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I – CONTINUOUS - FUNCTIONS AND I* –C CONTINUOUS –FUNCTIONS ON INFRA TOPOLOGICAL SPACES

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ABSRACT

In this paper, we introduced a new class of function called I-continuous functions and $\boldsymbol{I}^{*}$ *–continuous functions on infra Topological Spaces. We obtain several characterizations and some of their properties.*

Keywords and phrases: *Infra –Topological Space,* ***I*** *-continuous functions and* $\boldsymbol{I}^{*}$ *–continuous functions.*

1. INTRODUCTION

In 1983, A.S. Mashhour *et al*. [2] introduced the supra topological spaces and studied S-Continuous function and S^{*}-Continuous functionon supra topological spaces. In this paper we introduced I-Continuous Functions and $\mathrm{I}^{*}-$ continuous functionson Infra -Topological Space (ITS) [1]. The analogue concepts associated with infra- topological space. Such as, infra- derived set (resp .infra-closure, infra-interior, infra-exterior and infra-boundary) of subset A of infra-space X will be denoted by $ids(A)$ (resp. $icp(A), iip(A), iep(A)$ and $ibp(A)$) and studied by our work in [1]. As we shown, Various concepts like the interior, closure, derived set and boundary operators as well as set properties can be defined in infra topological space in analogy with topological spaces. At the same times many results of topological spaces Still valid in infra topological spaces, whereas some become invalid.

2. PRELIMINARIES

Definition 2.1 [1]: Let X be any arbitrary set. An *Infra -topology* on X is a collection τ_{iX} of subsets of X such that the following axioms are satisfying,
Ax-1 $\emptyset, X \in \tau_{iX}$, .
Ax-2 The intersection of the elements of any sub collection of τ_{iX} in τ_{iX}.i.e,

$$If\ O_i \in \tau_{iX}, \qquad 1 \le i \le n \rightarrow \bigcap O_i \in \tau_{iX}.$$

The ordered pair (X, τ_{iX}) is called ***I**nfra- Topological Space* (ITS), we simply say X is a *Infra -space*.

Definition 2.2[1]: Let (X, τ_{iX}) be an (ITS) and $A \subset X$. A is called *infra -open set* (IOS) if $A \in \tau_{iX}$.

Theorem 2.1[1]: Let (X, τ_X) be a *topological –space* (TS), then (X, τ_{iX}) is an *infra-topological space* (IITS)**.** But the conversely is not true.

Theorem 2.2[1]: Let (X, τ_{iX}) be *infra-topological space*. Then:
1. $\emptyset, X$ are *infra -open set.*
2. Any arbitrary intersections of infra- open sets are infra- open sets.
3. Finite union of infra- *open* sets may not be infra- *open* sets.

Theorem 2.3[1]: let (X, τ_{iX}) and $(X, {\tau_{iX}}^{*})$ be two*infra topological Spaces* on set X. Then the intersection τ_{iX} and ${\tau^{*}}_{its}$ is an *infra topological space*.

Theorem 2.4[1]: let (X, τ_{iX}) and $(X, {\tau_{iX}}^{*})$ be two*infra topological Spaces* on set X.Then the unionτ_{iX} and ${\tau^{*}}_{its}$ is an*infra topological space*.

Remark: In topological space the union of two topological spaces may not be topological space.

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3. INFRA-CONTINUOUS FUNCTIONS OR BRIEFLY I-CONTINUOUS FUNCTIONS

Definition 3.1: Let (X, τ_X) be *topological space* and (X, τ_{iX}) be infra-topological Space**.** We say that$\tau_{iX}$is infra-topological space associated with τ, if $\tau_{iX} \subset \tau_X$.That is, τ_X is finer than τ_{iX} or τ_{iX} is coarser than τ_X.

Definition 3.2: Let (X, τ_X) and (Y, τ_Y) be represent two topological Spaces and τ_{iX}be associated infra-topologyspace withτ_X. A function $f: X \to Y$ is called I-continuous function at $x \in X$, if for all open set O containing $f(x)$ in Y, then there exists infraopen set U containing x in τ_{iX} such that $f(U) \subset O$.

