# Further Study On Supra *β*-Irresolute Maps

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***Abstract-*** *In this paper, we investigate some other properties of supra β-irresolute maps, totally supra β-continuous functions, slightly supra β-continuous functions and strongly supra β-continuous functions. Also, the relationship between these functions are discussed.*

***Keywords***- slightly supra β-continuous function, strongly supra β-continuous function, supra β-irresolute map, supra β-Ti, totally supra β-continuous function.

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## I. INTRODUCTION

In 1983, A.S.Mashhour [3] introduced the supra topological spaces. In 2013, Saeid Jafari [4] introduced and studied a class of sets and a class of maps between topological spaces called supra β-open sets and supra β-continuous maps, respectively. In 2012, O.R.Sayed [5] researched supra β-connectedness by means of a supra β-separated sets. In [7], the authors introduced the notion of supra β-irresolute maps and supra β-$T_i$. In [6], the authors introduced the concepts of totally supra β-continuous functions, slightly supra β-continuous functions and strongly supra β-continuous functions.

Section 2 deals with the preliminary concepts. In Section 3, we investigate some other properties of supra β-irresolute maps. In Section 4, we discuss about slightly supra β-continuous functions, strongly supra β-continuous functions and totally supra β-continuous functions and the relationship between these functions.

## II. PRELIMINARIES

A subcollection $\mu \subseteq P(X)$ where $P(X)$ is the power set of $X$, is called a supra topology [3] on $X$ if $X, \emptyset \in \mu$ and μ is closed under arbitrary union. The ordered pair $(X, \mu)$ is called a supra topological space. The elements of μ are said to be supra open in $(X, \mu)$ and the complement of a supra open set is called a supra closed set. The supra closure of a set $A$, denoted by $Cl^{\mu}(A)$, is the intersection of supra closed sets containing $A$. The supra interior of a set $A$, denoted by $Int^{\mu}(A)$, is the union of supra open sets contained in $A$. The supra topology μ on $X$ is associated with the topology $\tau$ if $\tau \subseteq \mu$.

Throughout this paper, $(X,\tau), (Y,\sigma)$ and $(Z,\nu)$ (or simply X, Y and Z) denote topological spaces on which no separation axioms are assumed unless explicitly stated where μ, ρ and η are the associated supra topologies with $\tau, \sigma$ and $\nu$. For a subset $A$ of $X$, the complement of $A$ is denoted by $X$-$A$.

**Definition 2.1** Let $(X, \mu)$ be a supra topological space. Let $A$ be a subset of $X$. Then $A$ is said to be a

**(1)** **supra β-open set [4]** if $A \subseteq Cl^{\mu}\left(Int^{\mu}\left(Cl^{\mu}(A)\right)\right)$.
**(2)** **supra β-closed set [4]** if X-A is supra β-open set.
**(3)** **supra β-clopen set [6]** if A is both supra β-open and supra β-closed.

**Definition 2.2 [4]** The **supra β-closure** of a set $A$, denoted by $Cl^{\mu}_{\beta}(A)$, is the intersection of supra β-closed sets containing $A$. The **supra β-interior** of a set $A$, denoted by $Int^{\mu}_{\beta}(A)$, is the union of supra β-open sets contained in $A$.

**Definition 2.3 [5]** Let A and B be subsets of a supra topological space (X,μ). Then A and B are said to be **supra β-separated** if $A \cap Cl^{\mu}_{\beta}(B) = Cl^{\mu}_{\beta}(A) \cap B = \emptyset$.

**Definition 2.4 [5]** A subset $A$ of $X$ is a **supra β-connected set** if it cannot be represented as a union of two nonempty supra β-separated sets. If $X$ is supra β-connected, then $X$ is called a **supra β-connected space**.

