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REMARKS ON GENERALIZED TOPOLOGIES INDUCED BY SUPRA-NEIGHBORHOOD SYSTEMS

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Abstract: We investigate some properties for the generalized topological space induced by a given supra-neighborhood system. And we introduce the notions of S_{I^*}-continuity and $(sn)^*$-continuity, and study the relations among S_{I^*}-continuity, $(sn)^*$-continuity and the other continui.

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1. Introduction

The notion of generalized neighborhood system (briefly *GNS*) was introduced by Császár in [1]. He also introduced the notion of (ψ, ψ')-continuity on generalized neighborhood systems ψ, ψ'. In the same way, we introduced and studied the notion of the weak neighborhood systems in [7]. In [3], we investigated supra-neighborhood systems and supra-neighborhood spaces in order to generalize the notions of GNS, weak neighborhood system [7] and neighborhood structure [2]. In [3], we also introduced the notions of operators ι, γ, i and c in supra-neighborhood spaces, and studied basic properties for such operators.

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Recently, we investigated two special operators I^* and Cl^* induced by a given supra-neighborhood system in [4]. In this paper, we are going to investigate the collection Ψ_{I^*} induced by the operator I^*. In particular, we introduce the notions of S_{I^*}-continuity and $(sn)^*$-continuity between the collections, and study the relations among S_{I^*}-continuity, $(sn)^*$-continuity, S^*n-continuity and $s^*(\psi,\phi)$-continuity.

2. Preliminaries

Let X be a nonempty set, $exp(X)$ the power set of X and $\psi : X \to exp(exp(X))$ satisfy $x \in V$ for $V \in \psi(x)$. Then $V \in \psi(x)$ is called *a generalized neighborhood* [1] of $x \in X$ and ψ is called *a generalized neighborhood system* (briefly *GNS*) on X. Let g be a collection of subsets of X. Then g is called *a generalized topology* [1] on X iff $\emptyset \in g$ and $G_i \in g$ for $i \in I \neq \emptyset$ implies $G = \cup_{i\in I} G_i \in g$. The elements of g are called *g-open sets* and the complements are called *g-closed sets*. For $A \subseteq X$, we denote by $i_g A$ the union of all g-open sets contained in A, i.e. the largest g-open set contained in A. Any intersection of g-closed sets is g-closed, and for $A \subseteq X$, we denote by $c_g A$ the intersection of all g-closed sets containing A, i.e. the smallest g-closed set containing A. Then a function $f : X \to Y$ is said to be *(g_X, g_Y)-continuous* [5] if for each g_Y-open set V in Y, $f^{-1}(V)$ is g_X-open in X.

Let $\psi : X \to exp(exp(X))$. Then ψ is called *a supra-neighborhood system* [3] on X if it satisfies the following:

(1) For $x \in X$, $\psi(x) \neq \emptyset$.

(2) For $V \in \psi(x)$, $x \in V$.

Then the pair (X, ψ) is called *a supra-neighborhood space* (briefly *SNS*) on X. Then $V \in \psi(x)$ is called *a supra-neighborhood* of $x \in X$.

Let (X, ψ) be an SNS on X and $G \subseteq X$. Then G is called an *S^*-open set* [3] if for each $x \in G$, there is $V \in \psi(x)$ such that $V \subseteq G$. Let us denote $S^*(X)$ the collection of all *S^*-open sets* on an SNS (X, ψ). The complements of S^*-open sets are called *S^*-closed sets*. Then we have shown that the collection $S^*(X)$ of all S^*-open subsets of X is a supratopology [5] on X, that is, $X \in S^*(X)$ and $S^*(X)$ is closed under arbitrary union.

We recall the notions of interior operators i, ι and closure operators c, γ introduced in [3], respectively: Let (X, ψ) be an SNS on X and $A \subseteq X$. Then

(1) $i(A) = \cup\{G \subseteq: G \subseteq A$ and $G \in S^*(X)$;

(2) $c(A) = \cap\{F \subseteq: A \subseteq F$ and $X - F \in S^*(X)$;

(3) $\iota(A) = \{x \in A :$ there exists $V \in \psi(x)$ such that $V \subseteq A\}$;

(4) $\gamma(A) = \{x \in X : V \cap A \neq \emptyset$ for all $V \in \psi(x)\}$.

