$f\alpha gr\omega$-Connectedness in Fine-Topological Spaces

K. Rajak

Abstract: ***In this paper, we introduce the notions of $f\alpha gr\omega$-separated sets and $f\alpha gr\omega$-connectedness in fine-topological spaces and study some of their properties in fine-topological spaces.***

Keywords: Fine-open sets, $f\alpha gr\omega$-separated sets, $f\alpha gr\omega$ -connected sets, $f\alpha gr\omega$ -connected space.

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1. Introduction

Connectedness is one of the topological properties that is used to distinguish topological spaces. Many researchers have investigated the basic properties of connectedness. Stronger and weaker forms of connectedness have been introduced and investigated by Noiri [3], Reilly et al. [5] and Benchali and Bansali [1].

In this paper, we introduce the notions of $f\alpha gr\omega$ -separated sets, $f\alpha gr\omega$ -connectedness and $f\alpha gr\omega$ -disconnectedness and also, we study some of their properties in fine-topological spaces

2. Preliminaries

Throughout this paper X and Y denotes topological spaces (X, τ) and (Y, τ) respectively on which no separation axioms are assumed unless otherwise mentioned. For a subset A of a space (X, τ), cl(A) and $\alpha gr\omega$ -cl(A) denote the closure and $\alpha gr\omega$ closure of A, respectively. The complement of a set A of (X, τ) is denoted by A^c.

Definition 2.1 A subset A of a topological space (X, τ) is called regular open if $A = int(cl(A))$ (cf. [7]).

Definition 2.2 A subset A of a topological space (X, τ) is called regular semi-open if there is a regular open set U such that $U \subseteq A \subseteq cl(U)$ (cf. [2])

Definition 2.3 A subset A of a topological space (X, τ) is called αgrw-closed if $\alpha cl(A) \subseteq U$ whenever $A \subseteq U$ and U is regular semi-open. A subset A of a topological space (X, τ) is called αgrw -open if A^c is $\alpha gr\omega$ -closed (cf. [6]).

Definition 2.4 A function $f : (X,\tau) \to (Y,\tau')$ is said to be αgrw-continuous if $f^{-1}(V)$ is an $\alpha gr\omega$-closed set of (X, τ) for every closed set V of (Y, τ') (cf. [6]).

Definition 2.5 A function $f : (X,\tau) \to (Y,\tau')$ is said to be αgrw-irresolute if $f^{-1}(V)$ is an αgrw -closed set of (X, τ) for every $\alpha gr\omega$-closed set V of (Y,τ') (cf. [7])

Definition 2.6 Let A be a subset of X. Then $\alpha gr\omega$-closure of A is the intersection of all $\alpha gr\omega$-closed sets containing A (cf. [7]).

Definition 2.7 Let (X, τ) be a topological space. Two non-empty subsets A and B are said to be $\alpha gr\omega$ - separated iff $A \cap \alpha gr\omega - cl(B) = \phi$ and $\alpha gr\omega - cl(A) \cap B = \phi$ i.e., $[A \cap \alpha gr\omega - cl(B)] \cup [\alpha gr\omega - cl(A) \cap B] = \phi$ (cf. [8]).

Definition 2.8 Let (X, τ) be a topological space and $A \in X$. A point $x \in X$ is said to be an $\alpha gr\omega$ -adherent point of A if every $\alpha gr\omega$ -open set containing x, contains at least one point of A (cf. [8]).

Definition 2.9 If X = $A \cup B$ such that A and B are non-empty $\alpha gr\omega$ -separated sets then A, B form a $\alpha gr\omega$ -separation of X (cf. [8]).

Definition 2.10 A topological space (X, τ) is said to be $\alpha gr\omega$-connected if X cannot be written as a union of two disjoint non-empty $\alpha gr\omega$-open sets. If X is not $\alpha gr\omega$-connected then it is $\alpha gr\omega$-disconnected (cf. [8]).

Definition 2.11 A topological space (X, τ) is said to be $T\alpha gr\omega$-space if every $\alpha gr\omega$-closed set is closed in X (cf. [8]).

