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On Weakly $f-\omega$ Continuous Functions

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Abstract: ***In this paper, we introduced a new class of functions called weakly $f\omega$-continuous, $\alpha f\omega$ −continuous, $\beta f\omega$ −continuous, $pf\omega$ −continuous, $sf\omega$ −continuous, $\omega\alpha f$ −continuous, $\omega\beta f$ −continuous, ωpf −continuous and ωsf −continuous functions in fine-topological space and investigated some of their fundamental properties.***

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1. Introduction

The notion of generalized closed setshas been studied extensively in recent years by many topologists [cf. [3], [7], [9]] because generalized closed sets are only natural generalization of closed sets. Moreimportantly, they also suggest several new properties of topological spaces. Asgeneralization of closed sets, ω-closed sets were introduced and studied by Sundaram and Sheik John (cf. [8], [9]).

Powar P. L. and Rajak K. [4], have investigated a special case of generalized topological space called fine topological space. In this space, they have defined a new class of open sets namely fine-open sets which contains all α −open sets, β −open sets, semi-open sets, pre-open sets, regular open sets etc. By using these fine-open sets they have defined fine-irresolute mappings which include pre-continuous functions, semi-continuous function, α −continuouos function, β −continuous functions, α −irresolute functions, β −irresolute functions, etc.

In this paper, we introduced a new class of functionscalled weakly $f\omega$-continuous, $\alpha f\omega$ −continuous, $\beta f\omega$ −continuous, $pf\omega$ −continuous, $sf\omega$ −continuous, $\omega\alpha f$ −continuous, $\omega\beta f$ −continuous, ωpf −continuous and ωsf −continuous functions in fine-topological space and investigated some of their fundamental properties.

2. Preliminaries

Throughout this paper, spaces always mean topological spaces on which noseparation axioms are assumed unless otherwise mentioned. For a subset A ofa space (X, τ), Cl(A) and Int(A) denote the closure of A and the interior of Ain X, respectively. A subset A of X is said to be semi-open [2] if A ⊆Cl(Int(A)).The complement of a semi-open set is called a semi-closed set [1].

Definition 2.1 Let (X, τ) be a topological space. A subset A of (X, τ) issaid to be ω-closed in (X, τ) if Cl(A) ⊂U whenever A ⊂U and U is semi-open in X. A subset B of (X, τ) is said to be ω-open if $X - B$ is ω-closed (cf. [8]).

The family of all ω-open (resp. ω-closed) sets of (X, τ) is denoted by ω(X, τ)(resp. ωC(X, τ)) and sometimes they are denoted by $\omega(\tau)$ (resp. $\omega C(\tau)$). Weset ω(X, x) = {V ∈ $\omega(\tau)$)|x ∈ V} for x ∈X. Note that the family of ω-opensubsets of (X, τ) forms a topology.

Definition 2.2 The union (resp. intersection) of all ω-open (resp. ω-closed) sets each contained in (resp. containing) a set A in a space X is calledthe ω-interior (resp. ω-closure) of A and is denoted by ω_{Int}(A) (resp. ω_{Cl}(A))(cf. [9]).

Definition 2.3 A function f: (X, τ) → (Y, τ') is said to be ω-continuous[9] (resp. ω-irresolute [8]) if $f^{-1}(V) \in \omega(\tau)$ for every open set V of Y (resp.$V \in \omega(\tau')$).

Definition 2.4 A topological space (X, τ) is said to be ω-regular [12] if foreach closed set F and each $x \notin F$, there exist disjoint ω-open sets U and Vsuch that x ∈U and F ⊂V .

Definition 2.5 A function f : (X, τ) → (Y, τ') is called weakly ω-continuousif for each x ∈X and each open set V containing f(x) there exists $U \in \omega O(X,x)$such that $f(U) \subseteq \omega_{Cl}(V)$ (cf. [5]).

Definition 2.6 A topological space (X, τ) is called ω-connected [8] if Xcannot be written as the disjoint union of two nonempty ω-open sets (cf. [9]).