Theorem 2.1 ([3]). *Let (X, ψ) be an SNS on X and $A \subseteq X$. Then*
(1) $i(A) \subseteq \iota(A) \subseteq A$;
(2) $A \subseteq \gamma(A) \subseteq c(A)$;
(3) A is S^*-open iff $i(A) = A$;
(4) A is S^*-closed iff $c(A) = A$.

Remark 2.2. Let (X, ψ) and (Y, ϕ) be two SNS's. Then $f : X \to Y$ is said to be

(1) *$s^*(\psi, \phi)$-continuous* [3] if for each $x \in X$ and $V \in \phi(f(x))$, there is $U \in \psi(x)$ such that $f(U) \subseteq V$;
(2) *sn-continuous* [3] if for every $A \in S^*(Y)$, $f^{-1}(A)$ is in $S^*(X)$;
(3) *S^*n-continuous* [4] if for every $A \in \phi(f(x))$, $f^{-1}(A)$ is in $\psi(x)$.

$$S^*n\text{-continuous} \Rightarrow s^*(\psi, \phi)\text{-continuous} \Rightarrow sn\text{-continuous}$$

3. Main Results

We recall two special operators I^* and Cl^* introduced in [4]: Let (X, ψ) be an SNS and $A \subseteq X$.

$$I^*(A) = \{x \in A : A \in \psi(x)\}; \quad Cl^*(A) = \{x \in X : X - A \notin \psi(x)\}.$$

In [4], we showed that the operators satisfy $I^*(A) \subseteq A \subseteq Cl^*(A)$ but the following statements are not always true:
(1) If $A \subseteq B$, then $I^*(A) \subseteq I^*(B)$; $Cl^*(A) \subseteq Cl^*(B)$.
(2) $I^*(A) \cap I^*(B) = I^*(A \cap B)$; $Cl^*(A) \cup Cl^*(B) = Cl^*(A \cup B)$.
(3) $I^*(I^*(A)) = I^*(A)$; $Cl^*(Cl^*(A)) = Cl^*(A)$.

From now on, we study the collection induced by the operator I^*:

Definition 3.1. *Let (X, ψ) be an SNS on X and $\Psi_{I^*}(X) = \{\cup\sigma : \sigma \subseteq \mathbf{B}\}$ where $\mathbf{B} = \{A \subseteq X : I^*(A) = A\}$. For $G \subseteq X$, G is called an S_{I^*}-open set if $G \in \Psi_{I^*}(X)$.*

The complements of S_{I^*}-open sets are called S_{I^*}-closed sets. Set $\Psi_{I^*}(x) = \{G \in \Psi_{I^*}(X) : x \in G\}$.

Remark 3.2. Let (X, ψ) be an SNS on X. Then clearly $\Psi_{I^*}(X)$ is a generalized topology on X but it need not be a supra-topology (See Example 3.16 in [4]).

Definition 3.3. *Let (X, ψ) be an SNS on X and $A \subseteq X$. The S_{I^*}-interior of A, denoted by $i^*(A)$, is the union of all $G \subseteq A$, $G \in \Psi_{I^*}(X)$, and the S_{I^*}-closure of A, denoted by $c^*(A)$, is the intersection of all S_{I^*}-closed sets containing A.*

Theorem 3.4. *Let (X, ψ) be an SNS on X and $A \subseteq X$. Then the following hold.*
(1) $i^*(A) \subseteq i(A) \subseteq A$;
(2) $A \subseteq c^*(A) \subseteq c(A)$;
(3) A is S_{I^*}-open if and only if $i^*(A) = A$;
(4) A is S_{I^*}-closed if and only if $c^*(A) = A$.