Definition 2.12 Let (X, τ) be a topological space we define $\tau(A_\alpha) = \tau_\alpha$ (say) = $\{G_\alpha(\neq X) : G_\alpha \cap A_\alpha \neq \phi$, for $A_\alpha \in \tau$ and $A_\alpha \neq \phi, X$, for some $\alpha \in J$, where J is the index set.$\}$
Now, we define

$$\tau_f = \{\phi, X, \cup_{\{\alpha \in J\}} \{\tau_\alpha\}\}$$

The above collection τ_f of subsets of X is called the fine collection of subsets of X and (X, τ, τ_f) is said to be the fine space X generated by the topology τ on X (cf. [4]).

Definition 2.13 A subset U of a fine space X is said to be a fine-open set of X, if U belongs to the collection τ_f and the complement of every fine-open sets of X is called the fine-closed sets of X and we denote the collection by F_f (cf. [4]).

Definition 2.14 Let A be a subset of a fine space X, we say that a point $x \in X$ is a fine limit point of A if every fine-open set of X containing x must contains at least one point of A other than x (cf. [4]).

Definition 2.15 Let A be the subset of a fine space X, the fine interior of A is defined as the union of all fine-open sets contained in the set A i.e. the largest fine-open set contained in the set A and is denoted by f_{Int} (cf. [4]).

Definition 2.16 Let A be the subset of a fine space X, the fine closure of A is defined as the intersection of all fine-closed sets containing the set A i.e. the smallest fine-closed set containing the set A and is denoted by f_{cl} (cf. [4]).

Definition 2.17 A function f: $(X, \tau, \tau_f) \rightarrow (Y, \tau', \tau_f')$ is called fine-irresolute (or f-irresolute) if $f^{-1}(V)$ is fine-open in X for every fine-open set V of Y (cf. [4]).

Definition 2.18 A function f: $(X, \tau, \tau_f) \rightarrow (Y, \tau', \tau_f')$ is said to be αf-irresolute if $f^{-1}(V)$ is αf −open in X for every αf −open set V of Y (cf. [4]).

Definition 2.19 A function f: $(X, \tau, \tau_f) \rightarrow (Y, \tau', \tau_f')$ is said to be βf-irresolute if $f^{-1}(V)$ is βf −open in X for every βf −open set V of Y (cf. [4]).

Definition 2.20 A function f: $(X, \tau, \tau_f) \rightarrow (Y, \tau', \tau_f')$ is said to be pf-irresolute if $f^{-1}(V)$ is pf −open in X for every pf −open set V of Y (cf. [4]).

Definition 2.21 A function f: $(X, \tau, \tau_f) \rightarrow (Y, \tau', \tau_f')$ is said to be sf-irresolute if $f^{-1}(V)$ is sf −open in X for every sf −open set V of Y (cf. [4]).

3. fαgrw −Closed Sets

In this section we have defined $f\alpha grw$ −closed sets in fine-topological space and studied some of their properties.

Definition 3.1 A subset A of a fine-topological space (X, τ, τ_f) is called fine-regular open if $A = f_{int}(f_{cl}(A))$.

Example 3.1 Let $X = \{a, b, c\}$ be a topological space with the topology $\tau = \{\phi, X, \{b, c\}\}$, $\tau_f = \{\phi, X, \{b\}, \{c\}, \{a, b\}, \{a, c\}, \{b, c\}\}$, $F_f = \phi, X, \{a, c\}, \{a, b\}, \{c\}, \{b\}, \{a\}\}$. It may be easily checked that the only fine-regular open sets of fine-topological space (X, τ, τ_f) are $\phi, X, \{b\}, \{c\}, \{a, b\}, \{a, c\}$.

Definition 3.2 A subset A of a fine-topological space (X, τ, τ_f) is called fine-regular semi-open if there is a fine-regular open set U such that $U \subseteq A \subseteq f_{cl}(U)$.

Example 3.2 Let $X = \{a, b, c\}$ be a topological space with the topology $\tau = \{\phi, X, \{b, c\}\}$, $\tau_f = \{\phi, X, \{b\}, \{c\}, \{a, b\}, \{a, c\}, \{b, c\}\}$, $F_f = \phi, X, \{a, c\}, \{a, b\}, \{c\}, \{b\}, \{a\}\}$. It may be easily checked that the only fine-regular semi open sets of fine-topological space (X, τ, τ_f) are $\phi, X, \{b\}, \{c\}, \{a, b\}, \{a, c\}$.

