

ON COMPLETELY $\pi G \alpha$ -IRRESOLUTE FUNCTIONS IN TOPOLOGICAL SPACES

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ABSTRACT

In this paper a strong form of $\pi g \alpha$ -irresolute function namely completely $\pi g \alpha$ -irresolute function is defined and its characterizations are obtained. Further strongly $\pi g \alpha$ - normal space, strongly $\pi g \alpha$ -regular space, mildly $\pi g \alpha$ - regular spaces are studied.

Keyword and Phrases: Completely strongly $\pi g \alpha$ -irresolute functions strongly $\pi g \alpha$ -regular space, strongly $\pi g \alpha$ -normal space, mildly $\pi g \alpha$ -normal space, mildly $\pi g \alpha$ -regular space.

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1. INTRODUCTION

In 1972, Crossley and Hildebrand [6] introduced the notion of irresoluteness. Many different forms of irresolute functions have been introduced over the years. Various interesting problems, arise when one considers irresoluteness. Its importance is significant in various areas of mathematics and related sciences. In this paper we introduce and characterize the concepts of completely $\pi g \alpha$ - irresolute functions. Also we introduce the new concept of strongly $\pi g \alpha$ - normal space, mildly $\pi g \alpha$ - normal, strongly $\pi g \alpha$ - regular and mildly $\pi g \alpha$ - regular to study their basic properties and some related properties of these functions.

2. PRELIMINARIES

Throughout this paper, (X,τ) means topological spaces on which no separation axioms are assumed unless otherwise mentioned. Let A be a subset of a space X. The closure and the interior of A are denoted by cl(A) and int(A) respectively.

Definition 2.1: [1] A subset A of a space (X,τ) is called $\pi g\alpha$ -closed if $\alpha clA \subset U$ whenever $A \subset U$ and U is π -open. A subset A of (X,τ) is called $\pi g\alpha$ -open if its complement is $\pi g\alpha$ - closed.

The family of all $\pi g\alpha$ -open subsets of (X,τ) is denoted by $\pi G\alpha O(X)$

Definition 2.2: A function f: $(X,\tau) \rightarrow (Y,\sigma)$ is called

(a) Completely continuous [4] if $f^{-1}(V)$ is regular open in X for every open set V of Y.

(b) $\pi g\alpha$ -continuous [10] (resp. π -continuous) if f⁻¹(V) is $\pi g\alpha$ -open in X (resp. π -open) for every open set V of Y.

(c) $\pi g\alpha$ -irresolute [10] if $f^{-1}(V)$ is $\pi g\alpha$ -open in X for every $\pi g\alpha$ -open set V of Y.

(d) M- π g α -closed [10] if f (F) is π g α -closed in Y for every π g α -closed set F of X.

(e) Contra- $\pi g\alpha$ - continuous [3] if f⁻¹(V) is $\pi g\alpha$ -closed in X for every open set V of Y.

Definition 2.3[2]: A space X is said to be

(a) $\pi G\alpha$ -closed if every $\pi g\alpha$ -closed cover of X has a finite subcover.

- (b) countably- $\pi G\alpha$ -closed if every countable cover of X by $\pi g\alpha$ -closed sets has a finite subcover.
- (c) $\pi G\alpha$ -Lindelof if every cover of X by $\pi g\alpha$ -open sets has a countable cover.
- (d) $\pi G\alpha O$ -compact if every open covering of X by $\pi g\alpha$ -open sets has a finite subcover.

(e) countably- $\pi G\alpha$ -compact if every countable $\pi g\alpha$ -open covering of X sets has a finite subcover.

C. Janaki* and I. Arockiarani**/ ON COMPLETELY #G & IRRESOLUTE FUNCTIONS IN TOPOLOGICAL SPACES / IJMA- 2(10), Oct.-2011, Page: 2045-2050

Definition 2.4: A space X is said to be

(i) nearly compact [13, 16] if every regular open cover of X has a finite subcover.