Remark:

1. we say that f is an I-continuous function on $A \subset X$,if f is an I-continuous function at all points of A.
2. we say that f is an I-continuous function on X, if f is an I-continuous function at all points of X.

Example 3.1: Let (X, τ_X) and (Y, τ_Y) represents two topological Spaces such that, $X = \{a, b, c\}, Y = \{1,2,3\}$,
$\tau_X = \{\emptyset, X, \{a\}, \{b\}, \{a, b\}, \{a, c\}\}$, $\tau_Y = \{\emptyset, Y, \{1\}, \{2\}, \{1,2\}, \{1,3\}\}and\tau_{iX} = \{\emptyset, X, \{a\}, \{b\}\}$. Define
$f: X \to Y \ni f(a) = f(c) = 1, f(b) = 2$. It is clear that f is *I*-continuous function.

Example 3.2: Let (X, τ_X) and (Y, τ_Y) represents two topological Space such that:
$X = \{a, b, c\}, \tau_X = \{\emptyset, X, \{a\}, \{b\}, \{a, b\}, \{a, c\}\}, Y = \{1,2,3\}, \tau_Y = \{\emptyset, Y, \{1,2\}\}. \tau_{iX} = \{\emptyset, X, \{a\}, \{b\}\}$.
Define $f: X \to Y \ni f(a) = 1, f(b) = 2, f(c) = 3$. So that f is not *I*-continuous function.

Theorem 3.1: Let$f: (X, \tau_X) \to (Y, \tau_Y)$be a function between two topological spaces and τ_{iX} be infra-topological space associated with τ_X. Then the following statements are equivalents.

1. f is an I-continuous function.
2. The inverse image of each open set in Y is an τ_{iX}-infraopen set in X.
3. The inverse image of each closed set in Y is τ_{iX}- infraclosed set in X.

Proof:
1⇒ 2. Suppose that$f$isan I-continuous function. Let O be an open set in Y. To show that $f^{-1}(O) \in \tau_{iX}$. Assume that $a \in f^{-1}(O) \to f(a) \in O$. since f is an I-continuous function at $a \in X$, implies that, there exists infraopen set U containing a in τ_{iX} such that $f(U) \subset O$. Therefore $a \in U \subset f^{-1}(O)$. Hence $f^{-1}(O)$ is an infraopen set in X.

2⇒ 3. Let $C \subset Y$ be a closed set in Y. Then $Y - C$ is open set in Y, implies that:
$f^{-1}(Y - C) = f^{-1}(Y) - f^{-1}(C) = X - f^{-1}(C)$ is infraopen set in X. Therefore $f^{-1}(C)$ is infraclosed setin X.

3⇒ 1. Suppose that $f^{-1}(C)$ is infraclosed set in X for all closed set $C \subset Y$. Let $O \subset Y$ be an open set, then $Y - O$ is closed set in Y, then : $f^{-1}(Y - O) = f^{-1}(Y) - f^{-1}(O) = X - f^{-1}(O)$ is infraclosed set in X ,so $f^{-1}(O)$ is infraopen set in X, consequently, f is I-Continuous function.

Theorem 3.2: Let $f: (X, \tau_X) \to (Y, \tau_Y)$ and $g: (Y, \tau_Y) \to (Z, \tau_Z)$ be two *I*-continuous function**,** then**:** $gf: (X, \tau_X) \to (z, \tau_Z)$ is an *I*-continuous function.

Proof: Suppose that$f: (X, \tau_X) \to (Y, \tau_Y)$ and $g: (Y, \tau_Y) \to (Z, \tau_Z)$ are *I*-continuous function. Let O be an open subset of Z. Since gI-continuous function, implies that:$g^{-1}(O) \in \tau_{iY}$ – infraopen set in Y. But $\tau_{iY} \subset \tau_Y$. Therefore $g^{-1}(O) \in \tau_Y$ is an open set in Y. Also f *I*-continuous function, implies that $f^{-1}g^{-1}(O) \in \tau_{iX}$ – infraopen set in X, But $(gf)^{-1}(O) = f^{-1}g^{-1}(O) \in \tau_{iX}$ –infraopen set in X whenever O is an open subset of Z. Hence gf is *I*-continuous function.