Definition 3.3 A subset A of a fine-topological space (X, τ, τ_f) is called $f\alpha gr\omega$-closed if $f\alpha cl(A) \subseteq U$ whenever $A \subseteq U$ and U is fine-regular semi-open. A subset A of a fine-topological space (X, τ) is called $f\alpha gr\omega$ -open if A^c is $f\alpha gr\omega$ –closed.

Example 3.3 Let $X = \{a, b, c\}$ be a topological space with the topology $\tau = \{\phi, X, \{a\}, \{b\}, \{a, b\}\}$, $\tau_f = \{\phi, X, \{a\}, \{b\}, \{a, b\}, \{a, c\}, \{b, c\}\}$, $F_f = \{\phi, X, \{b, c\}, \{a, c\}, \{c\}, \{b\}, \{a\}\}$. It may be easily checked that the only $f\alpha gr\omega$-closed sets of fine-topological space (X, τ, τ_f) are $\phi, X, \{a\}, \{b\}, \{a, c\}, \{b, c\}, \{a, b\}$.

Definition 3.4 A function $f : (X, \tau, \tau_f) \rightarrow (Y, \tau', \tau_f')$ is said to be $f\alpha gr\omega$-continuous if $f^{-1}(V)$ is an $f\alpha gr\omega$-closed set of (X, τ, τ_f) for every fine-closed set V of (Y, τ', τ_f').

Example 3.4 Let $X = \{a, b, c\}$ be a topological space with the topology $\tau = \{\phi, X, \{a\}, \{a, b\}\}$, $\tau_f = \{\phi, X, \{a\}, \{a, b\}, \{a, c\}, \{b\}, \{b, c\}\}$, $F_f = \{\phi, X, \{b, c\}, \{c\}, \{b\}, \{a, c\}, \{a\}\}$ and let $Y = \{1, 2, 3\}$ with the topology $\tau' = \{\phi, X, \{1, 2\}\}$, $\tau_f' = \{\phi, X, \{1\}, \{2\}, \{1, 2\}, \{1, 3\}, \{2, 3\}\}$, $F_f' = \{\phi, X, \{2, 3\}, \{1, 3\}, \{3\}, \{2\}, \{1\}\}$. We define a map $f: (X, \tau, \tau_f) \rightarrow (Y, \tau', \tau_f')$ by $f(a) = 1, f(b) = 2, f(c) = 3$. It can be easily check that, the function f is $f\alpha gr\omega$-continuous.

Definition 3.5 A function $f : (X, \tau, \tau_f) \rightarrow (Y, \tau', \tau_f')$ is said to be $f\alpha gr\omega$-irresolute if $f^{-1}(V)$ is an $f\alpha gr\omega$ -closed set of (X, τ, τ_f) for every $f\alpha gr\omega$-closed set V of (Y, τ').

Example 3.5 Let $X = \{a, b, c\}$ be a topological space with the topology $\tau = \{\phi, X, \{a\}, \{a, b\}\}$, $\tau_f = \{\phi, X, \{a\}, \{a, b\}, \{a, c\}, \{b\}, \{b, c\}\}$, $F_f = \{\phi, X, \{b, c\}, \{c\}, \{b\}, \{a, c\}, \{a\}\}$ and let $Y = \{1, 2, 3\}$ with the topology $\tau' = \{\phi, X, \{1, 2\}\}$, $\tau_f' = \{\phi, X, \{1\}, \{2\}, \{1, 2\}, \{1, 3\}, \{2, 3\}\}$, $F_f' = \{\phi, X, \{2, 3\}, \{1, 3\}, \{3\}, \{2\}, \{1\}\}$. We define a map $f: (X, \tau, \tau_f) \rightarrow (Y, \tau', \tau_f')$ by $f(a) = 1, f(b) = 2, f(c) = 3$. It can be easily check that, the function f is $f\alpha gr\omega$-irresolute.

Definition 3.6 Let A be a subset of X. Then $f\alpha gr\omega$-closure of A is the intersection of all $f\alpha gr\omega$-closed sets containing A.