(ii) nearly countably compact [9] if every countable cover by regular open set has a finite subcover.

(iii) nearly lindelof [8] if every cover of X by regular open set has a countable subcover.

(iv) S-closed [17] if every regular closed cover of X has a finite subcover.

(v) countably S-closed compact [7] if every countable cover of X by regular closed sets has a finite subcover.

(vi) S-lindelof [12] if every cover of X by regular closed sets has a countable subcover.

Definition 2.5: A subset S of X is said to be

(a) N-closed relative to X [15] if for each cover $\{F_i: i \in I\}$ of S by open sets of X, there exists a finite subset I_o of I such that $S \subset \cup intcl(F_i: i \in I_o)$.

(b) $\pi G \alpha O$ -compact relative to X if for each cover $\{U_i : i \in \Lambda\}$ of $\pi g \alpha$ -open subsets of X such that $A \subset \cup \{U_i : i \in \Lambda\}$ there exists a finite subset Λ_0 of Λ such that $A \subset \cup \{U_i : i \in \Lambda\}$.

3. ON COMPLETELY $\pi g\alpha$ -IRRESOLUTE FUNCTIONS

Definition 3.1: A function f: $X \rightarrow Y$ is called completely $\pi g \alpha$ -irresolute if the inverse image of each $\pi g \alpha$ -open subset of Y is regular open in X.

Theorem 3.2: Every completely $\pi g \alpha$ -irresolute function is $\pi g \alpha$ -irresolute.

Proof: Straight forward.

Remark 3.3: Converse of the above need not be true as seen in the following example.

Example 3.4 : Let $X = \{a, b, c\}, \tau = \{\phi, X, \{a, b\}\}, \sigma = \{\phi, X, \{a\}, \{b\}, \{a, b\}\}.$

Then the identity function f: $(X,\tau) \rightarrow (Y,\sigma)$ is $\pi g \alpha$ - irresolute but not completely $\pi g \alpha$ - irresolute.

Theorem 3.5: A function f: $X \rightarrow Y$ is called completely $\pi g \alpha$ -irresolute if the inverse image of each $\pi g \alpha$ -closed set is regular closed set in X.

Proof: Let V be $\pi g\alpha$ -closed in Y. Then Y–V is $\pi g\alpha$ -open in Y. By hypothesis f⁻¹(Y–V) is regular open in X implies X–f⁻¹(V) is regular open in X.That is, f⁻¹(V) is regular closed in X. Hence f is completely $\pi g\alpha$ -irresolute.

Next, we characterize the completely $\pi g \alpha$ - irresolute functions in the following theorem.

Theorem 3.6: If f: $X \rightarrow Y$. Then the following are equivalent:

(a) f is completely πgα-irresolute.
(b) For each x∈ X and each πgα-open set V and Y containing f(x) there exists a regular open set U in X containing x such that f(U) ⊂ V.
(c) f⁻¹(V) is regular open in X for every πgα-open set V of Y.
(d) f⁻¹(F) is regular closed in X for every πgα-closed set F of Y.

Proof: Straight forward.

Lemma 3.7 [11]: Let S be an open subset of a space(X, τ). Then the following hold: (i) If U is regular open in X, then so is U \cap S in the subspace (S, τ_s) (ii) If B \subset S is regular open in (S, τ_s), then there exists a regular open set U in (X, τ) such that B = U \cap S.

Theorem 3.8: If $f:(X,\tau) \to (Y,\sigma)$ is a completely $\pi g\alpha$ -irresolute function and A is any open subset of X, then the restriction f/A: A \to Y is completely $\pi g\alpha$ -irresolute.

Proof: Let F be a $\pi g\alpha$ -open set of Y. By hypothesis $f^{-1}(F)$ is regular open in X. By Lemma 3.7 $(f/A)^{-1}(F) = A \cap f^{-1}(F)$ is regular open in A. Hence f/A is completely $\pi g\alpha$ -irresolute.