Proof. (1) We show that $i^*(A) \subseteq i(A)$. Let $x \in i^*(A)$. Then there exists an S_{I^*}-open set G such that $x \in G \subseteq A$. From the definition of S_{I^*}-openness, there is a family $\sigma = \{U \subseteq X : I^*(U) = U\}$ such that $G = \cup\sigma$. Let $U \in \sigma$. For each $z \in U$, from $z \in U = I^*(U)$, it follows $U \in \psi(z)$ and $z \in i(U)$, and so U is S^*-open. This implies G is S^*-open and $x \in i(A)$. So from Theorem 2.1, the inclusion relations are completed.
(2) It is similar to (1).
(3) and (4) are obvious. □

Example 3.5. Let $X = \{a, b, c, d\}$ and $\psi : X \to exp(exp(X))$ a supra-neighborhood system defined as the following: $\psi(a) = \{\{a, c\}\}$, $\psi(b) = \{\{b\}\}$, $\psi(c) = \psi(d) = \{X\}$. Then for $A = \{a, b, c\} \subseteq X$, $i(A) = \{a, b\}$ and $i^*(A) = \emptyset$, and so $i^*(A) \neq i(A)$.

Theorem 3.6. *Let (X, ψ) be an SNS on X. Then every S_{I^*}-open set is S^*-open.*

Proof. Let $A \subseteq X$ be an S_{I^*}-open set. From (1) and (3) of Theorem 3.4, $i(A) = A$ is obtained. It implies A is S^*-open. □

We recall the notion of m-family [6]: A collection $\mathbf{H}$ of subsets of X is called an *m-family* on X if $\cap\mathbf{H} = \cap\{G : G \in \mathbf{H}\} \neq \emptyset$.

Definition 3.7. *Let (X, ψ) be an SNS and let $\mathbf{H}$ be an m-family on X. Then we say that an m-family $\mathbf{H}$ s^*-converges to $x \in X$ if $\Psi_{I^*}(x) \subseteq \mathbf{H}$.*

Theorem 3.8. *Let (X, ψ) be an SNS and $A \subseteq X$. Then the following hold.*
(1) $i^*(A) = \{x \in A : A \in \mathbf{H}$, for every m-family $\mathbf{H}$ s^*-converging to $x\}$.
(2) $c^*(A) = \{x \in X :$ there exists an m-family $\mathbf{H}$ such that $\mathbf{H}$ s^*-converges to x and $A \in \mathbf{H}\}$.

Proof. (1) Let $x \in i^*(A)$ and an m-family $\mathbf{H}$ s^*-converge to x. Then it is obvious that $A \in \Psi_{I^*}(x) \subseteq \mathbf{H}$.

Suppose that for every m-family $\mathbf{H}$ s^*-converging to x, $A \in \mathbf{H}$. Since $\Psi_{I^*}(x)$ s^*-converges to x, by hypothesis, $A \in \Psi_{I^*}(x)$, so that $x \in i^*(A)$.

(2) Let $x \in Cl^*(A)$; then for all $V \in \Psi_{I^*}(x)$, $V \cap A \neq \emptyset$. Set $\mathbf{H} = \Psi_{I^*}(x) \cup \{A\}$; then $\mathbf{H}$ is an m-family s^*-converging to x such that $A \in \mathbf{H}$.

For the converse, let $\mathbf{H}$ be an m-family s^*-converging to x and $A \in \mathbf{H}$; then since $\Psi_{I^*}(x)$ is contained in $\mathbf{H}$, by definition of m-family, $V \cap A \neq \emptyset$ for all $V \in \Psi_{I^*}(x)$. Hence $x \in c^*(A)$. □

Theorem 3.9. *Let (X, ψ) be a generalized topological space and $A \subseteq X$. Then the following hold.*

(1) $i_g(A) = \{x \in A : A \in \mathbf{H}$, for every m-family $\mathbf{H}$ s^*-converging to $x\}$.

(2) $c_g(A) = \{x \in X :$ there exists an m-family $\mathbf{H}$ such that $\mathbf{H}$ s^*-converges to x and $A \in \mathbf{H}\}$.

