



Neutrosophic Closed Set and Neutrosophic Continuous Functions

A. A. Salama¹, Florentin Smarandache² and Valeri Kromov³

¹Department of Mathematics and Computer Science, Faculty of Sciences, Port Said University, 23 December Street, Port Said 42522, Egypt.

Email: drsalama44@gmail.com

² Department of Mathematics, University of New Mexico Gallup, NM, USA. Email: smarand@unm.edu

³Okayama University of Science, Okayama, Japan.

Abstract

In this paper, we introduce and study the concept of "neutrosophic closed set" and "neutrosophic continuous function". Possible application to GIS topology rules are touched upon.

Keywords: Neutrosophic Closed Set, Neutrosophic Set; Neutrosophic Topology; Neutrosophic Continuous Function.

1 INTRODUCTION

The idea of "neutrosophic set" was first given by Smarandache [11, 12]. Neutrosophic operations have been investigated by Salama at el. [1-10]. Neutrosophy has laid the foundation for a whole family of new mathematical theories, generalizing both their crisp and fuzzy counterparts [9, 13]. Here we shall present the neutrosophic crisp version of these concepts. In this paper, we introduce and study the concept of "neutrosophic closed set" and "neutrosophic continuous function".

2 TERMINOLOGIES

We recollect some relevant basic preliminaries, and in particular the work of Smarandache in [11, 12], and Salama at el. [1-10].

2.1 Definition [5]

A neutrosophic topology (NT for short) on a non empty set X is a family τ of neutrosophic subsets in X satisfying the following axioms

$$(NT_1) O_N, 1_N \in \tau,$$

$$(NT_2) G_1 \cap G_2 \in \tau \text{ for any } G_1, G_2 \in \tau,$$

$$(NT_3) \bigcup G_i \in \tau \quad \forall \{G_i : i \in J\} \subseteq \tau$$

In this case the pair (X, τ) is called a neutrosophic topological space (NTS for short) and any neutrosophic set in τ is known as neutrosophic open set (NOS for short) in X . The elements of τ are called open neutrosophic sets, A neutrosophic set F is closed if and only if $C(F)$ is neutrosophic open.

2.1 Definition [5]

The complement of $(C(A))$ for short) of is called a neutrosophic closed set (NCS for short) in A . NOSA NCS X .

3 Neutrosophic Closed Set .

3.1 Definition

Let (X, τ) be a neutrosophic topological space. A neutrosophic set A in (X, τ) is said to be neutrosophic closed (in shortly N-closed).

If $Ncl(A) \subseteq G$ whenever $A \subseteq G$ and G is neutrosophic open; the complement of neutrosophic closed set is Neutrosophic open.

3.1 Proposition

If A and B are neutrosophic closed sets then $A \cup B$ is Neutrosophic closed set.

3.1 Remark

The intersection of two neutrosophic closed (N-closed for short) sets need not be neutrosophic closed set.

3.1 Example

Let $X = \{a, b, c\}$ and

$$A = \langle (0.5, 0.5, 0.5), (0.4, 0.5, 0.5), (0.4, 0.5, 0.5) \rangle$$

$$B = \langle (0.3, 0.4, 0.4), (0.7, 0.5, 0.5), (0.3, 0.4, 0.4) \rangle$$

Then $T = \{0_N, 1_N, A, B\}$ is a neutrosophic topology on X . Define the two neutrosophic sets A_1 and A_2 as follows,

$$A_1 = \langle (0.5, 0.5, 0.5), (0.6, 0.5, 0.5), (0.6, 0.5, 0.5) \rangle$$

$$A_2 = \langle (0.7, 0.6, 0.6), (0.3, 0.5, 0.5), (0.7, 0.6, 0.6) \rangle$$

A_1 and A_2 are neutrosophic closed set but $A_1 \cap A_2$ is not a neutrosophic closed set.

3.2 Proposition

Let (X, τ) be a neutrosophic topological space. If B is neutrosophic closed set and $B \subseteq A \subseteq \text{Ncl}(B)$, then A is N -closed.

3.4 Proposition

In a neutrosophic topological space (X, T) , $T = \mathfrak{T}$ (the family of all neutrosophic closed sets) iff every neutrosophic subset of (X, T) is a neutrosophic closed set.