Lemma 3.9: [18] If R is regular open in A and A is regular open in X, then R is regular open in X.

C. Janaki* and I. Arockiarani**/ ON COMPLETELY #G & IRRESOLUTE FUNCTIONS IN TOPOLOGICAL SPACES / IJMA- 2(10), Oct.-2011, Page: 2045-2050

Theorem 3.10: Let f: $X \rightarrow Y$ be any function. If for each $x \in X$ there exists a regular open set R containing x such that f/R is completely $\pi g\alpha$ - irresolute function then f is completely $\pi g\alpha$ -irresolute function.

Proof: Let $x \in X$ and let V be a $\pi g\alpha$ -open subset containing f(x). By theorem 3.6, there exist a regular open set W in R containing x such that $f/R(W) \subset V$. Since R is regular open in X, by lemma 3.9 W is regular open in X and hence $f(W) \subset V$. Thus f is completely $\pi g\alpha$ -irresolute function.

Theorem 3.11: If $f : (X,\tau) \to (Y,\sigma)$ is a completely $\pi g \alpha$ -irresolute functions and f(X) is taken with the subspace topology, then $f: X \to f(X)$ is completely $\pi g \alpha$ -irresolute function.

Proof: Since f is completely $\pi g\alpha$ -irresolute function, $f^{-1}(H)$ is regular open for every $\pi g\alpha$ -open subset H of Y. Now $f^{-1}(H \cap f(X)) = f^{-1}(H) \cap X = f^{-1}(H)$ is regular open. Therefore f: $X \to f(X)$ is completely $\pi g\alpha$ -irresolute function.

Definition 3.12[14]: A space X is said to be r-disconnected if there exists two regular open sets R and W such that $X = R \cup W$ and $R \cap W = \phi$. Otherwise X is called r-connected.

Theorem 3.13: If X is r-connected space and f: $X \rightarrow Y$ is completely $\pi g\alpha$ -irresolute surjection, then Y is $\pi G\alpha$ -connected.

Proof: Suppose Y is not $\pi G\alpha$ -connected. Then there exists non-empty $\pi g\alpha$ -open sets H_1 and H_2 in Y such that $H_1 \cap H_2 = \phi$ and $Y = H_1 \cup H_2$. Since f is completely $\pi g\alpha$ -irresolute function, we have $f^{-1}(H_1) \cap f^{-1}(H_2) = \phi$ and $X = f^{-1}(H_1) \cup f^{-1}(H_2)$.

Since f is surjection f $^{-1}(H_j) \neq \phi$ and f $^{-1}(H_j) \in RO(X)$ for j = 1,2. This implies X is not r-connected which a contradiction is.

Definition 3.14: A space X is said to be $\pi g\alpha$ -Hausdorff (resp. rT₂ [5]) if for any x, y \in X, $x \neq y$, there exist $\pi g\alpha$ -open sets (resp. regular open) sets G and H such that $x \in G$, $y \in H$ and $G \cap H = \phi$.

Theorem 3.15: Let f: $X \rightarrow Y$ be injective and completely $\pi g \alpha$ -irresolute function. If Y is $\pi g \alpha$ -Hausdorff space, then X is rT_2 .

Proof: Let x and y be any two distinct points of X. Since f is injective, $f(x) \neq f(y)$. Since Y is $\pi g\alpha$ -Hausdorff space there exists disjoint $\pi g\alpha$ - open sets G and H such that $f(x) \in G$ and $f(y) \in H$. Since f is completely $\pi g\alpha$ -irresolute function it follows that $f^{-1}(G)$, $f^{-1}(H)$ are disjoint regular open sets containing x and y respectively.

Hence X is rT₂.

Theorem 3.16: If $f:(X,\tau) \to (Y,\sigma)$ is a completely $\pi g\alpha$ -irresolute function and F is N-closed subspace relative to X, then f(F) is $\pi G\alpha O$ -compact relative to Y.