Definition 3.7 Let (X, τ, τ_f) be a fine-topological space. Two non-empty subsets A and B are said to be $f\alpha gr\omega$ -separated iff $A \cap f\alpha gr\omega - cl(B) = \phi$ and $f\alpha gr\omega - cl(A) \cap B = \phi$ i.e., $[A \cap f\alpha gr\omega - cl(B)] \cup [f\alpha gr\omega - cl(A) \cap B] = \phi$

Definition 3.8 Let (X, τ, τ_f) be a fine-topological space and $A \in X$. A point $x \in X$ is said to be an $f\alpha gr\omega$ -adherent point of A if every $f\alpha gr\omega$ -open set containing x, contains at least one point of A.

Definition 3.9 If $X = A \cup B$ such that A and B are non-empty $f\alpha gr\omega$ -separated sets then A, B form a $f\alpha gr\omega$ -separation of X.

Definition 3.10 A fine-topological space (X, τ, τ_f) is said to be $f\alpha gr\omega$-connected if X cannot be written as a union of two disjoint non-empty $f\alpha gr\omega$-open sets. If X is not $f\alpha gr\omega$-connected then it is $f\alpha gr\omega$-disconnected.

Definition 3.11 A topological space (X, τ, τ_f) is said to be $Tf\alpha gr\omega$-space if every $f\alpha gr\omega$ −closed set is fine-closed in X.

Theorem 3.1 Two $f\alpha gr\omega$-separated sets are always disjoint.

Proof. Let A and B be $f\alpha gr\omega$ -separated sets. Then, we have $A \cap f\alpha gr\omega - cl(B) = \phi$ and $f\alpha gr\omega - cl(A) \cap B = \phi$
Now, $A \cap B \subseteq f\alpha gr\omega - cl(A) \cap B = \phi$. This implies $A \cap B = \phi$. Hence, A and B are disjoint.

Theorem 3.2 Every separated sets are $f\alpha gr\omega$ -separated but the converse is not true.

Proof. It is obvious from the definitions.

Theorem 3.3 Two sets are $f\alpha gr\omega$-separated iff they are disjoint and neither of them contains limit point of the other.

Proof. Let A and B be $f\alpha gr\omega$ -separated iff $A \cap f\alpha gr\omega - cl(B) = \phi$ and $f\alpha gr\omega - cl(A) \cap B = \phi$ Now, $A \cap f\alpha gr\omega - cl(B) = \phi \Leftrightarrow A \cap (B \cup B_l) = \phi$ where B_l is the limit point of B. $\Leftrightarrow A \cap B = \phi$ and $A \cap B_l = \phi$. A and B are disjoint and A contains no limit point of B. Similarly, $f\alpha gr\omega - cl(A) \cap B = \phi$ iff A and B are disjoint and B contains no limit point of A.
Hence the proof.

Theorem 3.8 Let A and B be two $f\alpha gr\omega$ -separated sets of (X, τ, τ_f). If $C \subseteq A$ and $D \subseteq B$, then C and D are $f\alpha gr\omega$ -separated.

Proof. Let A and B be two $f\alpha gr\omega$ -separated sets of a fine-topological space (X, τ, τ_f). Then, $A \cap f\alpha gr\omega - cl(B) = \phi$ and $f\alpha gr\omega - cl(A) \cap B = \phi$. Let $C \subseteq A$ and $D \subseteq B$. Then, we have $C \cap f\alpha gr\omega - cl(D) = \phi$ and $f\alpha gr\omega - cl(C) \cap D = \phi$. Thus C and D are $f\alpha gr\omega$ separated.

Theorem 3.9 Two $f\alpha gr\omega$ -closed subsets of a fine-topological space (X, , τ_f) are $f\alpha gr\omega$ -separated iff they are disjoint.

Proof. Since $f\alpha gr\omega$ -separated sets are disjoint, $f\alpha gr\omega$ -closed separated sets are disjoint. Conversely, let A and B be two disjoint $f\alpha gr\omega$ -closed sets. Then $f\alpha gr\omega$ -cl(A) = A, $f\alpha gr\omega$ -cl(B) = B and $A \cap B = \phi$. Consequently, $A \cap f\alpha gr\omega - cl(B) = \phi$ and $f\alpha gr\omega - cl(A) \cap B = \phi$. Hence, A and B are $f\alpha gr\omega$ -separated.

