

# Nano Generalized E-Continuous Mappings in Nano Topological Spaces



P. Manivannan, A. Vadivel, M. Seenivasan, V. Chandrasekar

**Abstract:** In this paper, we discuss  $ng\ e$ -continuous and irresoluteness via  $ng\ eO$ s in  $nts$ 's. Also some characterizations are discussed with necessary examples.

**Keywords and phrases:** nano  $e$ -Cts, nano generalized  $e$ -Cts, nano generalized  $e$ -Irr. AMS (2000) subject classification: 54B05.

## I INTRODUCTION AND PRELIMINARIES

Nano topology (briefly,  $\mathfrak{N}\tau$ ) was introduced by Lellis Thivagar [7] in the year 2013. Also he introduced nano closed ( $\mathfrak{N}c$ ) sets, nano-interior ( $\mathfrak{N}int$ ) and nano-closure ( $\mathfrak{N}cl$ ) in a nano topological spaces (briefly,  $\mathfrak{N}ts$ ). Various forms of sets were discussed in [1] -[13]. Nano regular open (briefly,  $\mathfrak{N}ro$ ) sets, nano  $\theta$ -interior (resp. nano  $\theta$ -closure, nano  $\delta$ -interior, nano  $\delta$ -closure) (briefly,  $\mathfrak{N}int_{\theta}(A)$  (resp.  $\mathfrak{N}cl_{\theta}(A)$ ,  $\mathfrak{N}int_{\delta}(A)$ ,  $\mathfrak{N}cl_{\delta}(A)$ )) and also nano  $\theta$ -open (resp. nano  $\theta$ -closed, nano  $\delta$ -open, nano  $\delta$ -closed) (briefly,  $\mathfrak{N}\theta o$  (resp.  $\mathfrak{N}\theta c$ ,  $\mathfrak{N}\delta o$ ,  $\mathfrak{N}\delta c$ )) sets were introduced in [4, 7, 11, 12]. Nano  $\delta$ -pre (resp. nano  $\delta$ -semi, nano  $e$ , nano  $\mathcal{M}$ , nano  $\theta$ -pre and nano  $\theta$ -semi) open set (briefly  $\mathfrak{N}\delta P o$  (resp.  $\mathfrak{N}\delta S o$ ,  $\mathfrak{N}e o$ ,  $\mathfrak{N}\mathcal{M} o$ ,  $\mathfrak{N}\theta P o$  and  $\mathfrak{N}\theta S o$ )), nano  $\delta$ -pre (resp.  $\delta$ -semi,  $e$ ,  $\mathcal{M}$  and  $\theta$ -semi) interior (briefly,  $\mathfrak{N}Pint_{\delta}(K)$  (resp.  $\mathfrak{N}Sint_{\delta}(K)$ ,  $\mathfrak{N}eint(K)$ ,  $\mathfrak{N}\mathcal{M}int(K)$  and  $\mathfrak{N}Sint_{\theta}(K)$ )), nano  $\delta$ -pre (resp.  $\delta$ -semi,  $e$ ,  $\mathcal{M}$  and  $\theta$ -semi) closure (briefly,  $\mathfrak{N}Pcl_{\delta}(K)$  (resp.  $\mathfrak{N}Scl_{\delta}(K)$ ,  $\mathfrak{N}ecl(K)$ ,  $\mathfrak{N}\mathcal{M}cl(K)$  and  $\mathfrak{N}Scl_{\theta}(K)$ )) were introduced in [10, 11, 12]. The collection of all  $\mathfrak{N}\delta P o$  (resp.  $\mathfrak{N}\delta S o$ ,  $\mathfrak{N}e o$ ,  $\mathfrak{N}\mathcal{M} o$  and  $\mathfrak{N}\theta S o$ ) sets is denoted

by  $\mathfrak{N}\delta P O(U, \tau_R(P))$  (resp.  $\mathfrak{N}\delta S O(U, \tau_R(P))$ ,  $\mathfrak{N}e O(U, \tau_R(P))$ ,  $\mathfrak{N}\mathcal{M} O(U, \tau_R(P))$  and  $\mathfrak{N}\theta S O(U, \tau_R(P))$ ) and the collection of all nano  $\delta$ -pre (resp.  $\delta$ -semi,  $e$ , nano  $\mathcal{M}$  and  $\theta$ -semi) closed (briefly,  $\mathfrak{N}\delta P c$  (resp.  $\mathfrak{N}\delta S c$ ,  $\mathfrak{N}e c$ ,  $\mathfrak{N}\mathcal{M} c$  and  $\mathfrak{N}\theta S c$ )) sets is denoted by  $\mathfrak{N}\delta P C(U, \tau_R(P))$  (resp.  $\mathfrak{N}\delta S C(U, \tau_R(P))$ ,  $\mathfrak{N}e C(U, \tau_R(P))$ ,  $\mathfrak{N}\mathcal{M} C(U, \tau_R(P))$  and  $\mathfrak{N}\theta S C(U, \tau_R(P))$ ). Nano generalized (resp.  $\theta$ ,  $\theta$  semi,  $\delta$ ,  $\delta$  semi,  $\delta$  pre,  $e$  and  $\mathcal{M}$ ) closed (briefly,  $\mathfrak{N}g c$ ,  $\mathfrak{N}g\theta c$ ,  $\mathfrak{N}g\theta S c$ ,  $\mathfrak{N}g\delta c$ ,  $\mathfrak{N}g\delta S c$ ,  $\mathfrak{N}g\delta P c$ ,  $\mathfrak{N}g e c$  and  $\mathfrak{N}g\mathcal{M} c$ ) were introduced in [1, 2, 4, 5, 9].