Note that: If$f: (X, \tau_X) \to (Y, \tau_Y)$ and $g: (Y, \tau_Y) \to (Z, \tau_Z)$be two *S*-continuous function**,** then$gf: (X, \tau_X) \to (z, \tau_Z)$may not be *S*-continuous function [2].

Theorem 3.3: Let $f: (X, \tau_X) \to (Y, \tau_Y)$be a constant function between two topological spaces and τ_{iX}be infra-topological space associated with τ_X. Then the constant function is an *I*-continuous function.

Proof: Suppose that$f: (X, \tau_X) \to (Y, \tau_Y)$ be a constant function, then there exists $y_0 \in Y$ such that $f(x) = y_0, \forall\, x \in X$.
Let O be an open subset of Y, then $f^{-1}(O) = \begin{cases} X, if\ y_0 \in O \\ \emptyset, if\ y_0 \notin O \end{cases}$.
Since$X$ and $\emptyset$ are infraopen sets, therefore gI-continuous function, implies that:$g^{-1}(O) \in \tau_{iY}$ – infraopen set in Y. But $\tau_{iY} \subset \tau_Y$. Therefore$f$ is an *I*-continuous function.

Theorem 3.4: Let $f: (X, \tau_X) \to (Y, \tau_Y)$ be an *I*-continuous function and$g: (Y, \tau_Y) \to (Z, \tau_Z)$is a continuous function, then$gf: (X, \tau_X) \to (z, \tau_Z)$ is an *I*-continuous function.

Proof: Suppose that O is an open subset of Z. S since g is a continuous function, then $g^{-1}(O) \in \tau_Y$is an open set in Y, implies that $f^{-1}g^{-1}(O) \in \tau_{iX}$ − infraopen set in X, But $(gf)^{-1}(O) = f^{-1}g^{-1}(O) \in \tau_{iX}$, whenever $O$is an open set Z. so that gf is an *I*-continuous function .

Note that:

1. If $f:(X,\tau_X) \to (Y,\tau_Y)$ is an *S*-continuous function and$g:(Y,\tau_Y) \to (Z,\tau_Z)$is a continuous function**,** then $gf:(X,\tau_X) \to (z,\tau_Z)$is a *S*-continuous function [2].
2. If $f:(X,\tau_X) \to (Y,\tau_Y)$ is a continuous function and $g:(Y,\tau_Y) \to (Z,\tau_Z)$is an *I*- continuous function**,** then $gf:(X,\tau_X) \to (z,\tau_Z)$is a continuous function.

Theorem 3.5: Let $f:(X,\tau_1) \to (X,\tau_2)$ be the identity function, where $f(x) = x, \forall x \in X$. Let ${\tau_1}^*$ associated infra-topology with τ_1, then f is called*I*-continuous function if and only if $\tau_2 \subset {\tau_1}^*$**.** (${\tau_1}^*$ is finer than τ_2).

Proof:⟹: Suppose that f is *I*-continuous function. To show that $\tau_2 \subset {\tau_1}^*$. Let O be an open set in τ_2, then $f^{-1}(O) = O$ be infraopen set in ${\tau_1}^*$. Hence $\tau_2 \subset {\tau_1}^*$.⟸: Suppose that $f:(X,\tau_1) \to (X,\tau_2)$ is the identity function, where, $f(x) = x, \forall x \in X \; and \; \tau_2 \subset {\tau_1}^*. Now\ Let\ O\ be\ an\ open\ set\ in\ \tau_2, then f^{-1}(O) = O \in {\tau_1}^*$,thus $f\ is$ $I - continuous\ function$.

Remark: Consider the sequences of identity functions:

$$(X,\tau_1) \xrightarrow[id-fun]{} (X,\tau_2) \xrightarrow[id-fun]{} (X,\tau_3) \xrightarrow[id-fun]{} (X,\tau_4) \ldots (X,\tau_{n-1}) \xrightarrow[id-fun]{} (X,\tau_n).$$

To reliable $I - continuous\ function$, we must have: ${\tau_1}^*$ is finer than τ_2, ${\tau_2}^*$ is finer than τ_3,… ${\tau_{n-1}}^*$ is finer than τ_n.