Theorem 3.10 Two $f\alpha gr\omega$ -open subsets of a fine-topological space (X, , τ_f) are $f\alpha gr\omega$ -separated iff they are disjoint.

Proof. Since $f\alpha gr\omega$ -separated sets are disjoint, $f\alpha gr\omega$ -open separated sets are disjoint. Conversely, let A and B be two disjoint $f\alpha gr\omega$ -open sets. Then, we have to prove that $A \cap f\alpha gr\omega - cl(B) = \phi$ and $f\alpha gr\omega - cl(A) \cap B = \phi$. Suppose $A \cap f\alpha gr\omega - cl(B) = \phi$ Let $x \in A \cap f\alpha gr\omega - cl(B)$. Then, $x \in A$ and x is an $f\alpha gr\omega$ -adherent point of B. Since A is an $f\alpha gr\omega$ -open set containing x and x is an $f\alpha gr\omega$ -adherent point of B, A contain at least one point of B. Thus $A \cap B = \phi$ This contradicts the fact that A and B are disjoint. Therefore, $A \cap f\alpha gr\omega - cl(B) = \phi$. Similarly, $f\alpha gr\omega - cl(A) \cap B = \phi$. Hence A and B are $f\alpha gr\omega$ -separated.

4. fαgrω -Connected Spaces

In this section we define $f\alpha gr\omega$ –connectedness in fine topological space.

Definition 4.1 If $X = A \cup B$ such that A and B are non-empty $f\alpha gr\omega$-separated sets then A, B form a $f\alpha gr\omega$ -separation of X.

Definition 4.2 A fine-topological space (X, , τ_f) is said to be $f\alpha gr\omega$ -connected if X cannot be written as a union of two disjoint non-empty $f\alpha gr\omega$ -open sets. If X is not $f\alpha gr\omega$ -connected then it is $f\alpha gr\omega$ -disconnected.

Theorem 4.1 Every $f\alpha gr\omega$ -connected space is fine-connected but not conversely.

Proof. Let (X, τ, τ_f) be an $f\alpha gr\omega$ -connected space. Suppose that X is not connected. Then $X = A \cup B$, where A and B are disjoint non-empty fine-open sets in (X, τ, τ_f). Since every fine-open set is $f\alpha gr\omega$ -open, A and B are $f\alpha gr\omega$ -open. Therefore, $X = A \cup B$. where A and B are disjoint non-empty $f\alpha gr\omega$ -open sets in (X, τ, τ_f): This contradicts the fact that X is $f\alpha gr\omega$ -connected and so X is fine-connected

Theorem 4.2 If (X, τ, τ_f) is a $Tf\alpha gr\omega$-space and fine-connected, then X is $f\alpha gr\omega$-connected.

Proof. Obvious from the definition.

Theorem 4.3 A fine-topological space (X, τ, τ_f) is $f\alpha gr\omega$-disconnected if there exists a non-empty proper subset of X which is both $f\alpha gr\omega$-open and $f\alpha gr\omega$-closed.

Proof. Let A be a non-empty proper subset of X which is both $f\alpha gr\omega$-open and $f\alpha gr\omega$-closed. Then clearly A^c is a non-empty proper subset of X which is both $f\alpha gr\omega$-open and $f\alpha gr\omega$-closed. Thus $A \cap A^c = \phi$ and also $X = A \cup A^c$. Thus X is the union of two non-empty $f\alpha gr\omega$-open sets. Hence, X is $f\alpha gr\omega$-disconnected.

Theorem 4.4 A fine-topological space (X, τ, τ_f) is $f\alpha gr\omega$-disconnected iff X is the union of two non-empty disjoint $f\alpha gr\omega$-open sets.

Proof. Let (X,τ, τ_f) be $f\alpha gr\omega$-disconnected. Then, there exists a non-empty proper subset A of X that is both $f\alpha gr\omega$-open and $f\alpha gr\omega$-closed. And therefore, A^c is a non-empty subset of X that is both $f\alpha gr\omega$-open and $f\alpha gr\omega$-closed. Thus $X = A \cup A^c$ and $A \cap A^c = \phi$. This shows that X is the union of two non-empty disjoint $f\alpha gr\omega$-open sets.