A subset  $K$  of a nano generalized (resp.  $\theta$ ,  $\theta$  semi,  $\delta$ ,  $\delta$  semi and  $\delta$  pre) open [1, 2, 4, 5] (briefly,  $\mathfrak{N}g o$  (resp.  $\mathfrak{N}g\theta o$ ,  $\mathfrak{N}g\theta S o$ ,  $\mathfrak{N}g\delta o$ ,  $\mathfrak{N}g\delta S o$  and  $\mathfrak{N}g\delta P o$ )) if its complement  $K^c$  is nano generalized (resp.  $\theta$ ,  $\theta$  semi,  $\delta$ ,  $\delta$  semi and  $\delta$  pre) closed (briefly,  $\mathfrak{N}g c$  (resp.  $\mathfrak{N}g\theta c$ ,  $\mathfrak{N}g\theta S c$ ,  $\mathfrak{N}g\delta c$ ,  $\mathfrak{N}g\delta S c$  and  $\mathfrak{N}g\delta P c$ )). The system of all nano generalized (resp.  $\theta$ ,  $\theta$  semi,  $\delta$ ,  $\delta$  semi,  $\delta$  pre,  $\mathfrak{N}g e$  and  $\mathfrak{N}g\mathcal{M}$ ) open sets of  $(U, \tau_R(P))$  is denoted by  $\mathfrak{N}g O(U, P)$  (resp.  $\mathfrak{N}g\theta O(U, P)$ ,  $\mathfrak{N}g\theta S O(U, P)$ ,  $\mathfrak{N}g\delta O(U, P)$ ,  $\mathfrak{N}g\delta S O(U, P)$ ,  $\mathfrak{N}g\delta P O(U, P)$ ,  $\mathfrak{N}g e C(U, P)$  and  $\mathfrak{N}g\mathcal{M} C(U, P)$ ). Nano continuous and irresolute (briefly,  $\mathfrak{N}Cts$  and  $\mathfrak{N}Irr$ ) were introduced by [3, 8].

## II NANO GENERALIZED $e$ CONTINUOUS MAPS

**Definition 2.1** A function  $f: (U, \tau_R(P)) \rightarrow (V, \sigma_{R'}(Q))$  is called nano generalized  $e$  (resp.  $\mathcal{M}$ ) continuous (briefly,  $\mathfrak{N}g e$  (resp.  $\mathfrak{N}g\mathcal{M}$ ) Cts), if for each  $\mathfrak{N}cs K$  of  $V$ ,  $f^{-1}(K)$  is  $\mathfrak{N}g ecs$  (resp.  $\mathfrak{N}g\mathcal{M}cs$ ) of  $U$ .

**Theorem 2.1** Let  $f: (U, \tau_R(P)) \rightarrow (V, \sigma_{R'}(Q))$  be a mapping. Then [(i)]

1. Every  $\mathfrak{N}eCts$  mapping is  $\mathfrak{N}g eCts$ .
2. Every  $\mathfrak{N}\mathcal{M}Cts$  mapping is  $\mathfrak{N}g\mathcal{M}Cts$ .
3. Every  $\mathfrak{N}g\theta Cts$  mapping is  $\mathfrak{N}g Cts$ .
4. Every  $\mathfrak{N}g Cts$  mapping is  $\mathfrak{N}g\theta S Cts$ .
5. Every  $\mathfrak{N}g\delta Cts$  mapping is  $\mathfrak{N}g\delta S Cts$ .
6. Every  $\mathfrak{N}g\delta Cts$  mapping is  $\mathfrak{N}g\delta P Cts$ .
7. Every  $\mathfrak{N}g\delta S Cts$  mapping is  $\mathfrak{N}g eCts$ .
8. Every  $\mathfrak{N}g\delta P Cts$  mapping is  $\mathfrak{N}g eCts$ .
9. Every  $\mathfrak{N}g\theta S Cts$  mapping is  $\mathfrak{N}g\mathcal{M}Cts$ .
10. Every  $\mathfrak{N}g\delta P Cts$  mapping is  $\mathfrak{N}g\mathcal{M}Cts$ .

But not conversely.

**Proof.** (i) Let  $f: (U, \tau_R(P)) \rightarrow (V, \sigma_{R'}(Q))$  be  $\mathfrak{N}eCts$  and  $L$  is a  $\mathfrak{N}cs$  in  $V$ . Then  $f^{-1}(L)$  is  $\mathfrak{N}e c$  in  $U$ . But every  $\mathfrak{N}e c$  is  $\mathfrak{N}g e c$ ,  $f^{-1}(L)$  is  $\mathfrak{N}g e c$  in  $U$ .

The others are proved in a similar way.

**Example 2.1** Let  $U = \{o, n, m, l\}$  with  $U/R = \{\{l\}, \{o\}, \{n, m\}\}$ ,  $P = \{o, m\}$ . Then, the  $\mathfrak{N}t$  is defined as  $\tau_R(P) = \{U, \phi, \{o\}, \{n, m\}, \{n, o, m\}\}$ . Then the mapping  $f: (U, \tau_R(P)) \rightarrow (U, \tau_R(P))$  defined by [(i)]

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## Nano Generalized E- $\epsilon$ Continuous Mappings in Nano Topological Spaces