**Definition 2.5** A map f:X→Y is said to be

**(1)** **supra β-continuous map [4]** if the inverse image of each open set in $Y$ is supra β-open in $X$.
**(2)** **supra β-open map [4]** if the image of each open set in $X$ is supra β-open in $Y$.
**(3)** **supra β-irresolute map [7]** if the inverse image of each supra β-open set in $Y$ is supra β-open in $X$.
**(4)** **continuous map [2]** if the inverse image of each open set in $Y$ is open in $X$.
**(5)** **totally supra β-continuous function [6]** if the inverse image of each open set in $Y$ is supra β-clopen in $X$.
**(6)** **slightly supra β-continuous function at a point** $x \in X$ **[6]** if for each clopen subset $V$ in $Y$ containing $f(x)$, there exists a supra β-open subset $U$ in $X$ containing $x$ such that $f(U) \subseteq V$. The function $f$ is said to be a **slightly supra β-continuous function** if $f$ is a slightly supra β-continuous function at each point of $X$.
**(7)** **strongly supra β-continuous function [6]** if the inverse image of every subset of $Y$ is a supra β-clopen subset of $X$.

**Definition 2.6 [2]** A topological space $(X, \tau)$ is said to be a $T_0$**-space** if for each pair of distinct points $x$ and $y$ in $X$, there exist an open set $U$ in $X$ which contains one of them but not the other.

**Definition 2.7 [7]** A supra topological space $(X, \mu)$ is said to be

**(1)** **supra β-**$T_1$ if for each pair of distinct points $x$ and $y$ in $X$, there exists supra β-open sets $U$ and $V$ in $X$ such that $x \in U$, $y \notin U$ and $y \in V$, $x \notin V$.
**(2)** **supra β-**$T_2$ if for each pair of distinct points $x$ and $y$ in $X$, there exists disjoint supra β-open sets $U$ and $V$ in $X$ such that $x \in U$ and $y \in V$.

**Definition 2.8 [1]** A space X is said to be

**(1)** **clopen-$T_1$** if for each pair of distinct points x and y in X, there exist clopen sets U and V in X containing x and y respectively such that $y \notin U$ and $x \notin V$.
**(2)** **clopen-$T_2$** if for each pair of distinct points x and y in X, there exist disjoint clopen sets U and V in X such that $x \in U$ and $y \in V$.

**Theorem 2.9 [4]** The following conditions are equivalent for a supra topological space $(X, \mu)$.

**(1)** $(X, \mu)$ is not supra β-connected.
**(2)** There exist two non-empty disjoint supra β-open sets such that $X = A \cup B$.
**(3)** There exist two non-empty disjoint supra β-closed sets such that $X = A \cup B$.

**Theorem 2.10** Let G$\subseteq X$. Then G is supra β-connected if and only if there do not exist two supra β-closed sets A and B in X such that $G \nsubseteq A$, $G \nsubseteq B$, $G \subseteq A \cup B$ and $A \cap B \cap G = \emptyset$.

## III. SUPRA β-IRRESOLUTE MAPS

In this section, some other properties of supra β-irresolute maps are investigated.

**Theorem 3.1** If one of the following conditions holds, then the map f:X→Y is supra β-irresolute.

1. $f^{-1}(Int_\beta^\rho(A) \subseteq Int_\beta^\mu(f^{-1}(A))$ for every subset A of Y.
2. $Cl_\beta^\mu(f^{-1}(A)) \subseteq f^{-1}(Cl_\beta^\rho(A))$ for every subset A of Y.
3. $f(Cl_\beta^\mu(B)) \subseteq Cl_\beta^\rho(f(B))$ for every subset B of X.

**Proof:** Let A be any supra β-open subset of Y. If Condition (1) $f^{-1}(Int_\beta^\rho(A) \subseteq Int_\beta^\mu(f^{-1}(A))$ holds, then $f^{-1}(A) \subseteq Int_\beta^\mu(f^{-1}(A))$. We know that $Int_\beta^\mu(f^{-1}(A)) \subseteq f^{-1}(A)$. Thus $f^{-1}(A) = Int_\beta^\mu(f^{-1}(A))$. Then $f^{-1}(A)$ is supra β-open set in X. Hence f is supra β-irresolute. If condition (2) $Cl_\beta^\mu(f^{-1}(A)) \subseteq f^{-1}(Cl_\beta^\rho(A))$ holds, then we have $f^{-1}(Int_\beta^\rho(A) \subseteq Int_\beta^\mu(f^{-1}(A))$. This is nothing but condition (1). If condition (3) $f(Cl_\beta^\mu(B)) \subseteq Cl_\beta^\rho(f(B))$ holds for every subset B of Y, then $Cl_\beta^\mu(f^{-1}(A)) \subseteq f^{-1}(Cl_\beta^\rho(A))$ for every subset A of Y. This is nothing but condition (2). Hence f is supra β-irresolute.

