Neutrosophic Strongly *b*-Open Mapping Via Neutrosophic Topological Spaces

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Abstract

In this paper, we introduce the notion of strongly neutrosophic b-open function and strongly neutrosophic b-closed functions in neutrosophic topological spaces. Further, we give some properties of these functions and investigate some relations among them.

Keywords: Neutrosophic Set, Neutrosophic Topology, Neutrosophic Strongly *b*-Open Set

1. Introduction

A pair (W,τ), where W is a non-empty set and τ is a neutrosophic topology on W is called a neutrosophic topological space. Salama and Alblowi [1] was first introduced the concept of neutrosophic topological space. Salama and Alblowi [2] also studied generalized neutrosophic set and generalized neutrosophic topological spaces. Iswaraya and Bageerathi [15] introduced the concept of neutrosophic semi-open set and neutrosophic semi-closed set. Rao and Srinivasa [17] introduced neutrosophic pre-open set and pre-closed set. Arokiarani, Dhavaseelan, Jafari, and Parimala [13] defined some new functions in neutrosophic topological spaces. Andrijevic [8] introduced the concept of *b*-open set in topological space. Thereafter Tripathy and Sarma [6] studied on *b*-locally open sets in bitopological space. The concept of strongly *b*-open function and strongly *b*-closed function in topological space was introduced by Mustafa [14]. Afterwards Tripathy and Sarma [4] studied the concept of pairwise strongly *b*-open function and pairwise strongly *b*-closed function in bitopological spaces. In this paper, we introduce some properties of neutrosophic *b*-open function, strongly neutrosophic *b*-open function and strongly neutrosophic *b*-closed function in neutrosophic topological spaces.

2. Preliminaries

In this section we discuss some basic existing definitions and notions those are defined by many researchers.

Definition 2.1 [12] An neutrosophic set E over a non-empty set W is denoted as follows:

$E = \{(y, T_E(y), I_E(y), F_E(y)): y \in W$, and $T_E(y), I_E(y), F_E(y) \in]^-0,1^+[\}$, where $T_E(y)$, $I_E(y)$, $F_E(y)$ denotes the degree of truthness, indeterminacy, and falseness of each $y \in W$.

There is no restriction on the sum of $T_E(y)$, $I_E(y)$, $F_E(y)$, so

$$^{-}0 \leq T_E(y) + I_E(y) + F_E(y) \leq 3^{+}.$$

Definition 2.2 [13] Let p, q, r be real standard and non-standard subsets of $]^{-}0,1^{+}[$. A neutrosophic set $x_{p.q.r}$ is said to be a neutrosophic point (in short NP) in a non-empty set W given by

$x_{p.q.r}(y)=\begin{cases}(p,q,r), if\ x=y\\(0,0,1), if\ x\neq y\end{cases}$, for $y\in x$ is called the support of $x_{p.q.r}$; where p, q, r denotes the degree of truth, indeterminacy and falsity membership values of $x_{p.q.r}$.

Definition 2.3 [1] A family τ of neutrosophic sets (in short NS) over a non-empty set W is said to be a neutrosophic topology (in short NT) on W if the following properties holds:

(i) $0_N, 1_N \in \tau$
(ii) $T_1, T_2 \in \tau \Rightarrow T_1 \cap T_2 \in \tau$
(iii) $\cup T_i \in \tau$, for every $\{T_i: i\in\Delta\}\subseteq\tau$.

In that case, the pair (W,τ) is called a neutrosophic topological space (in short NTS). Each element of τ are called a neutrosophic open set (in short NOS) and the complement of each neutrosophic open set are called a neutrosophic closed set (in short NCS).

Remark 2.1 [2] The collection of all neutrosophic open set and neutrosophic closed set in a NTS (W,τ) may be denoted by NOS(W) and NCS(W) respectively.

Definition 2.4 [2] Assume that (W,τ) be a NTS and β be a NS over W. Then the neutrosophic interior and neutrosophic closure of β are defined by

$N_{int}(\beta) = \cup\{V : V$ is a NOS in W and $V \subseteq\beta\}$;

$N_{cl}(\beta) = \cap\{F : F$ is a NCS in W and $\beta \subseteq F\}$.