Proof: Let $\{H_i: i \in I\}$ be a cover of f(F) by $\pi g \alpha$ -open sets in Y. For each $x \in F$ there exists an $i(x) \in I$ such that $f(x) \in H_{i(x)}$. Since f is completely $\pi g \alpha$ -irresolute function there exists a regular open set R_x of X such that $f(R_x) \subset H_{i(x)}$. The family $\{R_x: x \in F\}$ is a regular open cover of F. For some finite subset F_o of F, we have $F \subset \cup \{R_x: x \in F_0\}$ and hence $f(F) \subset \cup \{H_{i(x)}: x \in F_0\}$. This shows that f(F) is $\pi G \alpha O$ -compact relative to Y.

Theorem 3.17: Let g: $X \rightarrow Y_1 \times Y_2$ be completely $\pi g\alpha$ -irresolute function where X, Y_1 and Y_2 are any topological spaces. Let $f_{i:X} \rightarrow Y_i$ be defined as follows for $x \in X$ $g(x) = (x_1, x_2)$, $f_i(x) = x_i$ for i = 1, 2. Then $f_i: X \rightarrow Y_i$ is completely $\pi g\alpha$ -irresolute function for i = 1, 2.

Proof: Let x be any point in X and H_1 be any $\pi g \alpha$ -open set of Y_1 containing $f_1(x) = x_1$, then $H_1 \times Y_2$ is $\pi g \alpha$ -open in $Y_1 \times Y_2$ which contain (x_1, x_2) . Since g is completely $\pi g \alpha$ -irresolute, by theorem 3.6 there exist a regular open set R containing x such that $g(R) \subset H_1 \times Y_2$. Then $f_1(R) \times f_2(R) \subset H_1 \times Y_2$. Therefore $f_1(R) \subset H_1$. Hence f_1 is completely $\pi g \alpha$ -irresolute function. Similarly, f_2 is completely $\pi g \alpha$ -irresolute function.

Theorem 3.18: If f: $X \rightarrow Y$ is completely continuous and g: $Y \rightarrow Z$ is completely $\pi g\alpha$ -irresolute, then gof is completely $\pi g\alpha$ -irresolute function.

Proof: Straight forward.

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C. Janaki* and I. Arockiarani**/ ON COMPLETELY **n**G **c**+IRRESOLUTE FUNCTIONS IN TOPOLOGICAL SPACES / IJMA- 2(10), Oct.-2011, Page: 2045-2050

Theorem 3.19: The following hold for function $f: X \rightarrow Y$ and $g: Y \rightarrow Z$

(a) If f is completely $\pi g \alpha$ -irresolute and g: $Y \rightarrow Z$ is $\pi g \alpha$ -continuous, then gof is completely continuous. (b) If f is completely $\pi g \alpha$ -irresolute and g is $\pi g \alpha$ -irresolute, then gof is completely $\pi g \alpha$ -irresolute.

(c) If f is completely continuous and g is completely $\pi g \alpha$ -irresolute, gof is completely $\pi g \alpha$ -irresolute function.

Proof: Straight forward.

Theorem 3.20: If $f:(X,\tau) \to (Y,\sigma)$ be completely $\pi g\alpha$ -irresolute surjective function. Then the following statements hold.

(1) If X is nearly compact, then Y is $\pi G\alpha O$ -compact.

(2) If X is nearly Lindel of, then Y is $\pi G\alpha$ -Lindelof.

(3) X is nearly countably compact, then Y is countably $\pi G\alpha$ -compact

Proof: (1) Let f: $X \to Y$ be a completely $\pi g\alpha$ -irresolute function of nearly compact space X onto a space Y. Let $\{U_{\alpha}: \alpha \in \Delta\}$ be any $\pi g\alpha$ -open cover of Y. Then $\{f^{-1}(U_{\alpha}): \alpha \in \Delta\}$ is a regular open cover of X. Since X is nearly compact, there exist a finite subfamily $\{f^{-1}(U_{\alpha i}): i = 1, 2...n\}$ of $\{f^{-1}(U_{\alpha}): \alpha \in \Delta\}$ which cover X. It follows that $\{U_{\alpha i}: i=1...n\}$ is a finite subfamily of $\{U_{\alpha}: \alpha \in \Delta\}$ which cover Y. Hence Y is a $\pi G\alpha O$ -compact space.