Proof. First, for $A \subseteq X$, we know that $i^*(A)$ ($c^*(A)$) is generalized open (generalized close), since the family $\Psi_{I^*} = \{\cup\sigma : \sigma \subseteq \mathbf{B}\}$ is a generalized topology. So from Theorem 3.8, the above statements (1) and (2) are directly obtained. □

Definition 3.10. *Let $f : X \to Y$ be a function on two SNS's (X, ψ) and (Y, ϕ). Then f is said to be S_{I^*}-continuous if for every $A \in \Phi_{I^*}(Y)$, $f^{-1}(A)$ is in $\Psi_{I^*}(X)$.*

Theorem 3.11. *Let $f : X \to Y$ be a function on two SNS's (X, ψ) and (Y, ϕ). Then the following things are equivalent:*

(1) f is S_{I^*}-continuous.

(2) For each S_{I^*}-closed set F in Y, $f^{-1}(F)$ is S_{I^*}-closed in X.

(3) $f(c^*(A)) \subseteq c^*(f(A))$ for all $A \subseteq X$.

(4) $c^*(f^{-1}(B)) \subseteq f^{-1}(c^*(B))$ for all $B \subseteq Y$.

(5) $f^{-1}(i^*(B)) \subseteq i^*(f^{-1}(B))$ for all $B \subseteq Y$.

(6) $f : (X, \Psi_{I^*}(X)) \to (Y, \Phi_{I^*}(Y))$ is $(\Psi_{I^*}(X), \Phi_{I^*}(Y))$-continuous.

Proof. Obvious. □

Corollary 3.12. *Let $f : X \to Y$ be a function on generalized topological spaces (X, g_X) and (Y, g_Y). Then the following things are equivalent:*

(1) f is (g_X, g_Y)-continuous.

(2) For each g-closed set F in Y, $f^{-1}(F)$ is g-closed in X.

(3) $f(c_g(A)) \subseteq c_g(f(A))$ for all $A \subseteq X$.
(4) $c_g(f^{-1}(B)) \subseteq f^{-1}(c_g(B))$ for all $B \subseteq Y$.
(5) $f^{-1}(i_g(B)) \subseteq i_g(f^{-1}(B))$ for all $B \subseteq Y$.

Proof. Since $\Psi_{I^*}(X)$ and $\Phi_{I^*}(Y)$ are generalized topologies on X and Y, respectively, the corollary is obtained from Theorem 3.11. □

Theorem 3.13. *Let $f : X \to Y$ be a function on two SNS's (X, ψ) and (Y, ϕ). If f is S^*n-continuous, then it is also S_{I^*}-continuous.*

Proof. Let $A \in \Phi_{I^*}(Y)$. Then $A = \cup A_\alpha$ where $I^*(A_\alpha) = A_\alpha$. First, we show that for each α, $I^*(f^{-1}(A_\alpha)) = f^{-1}(A_\alpha)$. For the proof, let $x \in f^{-1}(A_\alpha)$; then $f(x) \in A_\alpha = I^*(A_\alpha)$, and $A_\alpha \in \phi(f(x))$. From S^*n-continuity of f, it is obtained $f^{-1}(A_\alpha) \in \psi(x)$. It implies $x \in I^*(f^{-1}(A_\alpha))$ and $I^*(f^{-1}(A_\alpha)) = f^{-1}(A_\alpha)$. From this fact, we have $f^{-1}(A) = \cup f^{-1}(A_\alpha)$ such that $I^*(f^{-1}(A_\alpha)) = f^{-1}(A_\alpha)$. Consequently, $f^{-1}(A)$ is S_{I^*}-open, that is, $f^{-1}(A) \in \Psi_{I^*}(X)$. □

In the next example, we can show that the converse is not always true:

Example 3.14. Let $X = \{a, b, c, d\}$ and let $\psi : X \to exp(exp(X))$ be a supra-neighborhood system defined as Example 3.5. Consider a function $f : (X, \psi) \to (X, \psi)$ as follows $f(a) = a, f(b) = b, f(c) = d, f(d) = c$.
Then f is S_{I^*}-continuous but not S^*n-continuous.