Definition 2.5 [13] Assume that (W,τ) be a NTS and E be a NS over W. Then E is said to be a neutrosophic neighbourhood of a neutrosophic point $x_{p.q.r}$ in (W,τ) if there exist a neutrosophic open set F in W such that $x_{p.q.r} \in F \subseteq E$.

Definition 2.6. Let (W,τ) be a NTS and G be a NS over W. Then β is called a

(i) [13] Neutrosophic α-open (Nα-O) set if and only if $\beta \subseteq N_{int}(N_{cl}(N_{int}(\beta)))$;

(ii) [15] Neutrosophic semi-open (NSO) set if and only if $\beta \subseteq N_{cl}(N_{int}(\beta))$;
(iii)[17] Neutrosophic pre-open (NPO) set if and only if $\beta\subseteq N_{int}(N_{cl}(\beta))$.
(iv) [10] Neutrosophic b-open (NBO) set if and only if $\beta \subseteq N_{int}(N_{cl}(\beta))\cup N_{cl}(N_{int}(\beta))$.

Remark 2.2. The collection of all Neutrosophic α-open, Neutrosophic semi-open, Neutrosophic pre-open, neutrosophic b-open sets and neutrosophic b-closed sets in a neutrosophic topological space (W,τ) may be denoted by Nα-O(W), NSO(W), NPO(W), NBO(W) and NBC(W) respectively. Clearly NOS(W)$\subseteq$NBO(W) and NCS(W)$\subseteq$ NBC(W).

Definition 2.7 [10] Let β be a NS over W and (W,τ) be a NTS. Then the neutrosophic b-interior and neutrosophic b-closure of β is defined by

(i) $N_{bint}(\beta) = \cup\{E : E$ is a NBO set in (W,τ) and $E \subseteq \beta\}$;

(ii) $N_{bcl}(\beta) = \cap\{F : F$ is a NBC set in (W,τ) and $\beta \subseteq F\}$.

Theorem 2.1 [13] Let ξ be a function from a NTS (W,τ_1) to another NTS (M,τ_2). Then ξ is called a

(i) neutrosophic open function if $\xi(K)$ is a neutrosophic open set in M, whenever K is a neutrosophic open set in W.
(ii) neutrosophic α-open function if $\xi(K)$ is a neutrosophic α-open set in M, whenever K is a neutrosophic open set in W.
(iii) neutrosophic pre-open function if $\xi(K)$ is a neutrosophic pre-open set in M, whenever K is a neutrosophic open set in W.
(iv) neutrosophic semi-open function if $\xi(K)$ is a neutrosophic semi-open set in M, whenever K is a neutrosophic open set in W.

Definition 2.8 [13] A function $\xi:(W,\tau_1)\rightarrow(M,\tau_2)$ is said to be an neutrosophic irresolute function if $\xi^{-1}(L)$ is neutrosophic closed set in W for every neutrosophic closed set L in M.

3. Neutrosophic strongly *b*-open function

In this section, we give some definitions and establish some results on neutrosophic *b*-open functions and neutrosophic strongly *b*-open functions via neutrosophic topological spaces.

Definition 3.1. A function $\xi:(W,\tau_1)\rightarrow(M,\tau_2)$ is said to be a neutrosophic *b*-open mapping if $\xi(K)$ is a neutrosophic *b*-open set in M for every neutrosophic open set K in W.

Definition 3.2. A function $\xi:(W,\tau_1)\rightarrow(M,\tau_2)$ is said to be a strongly neutrosophic *b*-open mapping if $\xi(K)$ is a neutrosophic *b*-open set in M for every neutrosophic *b*-open set K in W.

Definition 3.3. A function $\xi:(W,\tau_1)\rightarrow(M,\tau_2)$ is said to be a strongly neutrosophic *b*-closed mapping if $\xi(K)$ is a neutrosophic *b*-closed set in M for every neutrosophic *b*-closed set K in W.