The converse of Theorem 3.1 need not be true as shown by the following example.

**Example 3.2** Let X={a,b,c,d}. Clearly μ={φ,X,{a},{b},{a,b}} is a supra topology on X. Here the sets φ,X,{a},{b},{a,b},{a,c},{a,d},{b,c},{b,d},{a,b,c},{a,b,d},{a,c,d},{b,c,d} are supra β-open. Let Y={a,b,c}. Clearly ρ={φ,Y,{a},{a,b},{b,c}} is a supra topology on Y. Here all the subsets of X except {c} are supra β-open. Define f:X→Y by f(a)=c,f(b)=a,f(c)=f(d)=b. Clearly the inverse image of every supra β-open in Y is supra β-open in X. Hence f is a supra β-irresolute map. Then

**(1)** Let A={b}. Then $f^{-1}\left(Int_\beta^\rho(A)\right) = f^{-1}(\{b\}) = \{c,d\}$ and $Int_\beta^\mu(f^{-1}(A)) = Int_\beta^\mu(\{c,d\}) = \emptyset$. Hence $f^{-1}\left(Int_\beta^\rho(A)\right) \not\subseteq Int_\beta^\mu(f^{-1}(A))$.

**(2)** Let A={a,c}. Then $Cl_\beta^\mu(f^{-1}(A)) = Cl_\beta^\mu(\{a,b\}) = X$ and $f^{-1}\left(Cl_\beta^\rho(A)\right) = f^{-1}(\{a,c\}) = \{a,b\}$. Hence $Cl_\beta^\mu(f^{-1}(A)) \not\subseteq f^{-1}\left(Cl_\beta^\rho(A)\right)$.

**(3)**

**(4)** Let A={a,b}. Then $f\left(Cl_\beta^\mu(A)\right) = f(X) = Y$ and $Cl_\beta^\rho(f(A)) = Cl_\beta^\rho(\{a,c\}) = \{a,c\}$. Hence $f\left(Cl_\beta^\mu(A)\right) \not\subseteq Cl_\beta^\rho(f(A))$.

**Theorem 3.3** Let f:X→Y be a map. Then the following conditions are equivalent:

**(1)** f is a supra β-irresolute map.

**(2)** The inverse image of each supra β-closed set in Y is supra β-closed set in X.

**(3)** $Cl_\beta^\mu(f^{-1}(B)) \subseteq f^{-1}(Cl_\beta^\rho(B))$ for every subset B of Y.

**(4)** $f(Cl_\beta^\mu(A)) \subseteq Cl_\beta^\rho(f(A))$ for every subset A of X.

**(5)** $f^{-1}(Int_\beta^\rho(B)) \subseteq Int_\beta^\mu(f^{-1}(B))$ for every subset B of Y.

**Proof:**

**(1)⇒(2)** Let f be a supra β-irresolute map. Let A be a supra β-closed subset of Y. Then Y-A is supra β-open in Y. Since f is a supra β-irresolute map, $f^{-1}$(Y-A) is supra β-open in X. That is, X-$f^{-1}(A)$ is supra β-open in X. Hence $f^{-1}(A)$ is supra β-closed in X.

**(2)⇒(3)** Let B be any subset of Y. Since $Cl_\beta^\rho(B)$ is supra β-closed in Y and By (2), $f^{-1}(Cl_\beta^\rho(B))$ is supra β-closed in X. Therefore,

$$Cl_\beta^\mu(f^{-1}(B)) \subseteq Cl_\beta^\mu\left(f^{-1}\left(Cl_\beta^\rho(B)\right)\right) = f^{-1}(Cl_\beta^\rho(B)).$$

Hence $Cl_\beta^\mu(f^{-1}(B)) \subseteq f^{-1}(Cl_\beta^\rho(B))$ for every subset B of Y.

**(3)⇒(4)** Assume that the condition $Cl_\beta^\mu(f^{-1}(B)) \subseteq f^{-1}(Cl_\beta^\rho(B))$ holds for every subset B of Y. Let A be any subset of X. Then f(A)∈Y. By (3), $f^{-1}(Cl_\beta^\rho(f(A))) \supseteq Cl_\beta^\mu(f^{-1}(f(A))) \supseteq Cl_\beta^\mu(A)$. Hence $f(Cl_\beta^\mu(A)) \subseteq Cl_\beta^\rho(f(A))$ for every subset A of X.