Theorem 3.6: Let $f:(X,\tau_X)) \to (Y,\tau_Y = \{\emptyset, y\})$ be a function between two topological Spaces and τ_{iX} associated infra-topology with τ_X,then f always $I - continuous\ function$.

Proof: Since $\emptyset, y$ only two open set in Y, then $f^{-1}(\emptyset) = \emptyset \in \tau_{iX}$&$f^{-1}(Y) = X \in \tau_{iX}$, so that f always $I - continuous\ function$.

Note that:

1. If $f:(X,\tau_X = P(X)) \to (Y,\tau_Y)$is a function between two topological Spaces and ${\tau_X}^*$ associated infra-topology with τ_X, then f may not be $I - continuous\ function$**.** But in topological space is always continuous function**.**
2. Let $f:(X,\tau_X) \to (Y,\tau_Y)$ be a continuous function between two topological space and τ_{iX} is an infra-topological space associated with τ_X, then f may not be an *I* –continuous function.

Example 3.3: Let $X = \{a,b,c,d\}, \tau_X = \{\emptyset, X, \{a\}, \{a,b\}, \{a,b,c\}\}$ and $\tau_{iX} = \{\emptyset, X, \{a\}, \{a,b\}\}$.Take $Y = \{1,2,3,4\}$, $\tau_Y = \{\emptyset, Y, \{2\}, \{2,3,4\}\}$. Define $f: X \to Y = f(a) = f(b) = 2, f(c) = 4$ and $f(d) = 3$. It easy to check that f is a continuous function but not *I*-continuous function. If f is a continuous function, then f is a *S*-continuous function [2].

Theorem 3.7: Let f be a I-Continuous function from (X,τ_X) to (Y,τ_Y) and $C \subset Y$.

1. If C is a closed set in Y, then $icp(f^{-1}(C)) \subset icp(f^{-1}(cl(C)))$.
2. If C is an open set in Y, then $iip(f^{-1}(int(C))) \subset iip(f^{-1}(C)$.

Proof:

1. Let f be a I-Continuous function from (X,τ_X) to (Y,τ_Y) and $C \subset Y$, where C is a closed set in Y. Since C is a closed set in Y, then$C \subset cl(C)$, implies that $f^{-1}(C) \subset f^{-1}(cl(C))$, where $f^{-1}(C)$ and $f^{-1}(cl(C))$ are infraclosed sets in X. Therefore,$icp(f^{-1}(C)) \subset icp(f^{-1}(cl(C)))$ by [1].
2. Let f be a I-Continuous function from (X,τ_X) to (Y,τ_Y) and $C \subset Y$, where C is a open set in Y.Since C is an open set in Y, then $int(C) \subset C$, implies that $f^{-1}(int(C)) \subset f^{-1}(C)$, where $f^{-1}(int(C))$ and $f^{-1}(C)$ are infraopen sets in X. Therefore,$iip(f^{-1}(int(C))) \subset iip(f^{-1}(C)$ by [1].

Theorem 3.8: Let f be a I-Continuous function from (X,τ_X) to (Y,τ_Y) and $A \subset X$. Then:

1. $f(iip(A)) \subset f(icp(A))$.
2. $f(ibp(A)) \subset f(icp(A))$.
3. $f(ids(A)) \subset f(ids(icp(A)))$.

Proof: Let f be a I-Continuous function from (X,τ_X) to (Y,τ_Y) and $A \subset X$.

1. Since, $iip(A) \subset A \subset icp(A)[1] \to iip(A) \subset icp(A) \to f(iip(A)) \subset f(icp(A))$.
2. Since, $ibp(A) \subset icp(A)[1]$, then $f(ibp(A)) \subset f(icp(A))$.
3. Since, $A \subset icp(A) \to ids(A) \subset ids(icp(A)[1] \to f(ids(A)) \subset f(ids(icp(A)))$.