Theorem 3.1. Let ξ be a function from a NTS (W,τ_1) to another NTS (M,τ_2). Then the following two statements are equivalent:
(i) ξ is neutrosophic *b*-open function.
(ii) For every neutrosophic point $x_{p,q,r} \in W$ and for each neutrosophic neighbourhood K of $x_{p,q,r}$ in W there exists a neutrosophic *b*-open set N in M such that $\xi(x_{p,q,r}) \in N \subset \xi(K)$

Proof. (i)$\Rightarrow$(ii) Let ξ be a neutrosophic *b*-open function from a NTS (W,τ_1) to another NTS (M,τ_2). Let $x_{p,q,r}$ be a neutrosophic point in W and K be a neutrosophic neighbourhood of $x_{p,q,r}$. Then there exists a neutrosophic open set H in W such that $x_{p,q,r} \in H \subseteq G$.
Now $x_{p,q,r} \in H \subseteq K$ implies that $\xi(x_{p,q,r}) \in \xi(H) \subseteq \xi(K)$. Since ξ is a neutrosophic *b*-open function so $\xi(H) = N$ (say) is a neutrosophic *b*-open set in M.
Thus for every neutrosophic point $x_{p,q,r}$ in W and for each neutrosophic neighbourhood K of $x_{p,q,r}$ in W there exists a neutrosophic *b*-open set $N = \xi(H)$ in M such that $\xi(x_{p,q,r}) \in N \subset \xi(K)$
(ii)$\Rightarrow$(i) Let B be a neutrosophic open set in W and $x_{p,q,r}$ be a neutrosophic point in W such that $x_{p,q,r} \in B$. Therefore $\xi(x_{p,q,r}) \in \xi(B)$.We know that every neutrosophic open set is a neutrosophic neighbourhood of each of its neutrosophic point. So B is the neutrosophic neighbourhood of $x_{p,q,r}$. Then by the hypothesis there exists a neutrosophic *b*-open set A in M such that $\xi(x_{p,q,r}) \in A \subset \xi(B)$. This implies that, for each neutrosophic point $\xi(x_{p,q,r})$ in $\xi(B)$ there exist a neutrosophic *b*-open set A in M such that $\xi(x_{p,q,r}) \in A \subset \xi(B)$. Therefore $\xi(B)$ is a neutrosophic *b* neighbourhood of each of its points. Hence $\xi(B)$ is a neutrosophic *b*-open set in M. Thus ξ is a neutrosophic *b*-open function.

Theorem 3.2.
(i) Every neutrosophic semi-open (neutrosophic pre-open) function is a neutrosophic *b*- open function.
(ii) Every neutrosophic open function is a neutrosophic *b*-open function.
(iii) Every neutrosophic α-open function is a neutrosophic *b*-open function.

Proof. (i) Let ξ be a neutrosophic semi-open (neutrosophic pre-open) function from a NTS (W,τ_1) to another NTS (M,τ_2) and P be a neutrosophic open set in W. Since ξ is a neutrosophic semi open (neutrosophic pre open) function, so $\xi(P)$ is a neutrosophic semi open (neutrosophic pre open) set in M. We know that every neutrosophic semi open (neutrosophic pre open) set is again a neutrosophic b-open set. So $\xi(P)$ is a neutrosophioc b-open set in M. Hence ξ is a neutrosophic b-open function.

(ii) The proof is similar to the proof of the first part of theorem 3.2.

(iii) Assume that ξ is a neutrosophic α-open function from a NTS (W,τ_1) to another NTS (M,τ_2) and let Q be a neutrosophic open set in W. Then by hypothesis $\xi(Q)$ is a neutrosophic α-open set in M. Since every neutrosophic α-open set is a neutrosophic semi open set and every neutrosophic semi open set is a neutrosophic b-open set, so $\xi(Q)$ is a neutrosophic b-open set in M. Hence ξ is a neutrosophic b-open function.

Theorem 3.1. Assume that ξ be a function from a NTS (W,τ_1) to another NTS (M,τ_2). If ξ is strongly neutrosophic b-open function then it is a neutrosophic b-open function (neutrosophic open function, neutrosophic pre-open function, neutrosophic semi-open function).

Proof. Let $\xi:(W,\tau_1)\rightarrow(M,\tau_2)$ be a strongly neutrosophic b-open function. Then the image of every neutrosophic b-open set in W is a neutrosophic b-open set in M. We know that $NO(W)\subseteq NBO(W)$. So the image of every neutrosophic open sets in W is a neutrosophic b-open set in M. Hence ξ is a neutrosophic b-open function.