Proof of (2) and (3) are similar.

Theorem 3.21: Let $f:(X,\tau) \to (Y,\sigma)$ be completely $\pi g\alpha$ -irresolute surjective function. Then the following statements hold.

(1) If X is S-closed, then Y is $\pi G\alpha$ -closed.

(2) If X is S-Lindelof, then Y is $\pi G\alpha$ -Lindelof.

(3) If X is countably S-closed compact, then Y is countably $\pi G\alpha$ -closed.

Proof: (1) Let $\{U_{\alpha}: \alpha \in \Delta\}$ be a $\pi g\alpha$ -closed cover of X. Since f is completely $\pi g\alpha$ -irresolute $\{f^{-1}(U_{\alpha}): \alpha \in \Delta\}$ is regular closed cover in X. Since X is S-closed, there exist a finite subfamily $\{f^{-1}(U_{\alpha i}): i = 1, 2...n\}$ of $\{f^{-1}(U_{\alpha}): \alpha \in \Delta\}$ which cover X. It follows that $\{U_{\alpha i}: i = 1...n\}$ is a finite subfamily of $\{U_{\alpha}: \alpha \in \Delta\}$ which cover Y. Hence Y is $\pi G\alpha$ -closed.

Proof of (2) and (3) are similar.

Theorem 3.22 :If a mapping $f: X \to Y$ is M- $\pi g\alpha$ -closed then for each subset B of Y and each $\pi g\alpha$ -open set U of X containing $f^{-1}(B)$ there exists a $\pi g\alpha$ -open set V in Y containing B such that $f^{-1}(V) \subset U$.

Proof: Let B be a subset of Y and U be a $\pi g\alpha$ -open set of X such that $f^{-1}(B) \subset U$. Then Y-f(X-U) = V is a $\pi g\alpha$ -open set of Y containing B such that $f^{-1}(V) \subset U$.

Definition 3.23: A space X is said to be strongly $\pi g\alpha$ -normal (resp.mildly $\pi g\alpha$ -normal) if for each pair of distinct $\pi g\alpha$ -closed (resp. regular closed) sets A and B of X, there exist disjoint $\pi g\alpha$ -open sets U and V such that $A \subset U$ and $B \subset V$.

Obviously, every strongly $\pi g\alpha$ -normal space is mildly $\pi g\alpha$ -normal.

Theorem 3.24: If $f: X \to Y$ is completely $\pi g \alpha$ -irresolute, M- $\pi g \alpha$ -closed function from a mildly $\pi g \alpha$ -normal space X onto a space Y, then Y is strongly mildly $\pi g \alpha$ -normal.

Proof: Let A and B be two disjoint $\pi g\alpha$ -closed subsets of Y. Then f⁻¹(A) and f⁻¹(B) are disjoint regular closed subsets of X. Since X is mildly $\pi g\alpha$ -normal space, there exists disjoint $\pi g\alpha$ -open set U and V in X such that f⁻¹(A) \subset U and f⁻¹(B) \subset V. Then by theorem 3.22, there exists $\pi g\alpha$ -open set G = Y-f(X-U) and H = Y-f(X-V) such that A \subset G, f⁻¹(G) \subset U,B \subset H, f⁻¹(H) \subset V. Clearly, G and H are disjoint $\pi g\alpha$ -open subsets of Y. Hence Y is strongly $\pi g\alpha$ -normal.