4. INFRA STAR-CONTINUOUS FUNCTIONS OR BRIEFLY I^*-CONTINUOUS FUNCTIONS

Definition 4.1: Let (X,τ_X) and (Y,τ_Y) be represent two topological Spaces. Letτ_{iX} and τ_{iY}be two associated infra-topology space with$\tau_X$andτ_{iY}respectively. A function $f: X \to Y$ is called I^*-continuous function, if The inverse image of each infraopen set in τ_{iY} is an τ_{iX}-infraopen set in X.

Example 4.1: Let (X,τ_X) and (Y,τ_Y) represents two topological Spaces such that, $X = \{a,b,c\}, Y = \{1,2,3\}$, $\tau_X = \{\emptyset, X, \{a\},\{b\},\{a,b\},\{a,c\}\}$, $\tau_Y = \{\emptyset, Y, \{1\},\{2\},\{1,2\},\{1,3\}\}, \tau_{iX} = \{\emptyset, X, \{a\},\{b\}\}$ and$\tau_{iY} = \{\emptyset, Y, \{2\},\{3\}\}$. Define $f: X \to Y \ni f(a) = f(c) = 1, f(b) = 2$. It is clear that f is I^*-continuous function.

Example 4.2: Let (X,τ_X) and (Y,τ_Y) represents two topological Spaces such that, $X = \{a,b,c\}, Y = \{1,2,3\}$, $\tau_X = \{\emptyset, X, \{a\},\{b\},\{a,b\},\{a,c\}\}$, $\tau_Y = \{\emptyset, Y, \{1\},\{2\},\{1,2\},\{1,3\}\}, \tau_{iX} = \{\emptyset, X, \{a\},\{b\}\}$ and$\tau_{iY} = \{\emptyset, Y, \{2\},\{3\}\}$. Define $f: X \to Y \ni f(a) = 1, f(b) = 2, f(c) = 3$. So that f is notI^*-continuous function.

Theorem 4.1: Let $f:(X,\tau_X) \to (Y,\tau_Y)$be a function between two topological spaces and τ_{iX}, τ_{iY}be two associated infra-topology space with τ_X and τ_{iY}respectively.Then$f$isan I^*-continuous function, if and only if, the inverse image of each infraclosed set in $\tau_{iY}$is an τ_{iX}- infraclosed set in X.

Proof: ⇒: Suppose that f is an I^*-continuous function. Let C be an infraclosed set $\in \tau_{iY}$.Then $Y - C$ is infraopen set in Y, implies that $f^{-1}(Y - C) = f^{-1}(Y) - f^{-1}(C) = X - f^{-1}(C)$ is infraopen set in X. Therefore $f^{-1}(C)$ is infraclosed set in X.
⇐Let O be an infraopen set $\in \tau_{iY}$, then $Y - O$ is infraclosed set $\in \tau_{iY}$,this is implies that, $f^{-1}(Y - O) = f^{-1}(Y) - f^{-1}(O) = X - f^{-1}(O)$ is infraclosed set $\in \tau_{iX}$,so $f^{-1}(O)$ is infraopen set$\in \tau_{iX}$ and consequently, f is I^*-continuous function.

Theorem 4.2: Let $f:(X,\tau_X) \to (Y,\tau_Y)$ and $g:(Y,\tau_Y) \to (Z,\tau_Z)$be two I^*-continuous function**,** then**:** $gf:(X,\tau_X) \to (z,\tau_Z)$ is an I^*-continuous function

Proof: Suppose that$f:(X,\tau_X) \to (Y,\tau_Y)$ and $g:(Y,\tau_Y) \to (Z,\tau_Z)$ are I^*-continuous function. Let O be an infraopen set $\in \tau_{iZ}$. Since gI^*-continuous function, implies that:$g^{-1}(O) \in \tau_{iY}$ – infraopen set in Y.since f is I^*-continuous**.** Therefore $f^{-1}g^{-1}(O) \in \tau_{iX}$ – infraopen set in X. But $(gf)^{-1}(O) = f^{-1}g^{-1}(O) \in \tau_{iX}$.so that gf is I^*-continuous.