Similarly it can be shown that every strongly neutrosophic b-open function is a neutrosophic open function, neutrosophic pre-open function and neutrosophic semi-open function respectively.

Theorem 3.2. Let $\xi:(W,\tau_1)\rightarrow(M,\tau_2)$ be a mapping between two NTSs. Then the following two statements are equivalent:

(i) ξ is a strongly neutrosophic b-open function.

(ii) $\xi(N_{bint}(K))\subseteq N_{bint}(\xi(K))$, for each NS K over W.

Proof. (i)$\Rightarrow$(ii) Let K be a neutrosophic subset of (W,τ_1). Since $N_{bint}(K)\subseteq K$ and $N_{bint}(K)$ is an neutrosophic b-open set, so $\xi(N_{bint}(K))\subseteq\xi(K)$. Again since ξ is a strongly neutrosophic b-open function, so we have $\xi(N_{bint}(K))$ is an neutrosophic b-open set in M. Also we know that $N_{bint}(\xi(K))$ is the largest neutrosophic b-open set in (M,τ_2) which is contained in $\xi(K)$. Hence $\xi(N_{bint}(K))\subseteq N_{bint}(\xi(K))$.

(ii)$\Rightarrow$(i) Let ξ be a function from a NTS (W,τ_1) to another NTS (M,τ_2) and for any neutrosophic subset K of (W,τ_1), $\xi(N_{bint}(K))\subseteq N_{bint}(\xi(K))$.

Let H be an neutrosophic b-open set in (W,τ_1). So $N_{bint}(H)=H$. This implies that $\xi(N_{bint}(H))=\xi(H)$. By hypothesis $\xi(N_{bint}(H))\subseteq N_{bint}(\xi(H))$. This implies that $\xi(H)\subseteq N_{bint}(\xi(H))$. We know that $N_{bint}(\xi(H))\subseteq\xi(H)$. Hence $\xi(H)\subseteq N_{bint}(\xi(H))$ i.e. $\xi(H)$ is an neutrosophic b-open set in M. Therefore ξ is a strongly neutrosophic b-open function.

Proposition 3.1. Let $\xi:(W,\tau_1)\rightarrow(M,\tau_2)$ be a mapping between two NTSs. Then ξ is a strongly neutrosophic b-open function iff $N_{bint}((\xi^{-1}(K))\subseteq\xi^{-1}(N_{bint}(K))$, for every NS K over M.

Proof. Let ξ be a strongly neutrosophic b-open function from a NTS (W,τ_1) to another NTS (M,τ_2). Let V be a neutrosophic subset of (M,τ_2). Since $N_{bint}((\xi^{-1}(V))$ is an neutrosophic b-open set in W, so $\xi(N_{bint}((\xi^{-1}(V)))$ is an neutrosophic b-open set in M.

Also, $N_{bint}((\xi^{-1}(V))\subseteq\xi^{-1}(V)$

$\Rightarrow \xi(N_{bint}((\xi^{-1}(V)))\subseteq\xi(\xi^{-1}(V))=V$

Again we know that $N_{bint}(V)$ is the largest neutrosophic b-open set in M contained in V.

Hence $\xi(N_{bint}((\xi^{-1}(V)))\subseteq N_{bint}(V)$. This implies that $N_{bint}((\xi^{-1}(V))\subseteq\xi^{-1}(N_{bint}(V))$.

Definition 3.4. A neutrosophic subset K of W is said to be a neutrosophic b-neighbourhood of a neutrosophic point $x_{p,q,r}$ of (W,τ) if there exists a neutrosophic b-open set H in (W,τ) such that $x_{p,q,r}\in H\subseteq K$.

