambda\psi g$-open in $(U, \tau_R(X))$. Hence $N\lambda\psi gint(f^{-1}(N\lambda\psi gint(G))) = f^{-1}(N\lambda\psi gint(G))$. Since $G \subseteq V$, $N\lambda\psi gint(G) \subseteq G$ always. Hence $f^{-1}(N\lambda\psi gint(G)) = N\lambda\psi gint(f^{-1}(N\lambda\psi gint(G))) \subseteq N\lambda\psi gint(f^{-1}(G))$. Thus $f^{-1}(N\lambda\psi gint(G)) \subseteq N\lambda\psi gint(f^{-1}(G))$.

Conversely, let $f^{-1}(N\lambda\psi gint(G)) \subseteq N\lambda\psi gint(f^{-1}(G))$, for every subset G of V. Let F be $N\lambda\psi g$-open in V and hence $N\lambda\psi gint(F) = F$. By our assumption, $f^{-1}(F) \subseteq N\lambda\psi gint(f^{-1}(F))$. But $N\lambda\psi gint(f^{-1}(F)) \subseteq f^{-1}(F)$. Hence $f^{-1}(F) = N\lambda\psi gint(f^{-1}(F))$. Then $f^{-1}(F)$ is $N\lambda\psi g$-open in U, for every subset F of V. Hence f is $N\lambda\psi g$-irresolute. □

Theorem 3.9 *A function $f : (U, \tau_R(X)) \to (V, \tau'_R(Y))$ is $N\lambda\psi g$-irresolute if and only if $N\lambda\psi gcl(f^{-1}(G)) \subseteq f^{-1}(N\lambda\psi gcl(G))$, for every subset G of V.*

Proof Suppose f is $N\lambda\psi g$-irresolute. Let $G \subseteq V$, then $N\lambda\psi gcl(G)$ is $N\lambda\psi g$-closed in V. Since f is irresolute, $f^{-1}(N\lambda\psi gcl(G))$ is $N\lambda\psi g$-closed in U. Thus $N\lambda\psi gcl(f^{-1}(N\lambda\psi gcl(G))) = f^{-1}(N\lambda\psi gcl(G))$. Since $G \subseteq N\lambda\psi gcl(G)$, then $f^{-1}(G) \subseteq f^{-1}(N\lambda\psi gcl(G))$. Now, $N\lambda\psi gcl(f^{-1}(G)) \subseteq N\lambda\psi gcl(f^{-1}(N\lambda\psi gcl(G))) = f^{-1}(N\lambda\psi gcl(G))$ which implies $N\lambda\psi gcl(f^{-1}(G)) \subseteq f^{-1}(N\lambda\psi gcl(G))$, for every subset G of V.

Conversely, let $N\lambda\psi gcl(f^{-1}(G)) \subseteq f^{-1}(N\lambda\psi gcl(G))$, for every subset G of V. Let F be $N\lambda\psi g$-closed in V and hence $N\lambda\psi gcl(F) = F$. By our assumption, $N\lambda\psi gcl(f^{-1}(F)) \subseteq f^{-1}(F)$. But $f^{-1}(F) \subseteq N\lambda\psi gcl(f^{-1}(F))$. Hence $f^{-1}(F) = N\lambda\psi gcl(f^{-1}(F))$. Then $f^{-1}(F)$ is $N\lambda\psi g$-closed in U, for every subset F of V. Hence f is $N\lambda\psi g$-irresolute. □

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