Proof.

suppose that every neutrosophic set A of (X, T) is N -closed. Let $A \in T$, since $A \subseteq A$ and A is N -closed, $\text{Ncl}(A) \subseteq A$. But $A \subseteq \text{Ncl}(A)$. Hence, $\text{Ncl}(A) = A$. thus, $A \in \mathfrak{T}$. Therefore, $T \subseteq \mathfrak{T}$. If $B \in \mathfrak{T}$ then $1-B \in T \subseteq \mathfrak{T}$. and hence $B \in T$, That is, $\mathfrak{T} \subseteq T$. Therefore $T = \mathfrak{T}$ conversely, suppose that A be a neutrosophic set in (X, T) . Let B be a neutrosophic open set in (X, T) . such that $A \subseteq B$. By hypothesis, B is neutrosophic N -closed. By definition of neutrosophic closure, $\text{Ncl}(A) \subseteq B$. Therefore A is N -closed.

3.5 Proposition

Let (X, T) be a neutrosophic topological space. A neutrosophic set A is neutrosophic open iff $B \subseteq \text{Nint}(A)$, whenever B is neutrosophic closed and $B \subseteq A$.

Proof

Let A a neutrosophic open set and B be a N -closed, such that $B \subseteq A$. Now, $B \subseteq A \Rightarrow 1-A \Rightarrow 1-B$ and $1-A$ is a neutrosophic closed set $\Rightarrow \text{Ncl}(1-A) \subseteq 1-B$. That is, $B = 1-(1-B) \subseteq 1-\text{Ncl}(1-A)$. But $1-\text{Ncl}(1-A) = \text{Nint}(A)$. Thus, $B \subseteq \text{Nint}(A)$. Conversely, suppose that A be a neutrosophic set, such that $B \subseteq \text{Nint}(A)$ whenever B is neutrosophic closed and $B \subseteq A$. Let $1-A \subseteq B \Rightarrow 1-B \subseteq A$. Hence by assumption $1-B \subseteq \text{Nint}(A)$. that is, $1-\text{Nint}(A) \subseteq B$. But $1-\text{Nint}(A) = \text{Ncl}(1-A)$. Hence $\text{Ncl}(1-A) \subseteq B$. That is $1-A$ is neutrosophic closed set. Therefore, A is neutrosophic open set

3.6 Proposition

If $\text{Nint}(A) \subseteq B \subseteq A$ and if A is neutrosophic open set then B is also neutrosophic open set.

4 Neutrosophic Continuous Functions

4.1 Definition

i) If $B = \langle \mu_B, \sigma_B, \nu_B \rangle$ is a NS in Y , then the preimage of B under f , denoted by $f^{-1}(B)$, is a NS in X defined by $f^{-1}(B) = \langle f^{-1}(\mu_B), f^{-1}(\sigma_B), f^{-1}(\nu_B) \rangle$.

ii) If $A = \langle \mu_A, \sigma_A, \nu_A \rangle$ is a NS in X , then the image of A under f , denoted by $f(A)$, is the a NS in Y defined by $f(A) = \langle f(\mu_A), f(\sigma_A), f(\nu_A)^c \rangle$.

Here we introduce the properties of images and preimages some of which we shall frequently use in the following sections .

4.1 Corollary

Let $A, \{A_i : i \in J\}$, be NSs in X , and $B, \{B_j : j \in K\}$ NS in Y , and $f : X \rightarrow Y$ a function. Then

$$(a) A_1 \subseteq A_2 \Leftrightarrow f(A_1) \subseteq f(A_2),$$

$$B_1 \subseteq B_2 \Leftrightarrow f^{-1}(B_1) \subseteq f^{-1}(B_2),$$

(b) $A \subseteq f^{-1}(f(A))$ and if f is injective, then

$$A = f^{-1}(f(A)) .$$

(c) $f^{-1}(f(B)) \subseteq B$ and if f is surjective, then

$$f^{-1}(f(B)) = B .$$

$$(d) f^{-1}(\cup B_i) = \cup f^{-1}(B_i), f^{-1}(\cap B_i) = \cap f^{-1}(B_i),$$

(e) $f(\cup A_i) = \cup f(A_i); f(\cap A_i) \subseteq \cap f(A_i)$; and if f is injective, then $f(\cap A_i) = \cap f(A_i)$;

$$(f) f^{-1}(1_N) = 1_N, f^{-1}(0_N) = 0_N .$$

(g) $f(0_N) = 0_N, f(1_N) = 1_N$ if f is subjective.

Proof

Obvious.

4.2 Definition

Let (X, Γ_1) and (Y, Γ_2) be two NTSs, and let $f : X \rightarrow Y$ be a function. Then f is said to be continuous iff the preimage of each NCS in Γ_2 is a NS in Γ_1 .