Definition 2.7 A topologicalspace (X, τ) is said to be ω-T_2 [3] if for eachpair of distinct points x and y in X, there exist U ∈ ωO(X, x) and V ∈ ωO(X, y)such that U ∩ V = ϕ(cf. [5]).

Definition 2.8 Let *(X, τ)* be a topological space we define
$\tau(A_\alpha) = \tau_\alpha(say) = \{G_\alpha(\neq X) : G_\alpha \cap A_\alpha = \phi$,for $A_\alpha \in \tau$and $A_\alpha = \phi, X$,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 $\tau_f$of subsets of X is called the fine collection of subsetsof X and (X, τ, τ_f) is said to be the fine space X generated by the topology τ on$X$ (cf. [4]).

Definition 2.9 A subset U of a fine space X is said to be a fine-open set of X,if U belongs to the collection $\tau_f$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 2.10 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 atleast one point of A other than x(cf. [4]).

Definition 2.11 Let A be the subset of a fine space X, the fine interior of A isdefined as the union of all fine-open sets contained in the set A i.e. the largestfine-open set contained in the set A and is denoted by f_{Int} (cf. [4]).

Definition 2.12 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. thesmallest fine-closed set containing the set A and is denoted byf_{cl}(cf. [4]).

Definition 2.13A function f: $(X, \tau, \tau_f) \to (Y, \tau', \tau_f')$ 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 2.14A fine-open set S of a fine topological space (X, τ, τ_f) (cf. [4]) is called

1. αf −open if S is α −open subset of a topological space (X, τ).
2. βf −open if S is β −open subset of a topological space (X, τ).
3. pf −open if S is pre-open subset of a topological space (X, τ).
4. sf −open if S is semi-open subset of a topological space (X, τ).

Definition 2.15 A function f: (X, τ, τ_f) → (Y, τ', τ_f') is said to beαf-irresolute if $f^{-1}(V)$ is αf −open in X for every αf −open set V of Y(cf. [4]).

Definition 2.16 A function f: (X, τ, τ_f) → (Y, τ', τ_f') is said to beβf-irresolute if $f^{-1}(V)$ is βf −open in X for every βf −open set V of Y(cf. [4]).

Definition 2.17 A function f: (X, τ, τ_f) → (Y, τ', τ_f') is said to bepf-irresolute if $f^{-1}(V)$ is pf −open in X for every pf −open set V of Y(cf. [4]).

Definition 2.18 A function f: (X, τ, τ_f) → (Y, τ', τ_f') is said to besf-irresolute if $f^{-1}(V)$ is sf −open in X for every sf −open set V of Y(cf. [4]).

3. Weakly f − ω −Continuous Functions

In this section, we define weakly$f - \omega$ −continuous functions in fine-topological space.

Definition 3.1 Let (X, τ, τ_f) be a fine-topological space. A subset A of (X, τ, τ_f) issaid to be $f\omega$-closed in (X, τ, τ_f) if $f_{Cl}(A) \subset U$ whenever A ⊂ U and U is f-semi-open in X. A subset B of (X, τ, τ_f) is said to be fω-open if $X - B$ is $f\omega$-closed.

The family of all $f\omega$-open (resp. $f\omega$-closed) sets of (X, τ, τ_f) is denoted by ω(X, τ, τ_f)(resp. $f\omega$C(X, τ, τ_f)) and sometimes they are denoted by $\omega(\tau_f)$ (resp. $\omega C(\tau_f)$). Weset ω(X, x) = {V ∈ $\omega(\tau_f)$)|x ∈V } for x ∈X. Note that the family of $f\omega$-open subsets of (X, τ, τ_f) forms a topology.

Example 3.1 Let $X = \{a, b, c\}$and $\tau = \{\phi, X, \{a\}\}$, , $\tau_f = \{\phi, X, \{a\}, \{a, c\}, \{a, b\}\}$, $F_f = \{\phi, X, \{b, c\}, \{b\}, \{c\}\}$.
It may be easily checked that, the set $\{b, c\}$ is $f\omega$-closed.