1.  $f(l) = n, f(m) = o, f(n) = l$  and  $f(o) = m$  is  $\mathfrak{Ng}\delta\mathfrak{S}Cts$  but not  $\mathfrak{Ng}Cts$ . The set  $\{l\}$  is  $\mathfrak{Nc}$  in  $V$  but  $f^{-1}(\{l\}) = \{n\}$  is not  $\mathfrak{Ngc}$  in  $U$ .
2.  $f(l) = n, f(m) = o, f(n) = l$  and  $f(o) = m$  is  $\mathfrak{Ng}\delta\mathfrak{S}Cts$  but not  $\mathfrak{Ng}\delta Cts$ . The set  $\{l\}$  is  $\mathfrak{Nc}$  in  $V$  but  $f^{-1}(\{l\}) = \{n\}$  is not  $\mathfrak{Ng}\delta c$  in  $U$ .
3.  $f(l) = n, f(m) = m, f(n) = l$  and  $f(o) = o$  is  $\mathfrak{Nge}Cts$  but not  $\mathfrak{Ng}\delta\mathfrak{S}Cts$ . The set  $\{l, o\}$  is  $\mathfrak{Nc}$  in  $V$  but  $f^{-1}(\{l, o\}) = \{n, o\}$  is not  $\mathfrak{Ng}\delta\mathfrak{S}c$  in  $U$ .
4.  $f(l) = n, f(m) = o, f(n) = l$  and  $f(o) = m$  is  $\mathfrak{Nge}Cts$  but not  $\mathfrak{Ng}\delta\mathfrak{P}Cts$ . The set  $\{l, o\}$  is  $\mathfrak{Nc}$  in  $V$  but  $f^{-1}(\{l, o\}) = \{n, m\}$  is not  $\mathfrak{Ng}\delta\mathfrak{P}c$  in  $U$ .
5.  $f(l) = n, f(m) = m, f(n) = l$  and  $f(o) = o$  is  $\mathfrak{Ng}M Cts$  but not  $\mathfrak{Ng}\delta\mathfrak{S}Cts$ . The set  $\{l, o\}$  is  $\mathfrak{Nc}$  in  $V$  but  $f^{-1}(\{l, o\}) = \{n, o\}$  is not  $\mathfrak{Ng}\delta\mathfrak{S}c$  in  $U$ .
6.  $f(l) = n, f(m) = o, f(n) = l$  and  $f(o) = m$  is  $\mathfrak{Ng}M Cts$  but not  $\mathfrak{Ng}\delta\mathfrak{P}Cts$ . The set  $\{l, o\}$  is  $\mathfrak{Nc}$  in  $V$  but  $f^{-1}(\{l, o\}) = \{n, m\}$  is not  $\mathfrak{Ng}\delta\mathfrak{P}c$  in  $U$ .

**Example 2.2** Let  $U = \{o, n, m, l, p\}$  with  $U/R = \{\{p\}, \{m, l\}, \{o, n\}\}$ ,  $P = \{l, o, n\}$  and  $V = \{l, n, m\}$  with  $V/R' = \{\{l\}, \{n, m\}\}$ ,  $Q = \{l, n\}$ . Then,  $\tau_R(P) = \{U, \{m, l\}, \phi, \{o, n\}, \{o, n, m, l\}\}$  and  $\tau_{R'}(Q) = \{V, \{l\}, \phi, \{n, m\}\}$ . Then the mapping  $f: (U, \tau_R(P)) \rightarrow (V, \tau_{R'}(Q))$  defined by  $f(l) = n, f(m) = l, f(n) = m, f(o) = m$  and  $f(p) = m$  is  $\mathfrak{Ng}Cts$  but not  $\mathfrak{Ng}\theta Cts$ . The set  $\{l\}$  is  $\mathfrak{Nc}$  in  $V$  but  $f^{-1}(\{l\}) = \{m\}$  is not  $\mathfrak{Ngc}$  in  $U$ .

**Example 2.3** Let  $U = \{o, n, m, l\}$  with  $U/R = \{\{o\}, \{l\}, \{n, m\}\}$ ,  $P = \{o, m\}$  and  $V = \{o, n, m, l\}$  with  $V/R' = \{\{m, l\}, \{o, n\}\}$ ,  $Q = \{l, o, n\}$ . Then,  $\tau_R(P) = \{U, \{o\}, \phi, \{n, m\}, \{o, n, m\}\}$  and  $\tau_{R'}(Q) = \{V, \phi, \{m, l\}, \{o, n\}\}$ . Then the mapping  $f: (U, \tau_R(P)) \rightarrow (V, \tau_{R'}(Q))$  defined by [(i)]

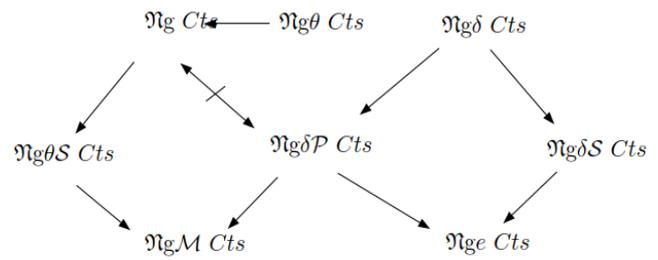
1.  $f(l) = l, f(m) = m, f(n) = n$  and  $f(o) = o$  is  $\mathfrak{Nge}Cts$  (resp.  $\mathfrak{Nge}Cts$ ) but not  $\mathfrak{Nec}Cts$  (resp.  $\mathfrak{Ng}M Cts$ ). The set  $\{o, n\}$  is  $\mathfrak{Nc}$  in  $V$  but  $f^{-1}(\{o, n\}) = \{o, n\}$  is not  $\mathfrak{Nec}$  (resp.  $\mathfrak{N}M c$ ) in  $U$ .
2.  $f(l) = l, f(m) = m, f(n) = n$  and  $f(o) = o$  is  $\mathfrak{Ng}\delta\mathfrak{P}Cts$  but not  $\mathfrak{Ng}\delta Cts$ . The set  $\{o, n\}$  is  $\mathfrak{Nc}$  in  $V$  but  $f^{-1}(\{o, n\}) = \{o, n\}$  is not  $\mathfrak{Ng}\delta c$  in  $U$ .