Theorem 3.3. A function $\xi:(W,\tau_1)\rightarrow(M,\tau_2)$, where (W,τ_1) and (M,τ_2) are two NTSs, is a strongly neutrosophic b-open function iff for each neutrosophic point $x_{p,q,r}$ and for every neutrosophic b-neighbourhood H of $x_{p,q,r}$ in W there exists a neutrosophic b-open set N in M such that $\xi(x_{p,q,r})\in N\subset\xi(H)$

Proof. Let $\xi:(W,\tau_1)\rightarrow(M,\tau_2)$ be a strongly neutrosophic b-open function. Let $x_{p,q,r}$ be a neutrosophic point in W and H be any neutrosophic b-neighbourhood of $x_{p,q,r}$. Then there exist a neutrosophic b-open set K in (W,τ_1) such that $x_{p,q,r}\in K\subseteq H$. This implies that $\xi(x_{p,q,r})\in\xi(K)\subseteq\xi(H)$. Now since ξ is a strongly neutrosophic b-open function, so $\xi(K)$ is a neutrosophic b-open set in M. Hence there exist a neutrosophic b-open set $\xi(K)=N$ (say) in M such that $\xi(x_{p,q,r})\in N\subset\xi(H)$.

Conversely, let K be a neutrosophic b-open set in W and $x_{p,q,r}\in K$. Then K is a neutrosophic b-neighbourhood of $x_{p,q,r}$. Now by the hypothesis, there exist a neutrosophic b-neighbourhood L of $\xi(x_{p,q,r})$ such that $\xi(x_{p,q,r})\in L\subset\xi(K)$. Therefore $\xi(K)$ is a neutrosophic b-neighbourhood of each of its neutrosophic points. Hence $\xi(K)$ is a neutrosophic b-open set in M. Thus ξ is a strongly neutrosophic b-open function.

Definition 3.5. A function $\xi:(W,\tau_1)\rightarrow(M,\tau_2)$ is said to be an neutrosophic *b*-irresolute function if $\xi^{-1}(L)$ is neutrosophic *b*-open (neutrosophic *b*-closed) set in *W* for every neutrosophic *b*-open (neutrosophic *b*-closed) set *L* in *M*.

Theorem 3.4. Let ξ be a function from a NTS (W,τ_1) to another NTS (M,τ_2). If ξ is a bijective mapping then the following three statements are equivalent:

(i) ξ is strongly neutrosophic *b*-open function.

(ii) ξ is strongly neutrosophic *b*-closed function.

(iii) ξ^{-1} is neutrosophic *b*-irresolute function.

Proof. (i)$\Rightarrow$(ii) Let ξ be a strongly neutrosophic *b*-open function and *K* be a neutrosophic *b*-closed set in *W*. Then K^c is neutrosophic-b-open set in *W*. Since ξ is a strongly neutrosophic *b*-open function so $\xi(K^c)= (\xi(K))^c$ is neutrosophic *b*-open set in *M* and so $\xi(K)$ is neutrosophic *b*-closed set in ***M*****.** Hence ξ is a strongly neutrosophic *b*-closed function.

(ii)$\Rightarrow$(iii) Let ξ be a strongly neutrosophic *b*-closed function. Let *L* be any neutrosophic *b*-closed set in *W*. By hypothesis $\xi(L)$ is neutrosophic *b*-closed in *M*. Thus we have $(\xi^{-1})^{-1}(L) =\xi(L)$ is neutrosophic *b*-closed in *M*.
Similarly for any neutrosophic *b*-open set *K* in *W* it can be shown that $(\xi^{-1})^{-1}(K) =\xi(K)$ is a neutrosophic *b*-open set in *M*. Hence ξ^{-1} is a neutrosophic *b*-irresolute function.

(iii)$\Rightarrow$(i) Let ξ^{-1} be neutrosophic *b*-irresolute function and *K* be any neutrosophic *b*-open set in *W*. Since ξ^{-1} is a neutrosophic *b*-irresolute function, so $(\xi^{-1})^{-1}(K)= \xi(K)$ is a neutrosophic b-open in *M*. Therefore for any neutrosophic *b*-open set *K* in *W*, $\xi(K)$ is neutrosophic *b*-open set in *M*. Hence ξ is a strongly neutrosophic *b*-open function.

5. Conclusions

In this study, we introduce the notion of strongly neutrosophic *b*-open function and strongly neutrosophic *b*-closed functions in neutrosophic topological spaces. Further we also give some properties of these functions and investigate some relations among them. By defining strongly neutrosophic *b*-open function and strongly neutrosophic *b*-closed functions, we provide some remark, theorem on neutrosophic topological spaces. In the future, we hope that based on these notions in NTSs, many new investigations can be carried out.

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