**(4)⇒(5)** Assume that the condition $f(Cl_\beta^\mu(A)) \subseteq Cl_\beta^\rho(f(A))$ holds for every subset A of X. Let B be any subset of Y. Then X-$f^{-1}(B) \in Y$. By (4), $f(Cl_\beta^\mu(X\,f^{-1}(B))) \subseteq Cl_\beta^\rho$(f(X-$f^{-1}$(B))). Then $f(X - Int_\beta^\mu(f^{-1}(B))) \subseteq Cl_\beta^\rho(Y - B) = Y - Int_\beta^\rho(B)$. Hence $f^{-1}\left(Int_\beta^\rho(B)\right) \subseteq Int_\beta^\mu(f^{-1}(B))$.

**(5)⇒(1)** Assume that the condition $f^{-1}\left(Int_\beta^\rho(B)\right) \subseteq Int_\beta^\mu(f^{-1}(B))$ holds for every subset B of Y. Let B be any supra β-open subset of Y. By (5), $f^{-1}(B) \subseteq Int_\beta^\mu(f^{-1}(B))$. We know that $Int_\beta^\mu(f^{-1}(B)) \subseteq f^{-1}(B)$. Thus $f^{-1}(B) = Int_\beta^\mu(f^{-1}(B))$. Therefore, $f^{-1}(B)$ is supra β-open in X. Hence f is a supra β-irresolute map.

**Theorem 3.4** If f:X→Y is a supra β-irresolute surjective map and C and D are supra β-separated sets in Y, then $f^{-1}(C)$ and $f^{-1}(D)$ are supra β-separated in X.

**Proof:** Let f:X→Y be a supra β-irresolute map. Since C and D are supra β-separated in Y, $C \cap Cl_{\beta}^{\rho}(D) = Cl_{\beta}^{\rho}(C) \cap D = \emptyset$. By Theorem 3.3 (3), $Cl_{\beta}^{\mu}(f^{-1}(C)) \subseteq f^{-1}(Cl_{\beta}^{\rho}(C))$. Then $Cl_{\beta}^{\mu}(f^{-1}(C)) \cap f^{-1}(D) \subseteq f^{-1}\left(Cl_{\beta}^{\rho}(C)\right) \cap f^{-1}(D) = f^{-1}\left(Cl_{\beta}^{\rho}(C) \cap D\right) = f^{-1}(\emptyset) = \emptyset.$ Hence $Cl_{\beta}^{\mu}(f^{-1}(C)) \cap f^{-1}(D) = \emptyset.$ Similarly we can prove that $f^{-1}(C) \cap Cl_{\beta}^{\mu}(f^{-1}(D)) = \emptyset$. Hence $f^{-1}(C)$ and $f^{-1}(D)$ are supra β-separated in X.

**Theorem 3.5** If f:X→Y is supra β-irresolute bijective map and A is a supra β-connected subset of X, then f(A) is a supra β-connected subset of Y.

**Proof:** Suppose f(A) is not a supra β-connected subset of Y. Then f(A)=C$\cup$D where C and D are non-empty supra β-separated sets in Y. By Theorem 3.4, $f^{-1}(C)$ and $f^{-1}(D)$ are supra β-separated sets in X. Since f is bijective, $f^{-1}(C)$ and $f^{-1}(D)$ are non-empty. Since f is bijective, A= $f^{-1}(C) \cup f^{-1}(D)$. Hence A is not a supra β-connected subset of X, which is a contradiction.Thus f(A) is a supra β-connected subset of Y.

**Theorem 3.6** If f:X→Y is a supra β-irresolute map and G is supra β-connected in X, then f(G) is supra β-connected in Y.
**Proof:** Suppose f(G) is not connected in Y, then there exist two supra β-closed sets A and B in Y such that $f(G) \nsubseteq A$, f($G) \nsubseteq B$, $f(G) \subseteq A \cup B$ and $A \cap B \cap f(G) = \emptyset$. Then $G \nsubseteq f^{-1}(A)$, $G \nsubseteq f^{-1}(B)$, $G \subseteq f^{-1}(A \cup B) = f^{-1}(A) \cup f^{-1}(B)$ and $f^{-1}(A) \cap f^{-1}(B) \cap G = \emptyset$. This implies that G is not supra β-connected in X, which is a contradiction. Hence f(G) is supra β-connected in Y.