**Remark 2.1** The concept of  $\mathfrak{Ng}Cts$  and  $\mathfrak{Ng}\delta\mathfrak{P}Cts$  are independent.

**Example 2.4** In Example 2.3, [(i)]

1.  $f(l) = l, f(m) = m, f(n) = n$  and  $f(o) = o$  is  $\mathfrak{Ng}\delta\mathfrak{P}Cts$  but not  $\mathfrak{Ng}Cts$ . The set  $\{o, n\}$  is  $\mathfrak{Nc}$  in  $V$  but  $f^{-1}(\{o, n\}) = \{o, n\}$  is not  $\mathfrak{Ngc}$  in  $U$ .
2.  $f(l) = n, f(m) = m, f(n) = l$  and  $f(o) = o$  is  $\mathfrak{Ng}Cts$  but not  $\mathfrak{Ng}\delta\mathfrak{P}Cts$ . The set  $\{m, l\}$  is  $\mathfrak{Nc}$  in  $V$  but  $f^{-1}(\{m, l\}) = \{n, m\}$  is not  $\mathfrak{Ng}\delta\mathfrak{P}c$  in  $U$ .

From Examples 2.1 to 2.4 & Theorem 2.1, we have



Note:  $K \rightarrow L$  denotes  $K$  implies  $L$ ,  $L$  does not implies  $K$ .

**Theorem 2.2** A map  $f: (U, \tau_R(P)) \rightarrow (V, \sigma_{R'}(Q))$  is  $\mathfrak{Nge}$  (resp.  $\mathfrak{Ng}M$ )  $Cts$  iff the inverse image of every  $\mathfrak{Nc}$  set in  $V$  is  $\mathfrak{Nge}$  (resp.  $\mathfrak{Ng}M o$ ) in  $U$ .

**Theorem 2.3** A map  $f: (U, \tau_R(P)) \rightarrow (V, \sigma_{R'}(Q))$  is  $\mathfrak{Nge}Cts$  iff  $f(\mathfrak{Nge}cl(K)) \subseteq \mathfrak{Ncl}(f(K)) \forall$  subset  $K$  of  $U$ .

**Proof.** We prove only the necessity part. Let  $K \subseteq U$  &  $f$  be  $\mathfrak{Nge}Cts$  implies  $f(K) \subseteq V$ . Implies  $\mathfrak{Ncl}(f(K))$  is  $\mathfrak{Nc}$  in  $V \Rightarrow f^{-1}(\mathfrak{Ncl}(f(K)))$  is  $\mathfrak{Ngc}$  in  $U$ . Clearly,  $f(K) \subseteq \mathfrak{Ncl}(f(K)) \Rightarrow f^{-1}(f(K)) \subseteq f^{-1}(\mathfrak{Ncl}(f(K))) \Rightarrow K \subseteq f^{-1}(\mathfrak{Ncl}(f(K)))$ . Hence  $\mathfrak{Nge}cl(K) \subseteq \mathfrak{Nge}cl[f^{-1}(\mathfrak{Ncl}(f(K)))] = f^{-1}(\mathfrak{Ncl}(f(K)))$ . Hence  $\mathfrak{Nge}cl(K) \subseteq f^{-1}(\mathfrak{Ncl}(f(K))) \Rightarrow f(\mathfrak{Nge}cl(K)) \subseteq \mathfrak{Ncl}(f(K)) \forall$  subset  $K$  of  $U$ .

The Theorem 2.3 is also satisfy the map  $\mathfrak{Ng}M Cts$  for their respective closure.

**Remark 2.2** A map  $f: (U, \tau_R(P)) \rightarrow (V, \sigma_{R'}(Q))$  is  $\mathfrak{Nge}Cts$  then  $f(\mathfrak{Nge}cl(K))$  is not necessarily equal to  $\mathfrak{Ncl}(f(K))$  where  $K \subseteq U$ .

**Example 2.5** In Example 2.1, Define an identity map, then  $f$  is  $\mathfrak{Nge}Cts$ . Let  $K = \{m, n\} \subset U$ . Then  $f(\mathfrak{Nge}cl(K)) = f(\mathfrak{Nge}cl(\{m, n\})) = f(\{m, n\}) = \{m, n\}$ . But  $\mathfrak{Ncl}(f(K)) = \mathfrak{Ncl}(\{m, n\}) = \{l, m, n\}$ . Thus  $f(\mathfrak{Nge}cl(K)) \neq \mathfrak{Ncl}(f(K))$ , even though  $f$  is  $\mathfrak{Nge}Cts$ . That is equality does not hold.

**Theorem 2.4** A map  $f: (U, \tau_R(P)) \rightarrow (V, \sigma_{R'}(Q))$  is  $\mathfrak{Nge}Cts$  iff  $\mathfrak{Nge}cl(f^{-1}(L)) \subseteq f^{-1}(\mathfrak{Ncl}(L)) \forall$  subset  $L$  of  $V$ .

**Remark 2.3** A map  $f: (U, \tau_R(P)) \rightarrow (V, \sigma_{R'}(Q))$  is  $\mathfrak{Nge}Cts$  then  $\mathfrak{Nge}cl(f^{-1}(L))$  is not necessarily equal to  $f^{-1}(\mathfrak{Ncl}(L))$  where  $L \subseteq V$ .

**Example 2.6** In Example 2.1, Define an identity map, then  $f$  is  $\mathfrak{Nge}Cts$ . Let  $L = \{m\} \subset V$ . Then  $\mathfrak{Nge}cl(f^{-1}(L)) = \mathfrak{Nge}cl(f^{-1}(\{m\})) = \mathfrak{Nge}cl(\{m\}) = \{m\}$

But  $f^{-1}(\mathfrak{Ncl}(f(L))) = f^{-1}(\mathfrak{Ncl}(\{m\})) = f^{-1}(\{l, m, n\}) = \{l, m, n\}$

. Thus  $\mathfrak{Nge}cl(f^{-1}(L)) \neq f^{-1}(\mathfrak{Ncl}(f(L)))$ , even though  $f$  is  $\mathfrak{Nge}Cts$ . That is equality does not hold.