4.3 Definition

Let (X, Γ_1) and (Y, Γ_2) be two NTSs and let $f : X \rightarrow Y$ be a function. Then f is said to be open iff the image of each NS in Γ_1 is a NS in Γ_2 .

4.1 Example

Let (X, Γ_o) and (Y, ψ_o) be two NTSs

(a) If $f : X \rightarrow Y$ is continuous in the usual sense, then in this case, f is continuous in the sense of Definition 5.1 too. Here we consider the NTs on X and Y , respectively, as follows : $\Gamma_1 = \langle \mu_G, 0, \mu_G^c \rangle : G \in \Gamma_o$ and

$$\Gamma_2 = \left\{ \langle \mu_H, 0, \mu_H^c \rangle : H \in \mathcal{P}_o \right\},$$

In this case we have, for each $\langle \mu_H, 0, \mu_H^c \rangle \in \Gamma_2$,

$$f^{-1} \left\langle \mu_H, 0, \mu_H^c \right\rangle = \left\langle f^{-1}(\mu_H), f^{-1}(0), f^{-1}(\mu_H^c) \right\rangle = \left\langle f^{-1}(\mu_H), f(0), (f(\mu))^c \right\rangle \in \Gamma_1.$$

(b) If $f : X \rightarrow Y$ is neutrosophic open in the usual sense, then in this case, f is neutrosophic open in the sense of Definition 3.2.

Now we obtain some characterizations of neutrosophic continuity:

4.1 Proposition

Let $f : (X, \Gamma_1) \rightarrow (Y, \Gamma_2)$.

f is neutrosophic continuous iff the preimage of each NS (neutrosophic closed set) in Γ_2 is a NS in Γ_1 .

4.2 Proposition

The following are equivalent to each other:

- (a) $f : (X, \Gamma_1) \rightarrow (Y, \Gamma_2)$ is neutrosophic continuous.
- (b) $f^{-1}(NInt(B)) \subseteq NInt(f^{-1}(B))$ for each CNS B in Y .
- (c) $NCl(f^{-1}(B)) \subseteq f^{-1}(NCl(B))$ for each NCB in Y .

4.2 Example

Let (Y, Γ_2) be a NTS and $f : X \rightarrow Y$ be a function. In this case $\Gamma_1 = \{f^{-1}(H) : H \in \Gamma_2\}$ is a NT on X . Indeed, it is the coarsest NT on X which makes the function $f : X \rightarrow Y$ continuous. One may call it the initial neutrosophic crisp topology with respect to f .

4.4 Definition

Let (X, T) and (Y, S) be two neutrosophic topological space, then

- (a) A map $f : (X, T) \rightarrow (Y, S)$ is called N-continuous (in short N-continuous) if the inverse image of every closed set in (Y, S) is Neutrosophic closed in (X, T) .
- (b) A map $f : (X, T) \rightarrow (Y, S)$ is called neutrosophic-gc irresolute if the inverse image of every Neutrosophic closed set in (Y, S) is Neutrosophic closed in (X, T) . Equivalently if the inverse image of every Neutrosophic open set in (Y, S) is Neutrosophic open in (X, T) .
- (c) A map $f : (X, T) \rightarrow (Y, S)$ is said to be strongly neutrosophic continuous if $f^{-1}(A)$ is both neutrosophic open and neutrosophic closed in (X, T) for each neutrosophic set A in (Y, S) .
- (d) A map $f : (X, T) \rightarrow (Y, S)$ is said to be perfectly neutrosophic continuous if $f^{-1}(A)$ is both neutrosophic open and neutrosophic closed in (X, T) for each neutrosophic open set A in (Y, S) .
- (e) A map $f : (X, T) \rightarrow (Y, S)$ is said to be strongly N-continuous if the inverse image of every Neutrosophic open set in (Y, S) is neutrosophic open in (X, T) .

(F) A map $f : (X, T) \rightarrow (Y, S)$ is said to be perfectly N-continuous if the inverse image of every Neutrosophic open set in (Y, S) is both neutrosophic open and neutrosophic closed in (X, T) .

4.3 Proposition

Let (X, T) and (Y, S) be any two neutrosophic topological spaces. Let $f : (X, T) \rightarrow (Y, S)$ be generalized neutrosophic continuous. Then for every neutrosophic set A in X , $f(Ncl(A)) \subseteq Ncl(f(A))$.