Moreover, we can show that there is no any relation between S_{I^*}-continuity and $s^*(\psi, \phi)$-continuity as in the next example:

Example 3.15. Let $X = \{a, b, c, d\}$ and let $\psi : X \to exp(exp(X))$ be a supra-neighborhood system defined as Example 3.5.

(1) Let us define the function $f : (X, \psi) \to (X, \psi)$ as follows

$$f(a) = a, f(b) = b, f(c) = d, f(d) = c.$$

Then f is S_{I^*}-continuous. For $a \in X$ and $V = \{a, c\} \in \psi(f(a))$, since $\{a, c\} \in \psi(a)$ and $f(\{a, c\}) = \{a, d\}$, there is no $U \in \psi(a)$ such that $f(U) \subseteq V$, so f is not $s^*(\psi, \psi)$-continuous.

(2) Let us define the function $f : (X, \psi) \to (X, \psi)$ as follows

$$f(a) = f(c) = b, f(b) = c, f(d) = d.$$

Then f is $s^*(\psi, \psi)$-continuous. For the S_{I^*}-open set $G = \{b\}$, $f^{-1}(G) = \{a, c\}$ and it is not S_{I^*}-open. So f is not S_{I^*}-continuous.

In the next examples, we show that there is no any relationship between S_{I^*}-continuity and sn-continuity:

Example 3.16. Let $X = \{a,b,c,d\}$. Consider a supra-neighborhood system $\psi : X \to exp(exp(X))$ defined as the following: $\psi(a) = \{\{a,b\}\}$, $\psi(b) = \psi(c) = \{\{b,c\}\}$, and $\psi(d) = \emptyset$. Note that $\Psi_{I^*}(X) = \{\emptyset, \{b,c\}\}$ and $S^*(X) = \{\emptyset, \{b,c\}, \{a,b,c\}\}$.

(1) Let us define the function $f : (X,\psi) \to (X,\psi)$ as the following:

$$f(a) = a, f(b) = c, f(c) = b, f(d) = a.$$

Then f is S_{I^*}-continuous, but it is not sn-continuous.

(2) Let us define the function $g : (X,\psi) \to (X,\psi)$ as the following:

$$g(a) = c, g(b) = c, g(c) = b, g(d) = d.$$

Then g is sn-continuous, but it is not S_{I^*}-continuous.

Finally, from the above examples and Remark 2.3, the following diagram is obtained:

S^*n-continuous $\Rightarrow$ $s^*(\psi,\phi)$-continuous $\Rightarrow$ sn-continuous
$\Downarrow$
S_{I^*}-continuous

Theorem 3.17. *Let $f : X \to Y$ be a bijective function between SNS's (X,ψ) and (Y,ϕ). Then f is S_{I^*}-continuous iff for an m-family $\mathbf{H}$ s^*-converging to $x \in X$, $f(\mathbf{H})$ s^*-converges to $f(x)$.*

Proof. Suppose f is S_{I^*}-continuous and $\mathbf{H}$ is an m-family s^*-converging to $x \in X$. It is obvious $f(\mathbf{H}) = \{f(F) : F \in \mathbf{H}\}$ is an m-family on Y. By hypothesis and surjectivity, we get $\Phi_{I^*}(f(x)) \subseteq f(\Psi_{I^*}(x)) \subseteq f(\mathbf{H})$, so that $f(\mathbf{H})$ s^*-converges to $f(x)$.

For the converse, let $G \in \Phi_{I^*}(f(x))$ for $G \subseteq Y$. Since $\Psi_{I^*}(x)$ s^*-converges to x, by hypothesis, we get $\Phi_{I^*}(f(x)) \subseteq f(\Psi_{I^*}(x))$ for $x \in X$. Since f is injective, $f^{-1}(G) \in \Psi_{I^*}(x)$. Hence f is S_{I^*}-continuous. □

From Theorem 3.17, we have the following:

Corollary 3.18. *Let $f : X \to Y$ be a bijective function between generalized topological spaces (X, g_X), (Y, g_Y). Then f is (g_X, g_Y)-continuous iff for an m-family $\mathbf{H}$ s^*-converging to $x \in X$, $f(\mathbf{H})$ s^*-converges to $f(x)$.*