**Theorem 2.5** A map  $f: (U, \tau_R(P)) \rightarrow (V, \sigma_{R'}(Q))$  is  $\mathfrak{Nge}Cts$  iff



$$f^{-1}(\mathfrak{Nint}(L)) \subseteq \mathfrak{Ngeint}(f^{-1}(L)) \forall \text{ subset } L \text{ of } V.$$

The map  $\mathfrak{NgMCts}$  satisfy the Theorems 2.4 & 2.5 for their respective interior.

**Remark 2.4** A map  $f: (U, \tau_R(P)) \rightarrow (V, \sigma_{R'}(Q))$  is  $\mathfrak{NgCts}$  then  $f^{-1}(\mathfrak{Nint}(L))$  is not necessarily equal to  $\mathfrak{Ngeint}(f^{-1}(L))$  where  $L \subseteq V$ .

**Example 2.7** In Example 2.1, Define an identity map, then  $f$  is  $\mathfrak{NgCts}$ . Let  $L = \{m\} \subset V$ . Then  $\mathfrak{Ngeint}(f^{-1}(L)) = \mathfrak{Ngeint}f^{-1}(\{m\}) = \mathfrak{Ngeint}(\{m\}) = \{m\}$

But  $f^{-1}(\mathfrak{Nint}(L)) = f^{-1}(\mathfrak{Nint}(\{m\})) = f^{-1}(\{\phi\}) = \phi$ . Thus  $\mathfrak{Ngeint}(f^{-1}(L)) \neq f^{-1}(\mathfrak{Nint}(L))$ , even though  $f$  is  $\mathfrak{NgCts}$ . That is equality does not hold.

**Theorem 2.6** In a  $\mathfrak{Nts}(U, \tau_R(P))$ , if the collection of  $\mathfrak{NGEO}(U, P)$  is closed under arbitrary union & let  $f: (U, \tau_R(P)) \rightarrow (V, \sigma_{R'}(Q))$  be a function. Then [(i)]

1.  $f$  is  $\mathfrak{NgCts}$
2.  $\forall l \in U$  and each  $\mathfrak{NOS} H$  in  $V$  with  $f(l) \in H \exists$  a  $\mathfrak{NGEOS} G$  in  $U \ni l \in G$  &  $f(G) \subset H$ .
3.  $\forall l \in U$ , the inverse of every  $\mathfrak{Nbd}$  of  $f(l)$  is  $\mathfrak{NgNbdS}(l)$  are equivalent.

The map  $\mathfrak{NgMCts}$  satisfy the Theorem 2.6 for their respective family of open sets.

**Remark 2.5** The composition of two  $\mathfrak{NgCts}$  functions need not be  $\mathfrak{NgCts}$  as seen from the example.

**Example 2.8** Let  $U = V = \{p, o, n, m, l\}$  with  $U/R = \{\{n\}, \{m, l\}, \{o, p\}\}$ ,  $P = \{l, n\}$ ,  $\tau_R(P) = \{U, \phi, \{n\}, \{l, m\}, \{l, m, n\}\}$  and  $V/R' = \{\{p\}, \{l, m\}, \{n, o\}\}$ ,  $Q = \{l, n, o\}$ ,  $\sigma_{R'}(Q) = \{V, \phi, \{m, l\}, \{n, o\}, \{o, n, m, l\}\}$ . Then, the identity mappings  $f: (U, \tau_R(P)) \rightarrow (V, \sigma_{R'}(Q))$  and  $g: (V, \sigma_{R'}(Q)) \rightarrow (V, \sigma_{R'}(Q))$  are  $\mathfrak{NgCts}$  but the composition  $g \circ f$  is not  $\mathfrak{NgCts}$ , the set  $\{l, n\}$  is  $\mathfrak{Nc}$  in  $V$  but  $(g \circ f)^{-1}(\{l, n\}) = \{l, n\}$  is not  $\mathfrak{Ngec}$  in  $U$ .

**Theorem 2.7** Let  $f: (U, \tau_R(P)) \rightarrow (V, \sigma_{R'}(Q))$  be  $\mathfrak{NgCts}$  and  $g: (V, \sigma_{R'}(Q)) \rightarrow (W, \mu_{R''}(S))$  be  $\mathfrak{NcTs}$ , then  $g \circ f$  is  $\mathfrak{NgCts}$ .

The map  $\mathfrak{NgMCts}$  also satisfy the Theorem 2.7.

**Definition 2.2** A map  $f: (U, \tau_R(P)) \rightarrow (V, \sigma_{R'}(Q))$  is nano generalized  $e^*$  (resp. nano generalized  $\mathcal{M}^*$ ) continuous (briefly,  $\mathfrak{Nge}^*$  (resp.  $\mathfrak{NgM}^*$ )  $Cts$ ), if  $\forall \mathfrak{Nec}$  (resp.  $\mathfrak{NMc}$ ) subset  $K$  of  $V$ ,  $f^{-1}(K)$  is  $\mathfrak{Ngec}$  (resp.  $\mathfrak{NgMc}$ ) subset of  $U$ .

**Theorem 2.8** A map  $f: (U, \tau_R(P)) \rightarrow (V, \sigma_{R'}(Q))$  is  $\mathfrak{Nge}^*Cts$  (resp.  $\mathfrak{NgM}^*Cts$ ), iff  $f^{-1}(K)$  is  $\mathfrak{Ngeo}$  (resp.  $\mathfrak{NgMo}$ ) in  $U \forall \mathfrak{Neo}$  set  $K$  in  $V$ .

**Theorem 2.9** Every  $\mathfrak{Nge}^*Cts$  (resp.  $\mathfrak{NgM}^*Cts$ ) function is  $\mathfrak{NgCts}$  (resp.  $\mathfrak{NgMCts}$ ). But not conversely.