4.4 Proposition

Let (X, T) and (Y, S) be any two neutrosophic topological spaces. Let $f : (X, T) \rightarrow (Y, S)$ be generalized neutrosophic continuous. Then for every neutrosophic set A in Y , $Ncl(f^{-1}(A)) \subseteq f^{-1}(Ncl(A))$.

4.5 Proposition

Let (X, T) and (Y, S) be any two neutrosophic topological spaces. If A is a Neutrosophic closed set in (X, T) and if $f : (X, T) \rightarrow (Y, S)$ is neutrosophic continuous and neutrosophic-closed then $f(A)$ is Neutrosophic closed in (Y, S) .

Proof.

Let G be a neutrosophic-open in (Y, S) . If $f(A) \subseteq G$, then $A \subseteq f^{-1}(G)$ in (X, T) . Since A is neutrosophic closed and $f^{-1}(G)$ is neutrosophic open in (X, T) , $Ncl(A) \subseteq f^{-1}(G)$, (i.e) $f(Ncl(A)) \subseteq G$. Now by assumption, $f(Ncl(A))$ is neutrosophic closed and $Ncl(f(A)) \subseteq Ncl(f(Ncl(A))) = f(Ncl(A)) \subseteq G$. Hence, $f(A)$ is N-closed.

4.5 Proposition

Let (X, T) and (Y, S) be any two neutrosophic topological spaces, If $f : (X, T) \rightarrow (Y, S)$ is neutrosophic continuous then it is N-continuous.

The converse of proposition 4.5 need not be true. See Example 4.3.

4.3 Example

Let $X = \{a, b, c\}$ and $Y = \{a, b, c\}$. Define neutrosophic sets A and B as follows $A = \langle (0.4, 0.4, 0.5), (0.2, 0.4, 0.3), (0.4, 0.4, 0.5) \rangle$

$$B = \langle (0.4, 0.5, 0.6), (0.3, 0.2, 0.3), (0.4, 0.5, 0.6) \rangle$$

Then the family $T = \{0_N, 1_N, A\}$ is a neutrosophic topology on X and $S = \{0_N, 1_N, B\}$ is a neutrosophic topology on Y . Thus (X, T) and (Y, S) are neutrosophic topological spaces. Define $f : (X, T) \rightarrow (Y, S)$ as $f(a) = b, f(b) = a, f(c) = c$. Clearly f is N-continuous. Now f is not neutrosophic continuous, since $f^{-1}(B) \notin T$ for $B \in S$.

4.4 Example

Let $X = \{a, b, c\}$. Define the neutrosophic sets A and B as follows.

$$A = \langle (0.4, 0.5, 0.4), (0.5, 0.5, 0.5), (0.4, 0.5, 0.4) \rangle$$

$B = \langle (0.7,0.6,0.5), (0.3,0.4,0.5), (0.3,0.4,0.5) \rangle$
and $C = \langle (0.5,0.5,0.5), (0.4,0.5,0.5), (0.5,0.5,0.5) \rangle$

$T = \{0_N, 1_N, A, B\}$

and $S = \{0_N, 1_N, C\}$ are neutrosophic topologies on X . Thus (X,T) and (X,S) are neutrosophic topological spaces. Define $f: (X,T) \rightarrow (X,S)$ as follows $f(a) = b, f(b) = b, f(c) = c$. Clearly f is N -continuous. Since

$D = \langle (0.6,0.6,0.7), (0.4,0.4,0.3), (0.6,0.6,0.7) \rangle$

is neutrosophic open in (X,S) , $f^{-1}(D)$ is not neutrosophic open in (X,T) .

4.6 Proposition

Let (X,T) and (Y,S) be any two neutrosophic topological space. If $f: (X,T) \rightarrow (Y,S)$ is strongly N -continuous then f is neutrosophic continuous.

The converse of Proposition 3.19 is not true. See Example 3.3

4.5 Example

Let $X = \{a,b,c\}$. Define the neutrosophic sets A and B as follows.

$A = \langle (0.9,0.9,0.9), (0.1,0.1,0.1), (0.9,0.9,0.9) \rangle$

$B = \langle (0.9,0.9,0.9), (0.1,0.1,0.1), (0.9,0.1,0.8) \rangle$

and $C = \langle (0.9,0.9,0.9), (0.1,0,0.1), (0.9,0.9,0.9) \rangle$

$T = \{0_N, 1_N, A, B\}$ and $S = \{0_N, 1_N, C\}$ are neutrosophic topologies on X . Thus (X,T) and (X,S) are neutrosophic topological spaces. Also define $f: (X,T) \rightarrow (X,S)$ as follows $f(a) = a, f(b) = c, f(c) = b$. Clearly f is neutrosophic continuous. But f is not strongly N -continuous. Since

$D = \langle (0.9,0.9,0.99), (0.05,0,0.01), (0.9,0.9,0.99) \rangle$

Is an Neutrosophic open set in (X,S) , $f^{-1}(D)$ is not neutrosophic open in (X,T) .