Definition 3.2 The union (resp. intersection) of all $f\omega$-open (resp. $f\omega$-closed) sets each contained in (resp. containing) a set A in a space X is calledthe $f\omega$-interior (resp. $f\omega$-closure) of A and is denoted by fω_{Int} (A) (resp. $f\omega_{Cl}$(A)).

Definition 3.3 A function f: (X, τ, τ_f) → (Y, τ', τ_f') is said to be $f\omega$-continuous if $f^{-1}(V) \in \omega(\tau_f)$ for every open set V of Y.

Example 3.2 Let$X = \{a, b, c\}$,$\tau = \{\phi, X, \{a, b\}\}$, $\tau_f = \{\phi, X, \{a\}, \{b\}, \{a, b\}, \{a, c\}, \{b, c\}\}$, $F_f = \{\phi, X, \{b, c\}, \{a, c\}, \{c\}, \{b\}, \{a\}\}andY = \{1, 2, 3\}$, $\tau' = \{\phi, Y, \{1\}\}$, $\tau'_f = \{\phi, Y, \{1\}, \{1,2\}, \{1,3\}$,, $F'_f = \{\phi, Y, \{2,3\}, \{3\}, \{2\}\}$. We define a map f: (X,$\tau, \tau_f$) → (Y, τ', τ_f') by $f(a) = 1, f(b) = 2, f(c) = 3$.
It may be easily checked that, the only open sets of Y are $\phi, Y, \{1\}, \{1, 2\}, \{1, 3\}$ and their respective pre-images are $\phi, X, \{a\}, \{a, b\}, \{a, c\}$, which are $f\omega$ −open in X. Thus, f is $f\omega$ −continuousmap.

Definition 3.4 A function f: (X,τ, τ_f) → (Y, τ', τ_f') is said to be $f\omega$-irresolute if $f^{-1}(V) \in \omega(\tau_f)$ for every $V \in \omega(\tau_f')$.

Example 3.3 Let $X = \{a, b, c\}$, $\tau = \{\phi, X, \{a, b\}\}$, $\tau_f = \{\phi, X, \{a\}, \{b\}, \{a, b\}, \{a, c\}, \{b, c\}\}$, $F_f = \{\phi, X, \{b, c\}, \{a, c\}, \{c\}, \{b\}, \{a\}\}$ and$Y = \{1, 2, 3\}$, $\tau' = \{\phi, Y, \{1\}\}$, $\tau'_f = \{\phi, Y, \{1\}, \{1,2\}, \{1,3\}$,, $F'_f = \{\phi, Y, \{2,3\}, \{3\}, \{2\}\}$. We define a map f: (X,$\tau, \tau_f$) → (Y, τ', τ_f') by $f(a) = 1, f(b) = 2, f(c) = 3$.
It may be easily checked that, the only $f\omega$ − open sets of Y are $\phi, Y, \{1\}, \{1, 2\}, \{1, 3\}$ and their respective pre-images are $\phi, X, \{a\}, \{a, b\}, \{a, c\}$, which are $f\omega$ −open in X. Thus, f is $f\omega$ −irresolute.

Definition 3.5 A function f : (X, τ) → (Y, τ') is called weakly $f\omega$-continuousif for each x ∈X and each open set V containing f(x) there exists $U \in \omega O(X, x)$such that $f(U) \subseteq \omega Cl(V)$.