**Proof.** Based on every  $\mathfrak{Nec}$  set is  $\mathfrak{Ngec}$ . The other case is also similar

**Example 2.9** Let  $U = \{p, o, n, m, l\}$ ,  $U/R = \{\{p\}, \{m, l\}, \{o, n\}\}$ ,  $P = \{l, o, n\}$  &  $V = \{p, o, n, m, l\}$ ,  $V/R' = \{\{n\}, \{m, l\}, \{o, p\}\}$ ,  $Q = \{l, n\}$ . Then,  $\tau_R(P) = \{U, \phi, \{m, l\}, \{o, n\}, \{m, l, o, n\}\}$  and  $\tau_{R'}(Q) = \{V, \phi, \{n\}, \{m, l\}, \{l, m, n\}\}$ . Then the mapping  $f: (U, \tau_R(P)) \rightarrow (V, \tau_{R'}(Q))$  defined by  $f(l) = l$ ,  $f(m) = m$ ,  $f(n) = n$  and  $f(o) = o$  is  $\mathfrak{NgeCts}$  but not  $\mathfrak{Nge}^*Cts$ . The set  $\{m, l, o\}$  is  $\mathfrak{Ngc}$  in  $V$  but  $f^{-1}(\{m, l, o\}) = \{m, l, o\}$  is not  $\mathfrak{Ngec}$  in  $U$ .

**Remark 2.6** The composition of two  $\mathfrak{Nge}^*Cts$  functions need not be  $\mathfrak{Nge}^*Cts$  as seen from the example.

**Example 2.10** Let  $U = \{p, o, n, m, l\}$ ,  $U/R = \{\{p\}, \{m, l\}, \{o, n\}\}$ ,  $P = \{l, o, n\}$  and  $V = \{p, o, n, m, l\}$ ,  $V/R' = \{\{n\}, \{m, l\}, \{o, p\}\}$ ,  $Q = \{l, n\}$ . Then,  $\tau_R(P) = \{U, \phi, \{m, l\}, \{o, n\}, \{m, l, o, n\}\}$  &  $\tau_{R'}(Q) = \{V, \phi, \{n\}, \{m, l\}, \{m, l, n\}\}$ . Then, the identity mappings  $f: (U, \tau_R(P)) \rightarrow (V, \sigma_{R'}(Q))$  &  $g: (V, \sigma_{R'}(Q)) \rightarrow (V, \sigma_{R'}(Q))$  are  $\mathfrak{Nge}^*Cts$  but the composition  $g \circ f$  is not  $\mathfrak{Nge}^*Cts$ , the set  $\{m, l, o\}$  is  $\mathfrak{Ngc}$  in  $V$  but  $(g \circ f)^{-1}(\{m, l, o\}) = \{m, l, o\}$  is not  $\mathfrak{Ngec}$  in  $U$ .

**Theorem 2.10** Let  $f: (U, \tau_R(P)) \rightarrow (V, \sigma_{R'}(Q))$  be  $\mathfrak{Nge}^*Cts$  and  $g: (V, \sigma_{R'}(Q)) \rightarrow (W, \mu_{R''}(S))$  be  $\mathfrak{NcTs}$ , then  $g \circ f$  is  $\mathfrak{NgCts}$ .

### III NANO GENERALIZED $e$ IRRESOLUTE MAPS

**Definition 3.1** A map  $f: (U, \tau_R(P)) \rightarrow (V, \sigma_{R'}(Q))$  is called nano generalized  $e$  (resp.  $\mathcal{M}$ ) irresolute (briefly,  $\mathfrak{NgeIrr}$  (resp.  $\mathfrak{NgMIrr}$ )) maps, if  $\forall \mathfrak{Ngec}$  (resp.  $\mathfrak{NgMc}$ ) subset  $K$  of  $V$ ,  $f^{-1}(K)$  is  $\mathfrak{Ngec}$  (resp.  $\mathfrak{NgMc}$ ) subset of  $U$ .

**Theorem 3.1** A map  $f: (U, \tau_R(P)) \rightarrow (V, \sigma_{R'}(Q))$  is [(i)]

1.  $\mathfrak{NgIrr}$ , then  $f$  is  $\mathfrak{NgCts}$ .
2.  $\mathfrak{Ng\theta Irr}$ , then  $f$  is  $\mathfrak{Ng\theta Cts}$ .
3.  $\mathfrak{Ng\delta Irr}$ , then  $f$  is  $\mathfrak{Ng\delta Cts}$ .
4.  $\mathfrak{Ng\theta\delta Irr}$ , then  $f$  is  $\mathfrak{Ng\theta\delta Cts}$ .
5.  $\mathfrak{Ng\delta P Irr}$ , then  $f$  is  $\mathfrak{Ng\delta P Cts}$ .
6.  $\mathfrak{Ng\delta S Irr}$ , then  $f$  is  $\mathfrak{Ng\delta S Cts}$ .
7.  $\mathfrak{Ngelrr}$ , then  $f$  is  $\mathfrak{NgCts}$ .
8.  $\mathfrak{NgMIrr}$ , then  $f$  is  $\mathfrak{NgMCts}$ .

But not conversely.