Conversely, let X be the union of two non-empty disjoint $f\alpha gr\omega$-open sets A and B. Then $B^c = A$. Now, B is $f\alpha gr\omega$-open, A is $f\alpha gr\omega$-closed. Since B is non-empty, A is a non-empty proper subset of X that is both $f\alpha gr\omega$-open and $f\alpha gr\omega$-closed. Thus X is $f\alpha gr\omega$-disconnected.

Theorem 4.5 For a fine-topological space (X, τ, τ_f); the following are equivalent:
(i) (X, τ, τ_f) is $f\alpha gr\omega$-connected.
(ii) The only subsets of (X, , τ_f) which are both $f\alpha gr\omega$-open and $f\alpha gr\omega$-closed are ϕ and X.

Proof. (i) ⇒ (ii) : Let U be an $f\alpha gr\omega$-open and $f\alpha gr\omega$-closed subset of X. Then U^c is both $f\alpha gr\omega$-open and $f\alpha gr\omega$-closed in X. Since X is disjoint union of $f\alpha gr\omega$ -open sets U and U^c , by assumption one of these must be empty. i.e., U = ϕ or U = X.
(ii) ⇒ (i) : Suppose that X is $f\alpha gr\omega$-disconnected. Then by Theorem 4.3, there exists a proper subset of X, which is both $f\alpha gr\omega$-open and $f\alpha gr\omega$-closed, which is a contradiction. Thus X is $f\alpha gr\omega$-connected.

Theorem 4.6 If A and B are $f\alpha gr\omega$-separated sets of (X, τ, τ_f) and if (Y, τ', τ_f') is an $f\alpha gr\omega$-connected subspace of (X, τ, τ_f), then Y lies entirely within A or B.

Proof. Since A and B are both $f\alpha gr\omega$-open in X, the sets $A \cap Y$ and $B \cap Y$ are $f\alpha gr\omega$-open in Y . These, two sets are disjoint and their union is Y. If they were both non-empty, they would be $f\alpha gr\omega$-separated sets of Y. Therefore, one of them is empty. Hence, Y must lie entirely in A or in B.

Theorem 4.7 If $f : (X, \tau, \tau_f) \to (Y, \tau', \tau_f')$ is $f\alpha gr\omega$ −continuous surjection and (X, τ, τ_f) is $f\alpha gr\omega$-connected then (Y, τ', τ_f') is fine- connected.

Proof. Suppose that Y is not fine-connected. Let $Y = A \cup B$. where A and B are disjoint non-empty open sets in Y. Since f is $f\alpha gr\omega$-continuous and onto, $X = f^{-1}(A) \cup f^{-1}(B)$ where $f^{-1}(A)$ and $f^{-1}(B)$ are disjoint non-empty $f\alpha gr\omega$-open sets in X. This contradicts the fact that X is $f\alpha gr\omega$-connected. Hence, Y is fine-connected.

Theorem 4.8 If $f : (X, \tau, \tau_f) \to (Y, \tau', \tau_f')$ is $f\alpha gr\omega$ -irresolute surjection and (X, τ, τ_f) is $f\alpha gr\omega$ -connected, then Y is $f\alpha gr\omega$ -connected.

Proof. Suppose that Y is not $f\alpha gr\omega$ -connected. Let $Y = A \cup B$. where A and B are disjoint non-empty $f\alpha gr\omega$ -open set in Y. Since f is $f\alpha gr\omega$ -irresolute and onto, $X = f^{-1}(A) \cup f^{-1}(B)$ where $f^{-1}(A)$ and $f^{-1}(B)$ are disjoint non-empty $f\alpha gr\omega$ -open sets in X. This contradicts the fact that X is $f\alpha gr\omega$ -connected. Hence, Y is $f\alpha gr\omega$ -connected.

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Author Profile

Dr. Kusumlata Rajak is an Assistant Professor in the Department of Mathematics, St. Aloysius College (Autonomous), Jabalpur. She has about 7 years research experience. She has published about 12 research papers in International Journal and two books from Lambert Academic Publisher, Germany. Her area of specialization is Topology