**Corollary 3.7** If f:X→Y is a surjective supra β-irresolute map and X is supra β-connected, then Y is supra β-connected
**Proof:** By Theorem 3.6, f(X) is supra β-connected. That is, Y is supra β-connected.

## IV TOTALLY SUPRA β-CONTINUOUS FUNCTIONS, SLIGHTLY SUPRA β-CONTINUOUS FUNCTIONS AND STRONGLY SUPRA β-CONTINUOUS FUNCTIONS

In this Section, we investigate some other properties of totally supra β-continuous functions, slightly supra β-continuous functions and strongly supra β-continuous functions. Also, the relationship between these functions and supra β-irresolute maps are discussed.

**Theorem 4.1** Let f:X→Y be a totally supra β-continuous injective function. If Y is a $T_0$-space, then X is a supra β-$T_2$ space.

**Proof:** Let x and y be any pair of distinct points in X. Since f is injective, f(x)$\neq$f(y) in Y. Since Y is a $T_0$-space, there exists an open set V in Y containing f(x) but not f(y) or containing f(y) but not f(x). Thus for the first case, $x \in f^{-1}(V)$ and $y \notin f^{-1}(V)$. Since f is a totally supra β-continuous function, $f^{-1}(V)$ and $X - f^{-1}(V)$ are disjoint supra β-clopen sets in X containing x and y respectively. The proof of the other case is similar. Hence X is a supra β-$T_2$ space.

**Theorem 4.2** Every slightly supra β-continuous function into a discrete space is strongly supra β-continuous function.

**Proof:** Let f:X→Y be a slightly supra β-continuous function where Y is a discrete space. Let A be any subset of Y. Then A is a clopen set in X. Since f is a slightly supra β-continuous function, $f^{-1}(A)$ is supra β-clopen in X. Hence f is a strongly supra β-continuous function.

**Theorem 4.3** Let f:X→Y and g:Y→Z be functions. Then gof:X→Z.

**(1)** If f is supra β-irresolute and g is slightly supra β-continuous then gof is slightly supra β-continuous.
**(2)** If f is slightly supra β-continuous and g is continuous, then gof is slightly supra β-continuous.

**Proof:** Let V be any clopen subset of Z.

**(1)** Since g is slightly supra β-continuous, $g^{-1}(V)$ is supra β-open in Y. Since f is supra β-irresolute, $f^{-1}(g^{-1}(V))$ is supra β-open in X. That is, $(gof)^{-1}(V)$ is supra β-open in X.

**(2)** Since g is continuous, $g^{-1}(V)$ is clopen in Y. Since f is slightly supra β-continuous, $f^{-1}(g^{-1}(V))$ is supra β-open in X. That is, $(gof)^{-1}(V)$ is supra β-open in X.

Hence gof is slightly supra β-continuous.

**Corollary 4.4** If f:X→Y is supra β-irresolute and g:Y→Z is supra β-continuous then gof:X→Z is slightly supra β-continuous.

**Proof:** Since every supra β-continuous function is slightly supra β-continuous function, g is slightly supra β-continuous function. By Theorem 4.3 (1), gof is slightly supra β-continuous.

**Theorem 4.5** Let f:X→Y be a supra β-irresolute supra β-open surjective map and g:Y→Z be a function. Then g is slightly supra β-continuous if and only if gof is slightly supra β-continuous.

**Proof:**

⇒ Let g be slightly supra β-continuous. By Theorem 4.3 (1), gof is slightly supra β-continuous.

.⇐ Let gof be slightly supra β-continuous. Let V be any clopen subset of Z. Then $(gof)^{-1}(V)$ is supra β-open in X. Since f is supra β-open, $f((gof)^{-1}(V))$ is supra β-open in Y. Since f is surjective, $f((gof)^{-1}(V))=f(f^{-1}(g^{-1}(V)))= g^{-1}(V)$ is supra β-open in Y. Hence g is slightly supra β-continuous.

**Theorem 4.6** Let f:X→Y be a slightly supra β-continuous injective map and Y is clopen-$T_i$, then X is supra β-$T_i$ for i=1,2.