Theorem 4.3: Let $f:(X,\tau_X) \to (Y,\tau_Y)$be I-continuous function**,** and $g:(Y,\tau_Y) \to (Z,\tau_Z)$be I^*-continuous function**,** then**:**$gf:(X,\tau_X) \to (z,\tau_Z)$is an$I^*$-continuous function

Proof: Suppose that $f:(X,\tau_X) \to (Y,\tau_Y)$ an I-continuous function and $g:(Y,\tau_Y) \to (Z,\tau_Z)$is an$I^*$-continuous function. Let O be an infra open set $\in \tau_{iZ}$. Since g is an I^*-continuous function, implies that:$g^{-1}(O) \in \tau_{iY}$ – infraopen set in Y. But $\tau_{iY} \subset \tau_Y$,,so that $g^{-1}(O) \in \tau_Y$is open set in Y . As that f is I-continuous**.** Therefore $f^{-1}g^{-1}(O) \in \tau_{iX}$ – infraopen set in X. Hence$(gf)^{-1}(O) = f^{-1}g^{-1}(O) \in \tau_{iX}$.so that gf is I^*-continuous.

Theorem 4.4: Let $f:(X,\tau_X) \to (Y,\tau_Y)$be I^*-continuous function**,** and $g:(Y,\tau_Y) \to (Z,\tau_Z)$be I-continuous function**,** then**:** $gf:(X,\tau_X) \to (z,\tau_Z)$is an$I$-continuous function.

Proof: By the same techniques of theorem 4.3.

Theorem 4.5: Let$f:(X,\tau_X) \to (Y,\tau_Y)$be a constant function between two topological spaces and$\tau_{iX}$and $\tau_{iY}$are infra-topological space associated with τ_X and τ_{iY} respectively .Then the constant function is an I^*-continuous function. .

Proof: By the similar way for theorem 3.3.

Theorem 4.6: Let f be a I^*-Continuous function from (X,τ_X) to (Y,τ_Y) and $C \subset Y$.

1. If C is a infraclosed set in Y, then $icp(f^{-1}(C)) \subset icp(f^{-1}(icp(C))$.
2. If C is an infraopen set in Y, then $iip(f^{-1}(int(C))) \subset iip(f^{-1}(C)$.

Proof:

1. Let f be a I^*-Continuous function from (X,τ_X) to (Y,τ_Y) and $C \subset Y$, where C is a infraclosed set in Y**.** Since C is a infraclosed set in Y, then$C \subset icp(C)$, implies that $f^{-1}(C) \subset f^{-1}(icp(C))$, where $f^{-1}(C)$and $f^{-1}(icp(C))$are infraclosed sets in X. Therefore,$icp(f^{-1}(C)) \subset icp(f^{-1}(icp(C))$ by [1].
2. Let f be a I^*-Continuous function from (X,τ_X) to (Y,τ_Y) and $C \subset Y$, where C is aninfraopen set in Y**.**Since C is an infraopen set in Y, then **:**
$inp(C) \subset C$, implies that $f^{-1}(iip(C)) \subset f^{-1}(C)$, where $f^{-1}(iip(C))$and $f^{-1}(C)$ are infraopen sets in X**.** Therefore,$iip(f^{-1}(iip(C))) \subset iip(f^{-1}(C)$ by [1].

Theorem 3.8: Let f be a I^*-Continuous function from (X,τ_X) to (Y,τ_Y) and $A\subset X$. Then:

1. $f(iip(A))\subset f(icp(A))$.
2. $f(ibp(A))\subset f(icp(A))$.
3. $f(ids(A))\subset f(ids(icp(A))$.

Proof: Let f be a I^*-Continuous function from (X,τ_X) to (Y,τ_Y) and $A\subset X$.

1. Since, $iip(A)\subset A\subset icp(A)[1]\to iip(A)\subset icp(A)\to f(iip(A))\subset f(icp(A))$.
2. Since, $ibp(A)\subset icp(A)[1]$, then $f(ibp(A))\subset f(icp(A))$.
3. Since, $A\subset icp(A)\to ids(A)\subset ids(icp(A)[1]\to f(ids(A))\subset f(ids(icp(A))$.

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