**Proof.** (vii) Let  $F$  be  $\mathfrak{Nc}$  in  $V$ ,  $\Rightarrow F$  is  $\mathfrak{Ngec}$  in  $V$ , since every  $\mathfrak{Ncs}$  is  $\mathfrak{Ngec}$ . By hypothesis,  $f^{-1}(F)$  is  $\mathfrak{Ngec}$ . Therefore,  $f$  is  $\mathfrak{NgCts}$ . The other cases are similar

**Example 3.1** Let  $U = V = \{p, o, n, m, l\}$ ,  $U/R = \{\{n\}, \{m, l\}, \{o, p\}\}$ ,  $P = \{l, n\}$ . Then  $\tau_R(P) = \{U, \phi, \{n\}, \{m, l\}, \{m, l, n\}\}$  and  $V/R' = \{\{p\}, \{m, l\}, \{o, n\}\}$ ,  $Q = \{l, o, n\}$ . Then

## Nano Generalized E- $\epsilon$ Continuous Mappings in Nano Topological Spaces

$\sigma_{R'}(Q) = \{V, \phi, \{m, l\}, \{o, n\}, \{m, l, o, n\}\}$ . Define  $f: (U, \tau_R(P)) \rightarrow (V, \sigma_{R'}(Q))$  as identity mapping. Then [(i)]

1.  $f$  is  $\mathfrak{NgCts}$ , but  $f$  is not  $\mathfrak{NgIrr}$ , since  $f^{-1}(\{l\}) = \{l\}$  which is not  $\mathfrak{Ngc}$  in  $U$  whereas  $\{l\}$  is  $\mathfrak{Ngc}$  in  $V$ .
2.  $f$  is  $\mathfrak{Ng\delta Cts}$ , but  $f$  is not  $\mathfrak{Ng\delta Irr}$ , since  $f^{-1}(\{l\}) = \{l\}$  which is not  $\mathfrak{Ng\delta c}$  in  $U$  whereas  $\{l\}$  is  $\mathfrak{Ng\delta c}$  in  $V$ .
3.  $f$  is  $\mathfrak{NgCts}$ , but  $f$  is not  $\mathfrak{NgIrr}$ , since  $f^{-1}(\{l, n\}) = \{l, n\}$  which is not  $\mathfrak{Ngec}$  in  $U$  whereas  $\{l, n\}$  is  $\mathfrak{Ngec}$  in  $V$ .
4.  $f$  is  $\mathfrak{NgMCts}$ , but  $f$  is not  $\mathfrak{NgMIrr}$ , since  $f^{-1}(\{l, n\}) = \{l, n\}$  which is not  $\mathfrak{NgMc}$  in  $U$  whereas  $\{l, n\}$  is  $\mathfrak{NgMc}$  in  $V$ .

**Example 3.2** Let  $U = V = \{p, o, n, m, l\}$ ,  $U/R = \{\{p\}, \{m, l\}, \{o, n\}\}$ ,  $P = \{l, o, n\}$ . Then  $\tau_R(P) = \{U, \phi, \{m, l\}, \{o, n\}, \{m, l, o, n\}\}$  &  $V/R' = \{\{n\}, \{m, l\}, \{o, p\}\}$ ,  $Q = \{l, n\}$ . Then  $\sigma_{R'}(Q) = \{V, \phi, \{n\}, \{m, l\}, \{m, l, n\}\}$ . Define  $f: (U, \tau_R(P)) \rightarrow (V, \sigma_{R'}(Q))$  as identity mapping. Then [(i)]

1.  $f$  is  $\mathfrak{Ng\theta Cts}$ , but  $f$  is not  $\mathfrak{Ng\theta Irr}$ , since  $f^{-1}(\{l, o\}) = \{l, o\}$  which is not  $\mathfrak{Ng\theta c}$  in  $U$  whereas  $\{l, o\}$  is  $\mathfrak{Ng\theta c}$  in  $V$ .
2.  $f$  is  $\mathfrak{Ng\theta\delta Cts}$ , but  $f$  is not  $\mathfrak{Ng\theta\delta Irr}$ , since  $f^{-1}(\{l, o\}) = \{l, o\}$  which is not  $\mathfrak{Ng\theta\delta c}$  in  $U$  whereas  $\{l, o\}$  is  $\mathfrak{Ng\theta\delta c}$  in  $V$ .
3.  $f$  is  $\mathfrak{Ng\delta PCts}$ , but  $f$  is not  $\mathfrak{Ng\delta PIrr}$ , since  $f^{-1}(\{o, n\}) = \{o, n\}$  which is not  $\mathfrak{Ng\delta Pc}$  in  $U$  whereas  $\{o, n\}$  is  $\mathfrak{Ng\delta Pc}$  in  $V$ .
4.  $f$  is  $\mathfrak{Ng\delta\delta Cts}$ , but  $f$  is not  $\mathfrak{Ng\delta\delta Irr}$ , since  $f^{-1}(\{l, o\}) = \{l, o\}$  which is not  $\mathfrak{Ng\delta\delta c}$  in  $U$  whereas  $\{l, o\}$  is  $\mathfrak{Ng\delta\delta c}$  in  $V$ .

**Theorem 3.2** A map  $f: (U, \tau_R(P)) \rightarrow (V, \sigma_{R'}(Q))$  is  $\mathfrak{Ngelrr}$  (resp.  $\mathfrak{NgMIrr}$ ) iff for every  $\mathfrak{Ng eos}$  (resp.  $\mathfrak{NgMos}$ )  $K$  in  $V$ ,  $f^{-1}(K)$  is  $\mathfrak{Ng eo}$  (resp.  $\mathfrak{NgMo}$ ) in  $U$ .

**Proof.** Follows from the fact that the complement of  $\mathfrak{Ng eo}$  (resp.  $\mathfrak{NgMo}$ ) set is  $\mathfrak{Ng ec}$  (resp.  $\mathfrak{NgMc}$ ) and vice versa.

**Theorem 3.3** If  $f: (U, \tau_R(P)) \rightarrow (V, \sigma_{R'}(Q))$  and  $g: (V, \sigma_{R'}(Q)) \rightarrow (W, \mu_{R''}(S))$  are both  $\mathfrak{Ngelrr}$ , then  $g \circ f: (U, \tau_R(P)) \rightarrow (W, \mu_{R''}(S))$  is  $\mathfrak{Ngelrr}$ .