**Proof:** Let x and y be any two distinct points in X. Then f(x) and f(y) are distinct points in Y.

**(1)** For i=1. Since Y is clopen-$T_1$, there exist clopen sets V and W in Y such that $f(x) \in V, f(y) \notin V$ and $f(y) \in W, f(x) \notin W$. Since f is slightly supra β-continuous, $f^{-1}(V)$ and $f^{-1}(W)$ are supra β-open in X such that $x \in f^{-1}(V), y \notin f^{-1}(V)$ and $y \in f^{-1}(W), x \notin f^{-1}(W)$. This shows that X is supra β-$T_1$.

**(2)** For i=2. Since Y is clopen-$T_2$, there exist disjoint clopen sets V and W in Y such that $f(x) \in V$ and $f(y) \in W$. Since f is slightly supra β-continuous, $f^{-1}(V)$ and $f^{-1}(W)$ are disjoint supra β-open in X containing x and y respectively. Hence X is supra β-$T_2$.

**Proposition 4.7** Every supra β-irresolute map is slightly supra β-continuous.

**Proof:** Let f:X→Y be a supra β-irresolute map. Let A be any clopen subset of Y. Then A is open in Y. Since ρ is the associated supra topology with σ, A is supra open in Y. Then A is supra β-open in Y. Since f is supra β-irresolute, $f^{-1}(A)$ is supra β-open in X. Hence f is slightly supra β-continuous.

The converse of Proposition 4.7 need not be true as shown by the following example.

**Example 4.8** Let X={a,b,c} and τ={φ,X,{a,b}} be a topology on X. Clearly μ={φ,X,{a},{a,b},{b,c}} is a supra topology on X. Here the only clopen sets are φ and X and all the subsets of X except {c} are supra β-open in X. Define f:X→X by f(a)=c,f(b)=a,f(c)=b. Clearly the inverse image of every clopen set is supra β-open. Hence f is a slightly supra β-continuous function. But the inverse image of a supra β-open set {b} is {c} which is not a supra β-open set. Hence f is not a supra β-irresolute map.

**Proposition 4.9** Every strongly supra β-continuous function is supra β-irresolute.

**Proof:** Let f:X→Y be a strongly supra β-continuous function. Let A be any supra β-open subset of Y. Since f is a strongly supra β-continuous function, $f^{-1}(A)$ is supra β-clopen in X. That is, $f^{-1}(A)$ is supra β-open in X. Hence f is supra β-irresolute.

The converse of Proposition 4.9 need not be true as shown by the following example.

**Example 4.10** Let X={a,b,c} and τ={φ,X,{a,b}} be a topology on X. Clearly μ={φ,X,{a},{a,b},{b,c}} is a supra topology on X. Here all the subsets of X except {c} are supra β-open and all the subsets of X except {c} and {a,b} are supra β-clopen in X. Define f:X→X by f(a)=b,f(b)=a,f(c)=c. Example 3.6 in [7] shows that this map f is a supra β-irresolute map. But the inverse image of the set {a,b} is {a,b} which is not supra β-clopen. Hence f is not a strongly supra β-continuous function.

**Remark 4.11** Totally supra β-continuous functions and supra β-irresolute maps are independent.

For example, Let X={a,b,c} and τ={φ,X,{a,b}} be a topology on X. Clearly μ={φ,X,{a},{a,b},{b,c}} is a supra topology on X. Here the sets φ,X,{a,b} are open, all the subsets of X except {c} are supra β-open and all the subsets of X except {c} and {a,b} are supra β-clopen in X.

**(1)** Define f:X→X by f(a)=c, f(b)=a, f(c)=b. Clearly the inverse image of every open set is supra β-clopen. Hence f is a totally supra β-continuous function. Example 4.8 shows that this map f is not a supra β-irresolute map.

**(2)** Define f:X→X by f(a)=b, f(b)=a, f(c)=c. Example 3.6 in [7] shows that this map f is a supra β-irresolute map. Clearly the inverse image of the open set {a,b} is {a,b} which is not supra β-clopen. Hence f is not a totally supra β-continuous function.

## V. CONCLUSION

In this paper, we have investigated some other properties of supra β-irresolute maps, totally supra β-continuous functions, slightly supra β-continuous functions and strongly supra β-continuous functions. Also, the relationship between these functions are discussed.


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