4.7 Proposition

Let (X,T) and (Y,S) be any two neutrosophic topological spaces. If $f: (X,T) \rightarrow (Y,S)$ is perfectly N -continuous then f is strongly N -continuous.

The converse of Proposition 4.7 is not true. See Example 4.6

4.6 Example

Let $X = \{a,b,c\}$. Define the neutrosophic sets A and B as follows.

$A = \langle (0.9,0.9,0.9), (0.1,0.1,0.1), (0.9,0.9,0.9) \rangle$

$B = \langle (0.99,0.99,0.99), (0.01,0,0), (0.99,0.99,0.99) \rangle$

And $C = \langle (0.9,0.9,0.9), (0.1,0.1,0.05), (0.9,0.9,0.9) \rangle$

$T = \{0_N, 1_N, A, B\}$ and $S = \{0_N, 1_N, C\}$ are neutrosophic topologies space on X . Thus (X,T) and (X,S) are neutrosophic topological spaces. Also define $f: (X,T) \rightarrow (X,S)$ as follows $f(a) = a, f(b) = f(c) = b$. Clearly f is strongly N -continuous. But f is not perfectly N continuous. Since $D = \langle (0.9,0.9,0.9), (0.1,0.1,0.1), (0.9,0.9,0.9) \rangle$

Is an Neutrosophic open set in (X,S) , $f^{-1}(D)$ is neutrosophic open and not neutrosophic closed in (X,T) .

4.8 Proposition

Let (X,T) and (Y,S) be any neutrosophic topological spaces. If $f: (X,T) \rightarrow (Y,S)$ is strongly neutrosophic continuous then f is strongly N -continuous.

The converse of proposition 3.23 is not true. See Example 4.7

4.7 Example

Let $X = \{a,b,c\}$ and Define the neutrosophic sets A and B as follows.

$A = \langle (0.9,0.9,0.9), (0.1,0.1,0.1), (0.9,0.9,0.9) \rangle$

$B = \langle (0.99,0.99,0.99), (0.01,0,0), (0.99,0.99,0.99) \rangle$

and $C = \langle (0.9,0.9,0.9), (0.1,0.1,0.05), (0.9,0.9,0.9) \rangle$

$T = \{0_N, 1_N, A, B\}$ and $S = \{0_N, 1_N, C\}$ are neutrosophic topologies on X . Thus (X,T) and (X,S) are neutrosophic topological spaces. Also define $f: (X,T) \rightarrow (X,S)$ as follows: $f(a) = a, f(b) = f(c) = b$. Clearly f is strongly N -continuous. But f is not strongly neutrosophic continuous. Since

$D = \langle (0.9,0.9,0.9), (0.1,0.1,0.1), (0.9,0.9,0.9) \rangle$

be a neutrosophic set in (X,S) , $f^{-1}(D)$ is neutrosophic open and not neutrosophic closed in (X,T) .

4.9 Proposition

Let $(X,T), (Y,S)$ and (Z,R) be any three neutrosophic topological spaces. Suppose $f: (X,T) \rightarrow (Y,S)$, $g: (Y,S) \rightarrow (Z,R)$ be maps. Assume f is neutrosophic gc -irresolute and g is N -continuous then $g \circ f$ is N -continuous.

4.10 Proposition

Let $(X,T), (Y,S)$ and (Z,R) be any three neutrosophic topological spaces. Let $f: (X,T) \rightarrow (Y,S)$, $g: (Y,S) \rightarrow (Z,R)$ be map, such that f is strongly N -continuous and g is N -continuous. Then the composition $g \circ f$ is neutrosophic continuous.

4.5 Definition

A neutrosophic topological space (X,T) is said to be neutrosophic $T_{1/2}$ if every Neutrosophic closed set in (X,T) is neutrosophic closed in (X,T) .