**Proof.** Let  $K$  be  $\mathfrak{Ng eo}$  in  $W$ . Then  $g^{-1}(K)$  is  $\mathfrak{Ng eo}$  in  $V$ , since  $g$  is  $\mathfrak{Ngelrr}$  and  $f^{-1}(g^{-1}(K)) = (g \circ f)^{-1}(K)$  is  $\mathfrak{Ng eo}$  in  $U$ , clearly  $f$  is  $\mathfrak{Ngelrr}$ . Hence  $g \circ f$  is  $\mathfrak{Ngelrr}$ . The map  $\mathfrak{NgMIrr}$  is also satisfy the Theorem 3.3.

**Theorem 3.4** [(i)]

1. If  $f: (U, \tau_R(P)) \rightarrow (V, \sigma_{R'}(Q))$  is  $\mathfrak{Ngelrr}$  &  $g: (V, \sigma_{R'}(Q)) \rightarrow (W, \mu_{R''}(S))$  is  $\mathfrak{NgCts}$ , then  $g \circ f: (U, \tau_R(P)) \rightarrow (W, \mu_{R''}(S))$  is  $\mathfrak{NgCts}$ .
2. If  $f: (U, \tau_R(P)) \rightarrow (V, \sigma_{R'}(Q))$  is  $\mathfrak{NgCts}$  &  $g: (V, \sigma_{R'}(Q)) \rightarrow (W, \mu_{R''}(S))$  is  $\mathfrak{NgCts}$ , then  $g \circ f: (U, \tau_R(P)) \rightarrow (W, \mu_{R''}(S))$  is  $\mathfrak{NgCts}$ .

The map  $\mathfrak{NgMIrr}$  is also satisfy the Theorem 3.4.

**Theorem 3.5** If  $f: (U, \tau_R(P)) \rightarrow (V, \sigma_{R'}(Q))$  is  $\mathfrak{Ngelrr}$  &  $g: (V, \sigma_{R'}(Q)) \rightarrow (W, \mu_{R''}(S))$  is  $\mathfrak{NgCts}$ , then  $g \circ f: (U, \tau_R(P)) \rightarrow (W, \mu_{R''}(S))$  is  $\mathfrak{NgCts}$ .

**Proof.** Let  $K$  be  $\mathfrak{Ng eo}$  in  $W$ . Then  $g^{-1}(K)$  is  $\mathfrak{Ng eo}$  in  $V$ , clearly  $g$  is  $\mathfrak{NgCts}$ . Thus  $g^{-1}(K)$  is  $\mathfrak{Ng eo}$  in  $V$ , clearly every  $\mathfrak{Ng eo}$  set is  $\mathfrak{Ng eo}$  and  $f^{-1}(g^{-1}(K)) = (g \circ f)^{-1}(K)$  is  $\mathfrak{Ng eo}$  in  $U$ , since  $f$  is  $\mathfrak{Ngelrr}$ . Hence  $g \circ f$  is  $\mathfrak{NgCts}$ .

The map  $\mathfrak{NgMIrr}$  is also satisfy the Theorem 3.5.

**Theorem 3.6** If  $f: (U, \tau_R(P)) \rightarrow (V, \sigma_{R'}(Q))$  is  $\mathfrak{Ngelrr}$  &  $g: (V, \sigma_{R'}(Q)) \rightarrow (W, \mu_{R''}(S))$  is  $\mathfrak{NgCts}$ , then  $g \circ f: (U, \tau_R(P)) \rightarrow (W, \mu_{R''}(S))$  is  $\mathfrak{NgCts}$ .

**Proof.** Proof is similar from the Theorem 3.5.

**Proposition 3.1** Let  $f: (U, \tau_R(P)) \rightarrow (V, \sigma_{R'}(Q))$  be a function. If  $f$  is [(i)]

1.  $\mathfrak{Ngelrr}$ , then it is  $\mathfrak{Ng e^* Cts}$ .
2.  $\mathfrak{Ng e^* Cts}$ , then it is  $\mathfrak{Ng e^* Cts}$ .

**Proof.** The proof is immediate.

**Remark 3.1** Every  $\mathfrak{NgIrr}$  function is  $\mathfrak{Ng e^* Cts}$ . But not conversely.

**Example 3.3** In Example 3.1,  $f$  is  $\mathfrak{Ng e^* Cts}$ , but  $f$  is not  $\mathfrak{Ng e^* Irr}$ , since  $f^{-1}(\{l, n\}) = \{l, n\}$  which is not  $\mathfrak{Ng ec}$  in  $U$  whereas  $\{l, n\}$  is  $\mathfrak{Ng ec}$  in  $V$ .

**Theorem 3.7** Let  $f: (U, \tau_R(P)) \rightarrow (V, \sigma_{R'}(Q))$  &  $g: (V, \sigma_{R'}(Q)) \rightarrow (W, \mu_{R''}(S))$  be any two maps. Then if  $f$  is  $\mathfrak{Ng e^* Cts}$  &  $g$  is  $\mathfrak{NgIrr}$ , then  $g \circ f: (U, \tau_R(P)) \rightarrow (W, \mu_{R''}(S))$  is  $\mathfrak{Ng e^* Cts}$ .

**Theorem 3.8** Let  $f: (U, \tau_R(P)) \rightarrow (V, \sigma_{R'}(Q))$  &  $g: (V, \sigma_{R'}(Q)) \rightarrow (W, \mu_{R''}(S))$  be any two functions. [(i)]

1. If  $f$  is  $\mathfrak{Ngelrr}$  &  $g$  is  $\mathfrak{NgCts}$ , then  $g \circ f$  is  $\mathfrak{NgCts}$ .
2. If  $f$  is  $\mathfrak{Ngelrr}$  &  $g$  is  $\mathfrak{Ng e^* Cts}$ , then  $g \circ f$  is  $\mathfrak{Ng e^* Cts}$ .

### CONCLUSION

In this paper,  $\mathfrak{NgCts}$ ,  $\mathfrak{NgMCts}$  and their respective irresoluteness are studied and many interesting examples in various forms are discussed.

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