Definition 3.25: A space X is called strongly $\pi g \alpha$ -regular if for each $\pi g \alpha$ -closed subsets F and each point $x \notin F$ there exists disjoint $\pi g \alpha$ -open sets U and V in X such that $x \in U$ and $F \subset V$.

Definition 3.26: A space X is called mildly $\pi g \alpha$ -regular if for each regular closed subset F and every point $x \notin F$ there exists disjoint $\pi g \alpha$ -open sets U and V in X such that $x \in U$ and $F \subset V$.

C. Janaki* and I. Arockiarani**/ ON COMPLETELY #G & IRRESOLUTE FUNCTIONS IN TOPOLOGICAL SPACES / IJMA- 2(10), Oct.-2011, Page: 2045-2050

Theorem 3.27: If f: $X \rightarrow Y$ is completely $\pi g \alpha$ -irresolute, M- $\pi g \alpha$ -closed injection of a mildly $\pi g \alpha$ -regular space onto a space Y, then Y is strongly $\pi g \alpha$ -regular space.

Proof: Let F be a $\pi g\alpha$ -closed subset of Y and let $y \notin F$. Then $f^{-1}(F)$ is regular closed subset of X such that $f^{-1}(y) = x \notin f^{-1}(F)$. Since X is mildly $\pi g\alpha$ -regular space, there exists disjoint $\pi g\alpha$ -open sets U and V in X such that

 $f^{-1}(y) \in U$ and $f^{-1}(F) \subset V$. By theorem 3.22, there exists $\pi g \alpha$ -open sets G = Y - f(X - U) such that $f^{-1}(G) \subset U$, $y \in G$ and H = Y - f(X - V) such that $f^{-1}(H) \subset V$, $F \subset H$. Clearly G and H are disjoint $\pi g \alpha$ -open subsets of Y. Hence Y is strongly $\pi g \alpha$ -regular space.

Definition 3.28: A space(X, τ) is said to be $\pi g\alpha$ -T₁ (resp. rT₁ [14]) if for each pair of distinct points x and y of X there exists $\pi g\alpha$ -open (resp. regular open) sets U₁ and U₂ such that $x \in U_1$, $y \in U_2$, $x \notin U_2$ and $y \notin U_1$.

Theorem 3.29: If $f:(X,\tau) \to (Y,\sigma)$ is completely $\pi g\alpha$ -irresolute injective function and Y is $\pi g\alpha$ -T₁, then X is rT₁.

Proof: Let x, y be distinct points of X. Since Y is $\pi g\alpha - T_1$, there exists $\pi g\alpha$ -open sets F_1 and F_2 of Y such that $f(x) \in F_1$, $f(y) \in F_2 f(x) \notin F_2 f(y) \notin F_1$. Since f is injective completely $\pi g\alpha$ -irresolute function we have $x \in f^{-1}(F1)$, $y \in f^{-1}(F_2)$, $x \notin f^{-1}(F2)$, $y \notin f^{-1}(F_1)$. Hence X is rT_1 .

Theorem 3.30: If $f:(X,\tau) \to (Y,\sigma)$ is completely $\pi g\alpha$ -irresolute injective function and Y is $\pi g\alpha$ -Hausdorff, then X is T_2 .

Proof: Let x, y be distinct points of X. Then $f(x) \neq f(y) \in Y$. Since Y is $\pi g\alpha$ -Hausdorff, there exists disjoint $\pi g\alpha$ -open sets U and V such that $f(x) \in U$ and $f(y) \in V$. Since f is completely $\pi g\alpha$ -irresolute $f^{-1}(U)$, $f^{-1}(V)$ are regular open and hence open such that $x \in f^{-1}(U)$ and $y \in f^{-1}(V)$, $f^{-1}(U) \cap f^{-1}(V) = \phi$.

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C. Janaki* and I. Arockiarani**/ON COMPLETELY #G @ IRRESOLUTE FUNCTIONS IN TOPOLOGICAL SPACES / IJMA- 2(10), Oct.-2011, Page: 2045-2050

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