4.11 Proposition

Let $(X,T), (Y,S)$ and (Z,R) be any neutrosophic topological spaces. Let $f: (X,T) \rightarrow (Y,S)$ and $g: (Y,S) \rightarrow (Z,R)$ be mapping and (Y,S) be neutrosophic $T_{1/2}$ if f and g are N -continuous then the composition $g \circ f$ is N -continuous.

The proposition 4.11 is not valid if (Y,S) is not neutrosophic $T_{1/2}$.

4.8 Example

Let $X = \{a,b,c\}$. Define the neutrosophic sets A, B and C as follows.

$A = \langle (0.4,0.4,0.6), (0.4,0.4,0.3) \rangle$

$B = \langle (0.4,0.5,0.6), (0.3,0.4,0.3) \rangle$

and $C = \langle (0.4,0.6,0.5), (0.5,0.3,0.4) \rangle$

Then the family $T = \{0_N, 1_N, A\}$, $S = \{0_N, 1_N, B\}$ and $R = \{0_N, 1_N, C\}$ are neutrosophic topologies on X . Thus $(X, T), (X, S)$ and (X, R) are neutrosophic topological spaces. Also define $f : (X, T) \rightarrow (X, S)$ as $f(a) = b$, $f(b) = a$, $f(c) = c$ and $g : (X, S) \rightarrow (X, R)$ as $g(a) = b$, $g(b) = c$, $g(c) = b$. Clearly f and g are N -continuous function. But $g \circ f$ is not N -continuous. For $1 - C$ is neutrosophic closed in (X, R) . $f^{-1}(g^{-1}(1-C))$ is not N closed in (X, T) . $g \circ f$ is not N -continuous.

References

- [1] S. A. Alblowi, A. A. Salama and Mohamed Eisa, New Concepts of Neutrosophic Sets, International Journal of Mathematics and Computer Applications Research (IJMCAR), Vol. 3, Issue 3, Oct (2013) 95-102.
- [2] I. Hanafy, A.A. Salama and K. Mahfouz, Correlation of Neutrosophic Data, International Refereed Journal of Engineering and Science (IRJES), Vol.(1), Issue 2.(2012) PP.39-33
- [3] I.M. Hanafy, A.A. Salama and K.M. Mahfouz, "Neutrosophic Classical Events and Its Probability" International Journal of Mathematics and Computer Applications Research (IJMCAR) Vol.(3), Issue 1, Mar (2013) pp171-178.
- [4] A.A. Salama and S.A. Alblowi, "Generalized Neutrosophic Set and Generalized Neutrosophic Topological Spaces," Journal Computer Sci. Engineering, Vol. (2) No. (7) (2012) pp 129-132 .
- [5] A.A. Salama and S.A. Alblowi, Neutrosophic Set and Neutrosophic Topological Spaces, ISORJ. Mathematics, Vol.(3), Issue(3), (2012) pp-31-35.
- [6] A. A. Salama, "Neutrosophic Crisp Points & Neutrosophic Crisp Ideals", Neutrosophic Sets and Systems, Vol.1, No. 1, (2013) pp. 50-54.
- [7] A. A. Salama and F. Smarandache, "Filters via Neutrosophic Crisp Sets", Neutrosophic Sets and Systems, Vol.1, No. 1, (2013) pp. 34-38.
- [8] A.A. Salama, and H.Elagamy, "Neutrosophic Filters" International Journal of Computer Science Engineering and Information Technology Research (IJCEITR), Vol.3, Issue(1), Mar 2013, (2013) pp 307-312.
- [9] A.A. Salama and S.A. Alblowi, Intuitionistic Fuzzy Ideals Spaces, Advances in Fuzzy Mathematics , Vol.(7), Number 1, (2012) pp. 51- 60.
- [10] A. A. Salama, F.Smarandache and Valeri Kroumov "Neutrosophic Crisp Sets & Neutrosophic Crisp Topological Spaces" Bulletin of the Research Institute of Technology (Okayama University of Science, Japan), in January-February (2014). (Accepted)
- [11] Florentin Smarandache, Neutrosophy and Neutrosophic Logic, First International Conference on Neutrosophy , Neutrosophic Logic , Set, Probability, and Statistics University of New Mexico, Gallup, NM 87301, USA(2002).
- [12] F. Smarandache. A Unifying Field in Logics: Neutrosophic Logic. Neutrosophy, Neutrosophic Set, Neutrosophic Probability. American Research Press, Rehoboth, NM, (1999).
- [13] L.A. Zadeh, Fuzzy Sets, Inform and Control 8, (1965) 338-353.

Received: June 29, 2014. Accepted: July 6, 2014.