Definition 3.19. *Let $f : X \to Y$ be a function on two SNS's (X,ψ) and (Y,ϕ). Then f is said to be $(sn)^*$-continuous if for every S_{I^*}-open set A in Y, $f^{-1}(A)$ is S^*-open in X.*

Theorem 3.20 ([3]). *Let $f : X \to Y$ be a function on two SNS's (X, ψ) and (Y, ϕ). Then the following things are equivalent:*
(1) f is sn-continuous.
(2) For each S^*-closed set F in Y, $f^{-1}(F)$ is S^*-closed in X.
(3) $f(c(A)) \subseteq c(f(A))$ for all $A \subseteq X$.
(4) $c(f^{-1}(B)) \subseteq f^{-1}(c(B))$ for all $B \subseteq Y$.
(5) $f^{-1}(i(B)) \subseteq i(f^{-1}(B))$ for all $B \subseteq Y$.

Theorem 3.21. *Let $f : X \to Y$ be a function on two SNS's (X, ψ) and (Y, ϕ). Then the following things are equivalent:*
(1) f is $(sn)^*$-continuous.
(2) For each S_{I^*}-closed set F in Y, $f^{-1}(F)$ is S^*-closed in X.
(3) $f(c(A)) \subseteq c^*(f(A))$ for all $A \subseteq X$.
(4) $c(f^{-1}(B)) \subseteq f^{-1}(c^*(B))$ for all $B \subseteq Y$.
(5) $f^{-1}(i^*(B)) \subseteq i(f^{-1}(B))$ for all $B \subseteq Y$.

Proof. It follows from Theorem 3.11 and Theorem 3.20. □

Theorem 3.22. *Let $f : X \to Y$ be a function on two SNS's (X, ψ) and (Y, ϕ). Then:*
(1) If f is S_{I^*}-continuous, then it is also $(sn)^*$-continuous.
(2) If f is sn-continuous, then it is also $(sn)^*$-continuous.

Proof. It is obvious from Theorem 3.6 and definitions of such continuous functions. □

In Theorem 3.22, the converses may not be true as the next example:

Example 3.23. Let $X = \{a, b, c, d\}$. Consider a supra-neighborhood system $\psi : X \to exp(exp(X))$ defined as the following: $\psi(a) = \{\{a, b\}\}$, $\psi(b) = \psi(c) = \{\{b, c\}\}$, and $\psi(d) = \emptyset$. Note that $\Psi_{I^*}(X) = \{\emptyset, \{b, c\}\}$ and $S^*(X) = \{\emptyset, \{b, c\}, \{a, b, c\}\}$.
(1) Let us define the function $f : (X, \psi) \to (X, \psi)$ as follows
$$f(a) = b, f(b) = b, f(c) = b, f(d) = a.$$
Then f is $(sn)^*$-continuous, but it is not sn-continuous.

(2) Let us define the function $g : (X, \psi) \to (X, \psi)$ as follows
$$g(a) = c, g(b) = c, g(c) = b, g(d) = d.$$
Then g is $(sn)^*$-continuous, but it is not S_{I^*}-continuous.

In summary, we have the following implications:

$$\begin{array}{ccccc} S^*n\text{-continuous} & \Rightarrow & s^*(\psi,\phi)\text{-continuous} & \Rightarrow & sn\text{-continuous} \\ \Downarrow & & & & \Downarrow \\ S_{I^*}\text{-continuous} & & \Rightarrow & & (sn)^*\text{-continuous} \end{array}$$

4. Conclusion

We investigated some properties for the generalized topology induced by a given supra-neighborhood system on X. And we introduced the notions of S_{I^*}-continuity and $(sn)^*$-continuity, and studied the relations among S_{I^*}-continuity, $(sn)^*$-continuity, S^*n-continuity and $s^*(\psi,\phi)$-continuity. In the next research, we are going to study a soft generalized topological unverse induced by soft supra-neighborhood systems on a universe set, and investigate soft S_{I^*}-continuity and soft $(sn)^*$-continuity.

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