Example 3.4 Let $X = \{a, b, c\}$, $\tau = \{\phi, X, \{a\}, \{b\}, \{a, b\}\}$, $\tau_f = \{\phi, X, \{a\}, \{b\}, \{a, b\}, \{a, c\}, \{b, c\}\}$, $F_f = \{\phi, X, \{b, c\}, \{a, c\}, \{c\}, \{b\}, \{a\}\}$ and$Y = \{1, 2, 3\}$, $\tau' = \{\phi, Y, \{1, 2\}\}$, $\tau'_f = \{\phi, Y, \{1\}, \{2\}, \{2, 3\}, \{1,2\}, \{1,3\}$, $F'_f = \{\phi, Y, \{2,3\}, \{1,3\}, \{1\}, \{3\}, \{2\}\}$. We define a map f: (X,$\tau, \tau_f$) → (Y, τ', τ_f') by $f(a) = 1, f(b) = 2, f(c) = 3$. It may be easily checked that, the map f is weakly $f\omega$-continuous.
Example 3.5 Let X = {a, b, c}, τ= {ϕ, X, {b}}and μ' = {ϕ, {a}, X}.Then the identity function $f : (X, \tau_f, \tau_f') \to (X, \mu_f, \mu_f')$ is weakly ω-continuous but notω-continuous.

Definition 3.6 A function f: (X, τ, τ_f) → (Y, τ', τ_f') is said to be fine semi-ω-continuous if $f^{-1}(V)$ is $f\omega$ −open in X for every semi-open set V of Y.

Definition 3.7 A function f: (X, τ, τ_f) → (Y, τ', τ_f') is said to be$\alpha f\omega$-continuous if $f^{-1}(V)$ is αf −open in X for every ω-open set V of Y.

Definition 3.8 A function f: $(X, \tau, \tau_f) \to (Y, \tau', \tau_f')$ is said to be$\beta f\omega$-continuous if $f^{-1}(V)$ is βf $-$open in X for every ω $-$open set V of Y.

Definition 3.9 A function f: $(X, \tau, \tau_f) \to (Y, \tau', \tau_f')$ is said to be$pf\omega$-continuous if $f^{-1}(V)$ is pf $-$open in X for every ω $-$open set V of Y.

Definition 3.10 A function f: $(X, \tau, \tau_f) \to (Y, \tau', \tau_f')$ is said to be $sf\omega$-continuous if $f^{-1}(V)$ is sf $-$open in X for every ω $-$open set V of Y.

Definition 3.11 A function f: $(X, \tau, \tau_f) \to (Y, \tau', \tau_f')$ is said to be$\omega\alpha f$-continuous if $f^{-1}(V)$ is ω $-$open in X for every αf $-$open set V of Y.

Definition 3.12 A function f: $(X, \tau, \tau_f) \to (Y, \tau', \tau_f')$ is said to be$\omega\beta f$-continuous if $f^{-1}(V)$ is ω $-$open in X for every βf $-$open set V of Y.

Definition 3.13 A function f: $(X, \tau, \tau_f) \to (Y, \tau', \tau_f')$ is said to beωpf-continuous if $f^{-1}(V)$ is ω $-$open in X for every pf $-$open set V of Y.

Definition 3.14 A function f: $(X, \tau, \tau_f) \to (Y, \tau', \tau_f')$ is said to beωsf-continuous if $f^{-1}(V)$ is ω $-$open in X for every sf $-$open set V of Y.

Theorem 3.1 Let f: $(X, \tau, \tau_f) \to (Y, \tau', \tau_f)$ and g: $(Y, \tau', \tau'_f) \to (Z, \tau'', \tau''_f)$be functions. Then the composition gof: $(X, \tau, \tau_f) \to (Z, \tau'', \tau''_f)$ is αf $-$iirresolute if f is $\alpha f\omega$ $-$ccontinuous and g is $\omega\alpha f$ $-$ccontinuous.
Proof. Let V be any ω $-$open subset of Z. Since g is $\omega\alpha f$ $-$ccontinuous$g^{-1}(V)$ is αf $-$open in Y. Since $g^{-1}(V)$ is aαf $-$open in Y and f is $\alpha f\omega$ $-$ccontinuous$f^{-1}(g^{-1}(V))$ is αf $-$open in X but $f^{-1}\left(g^{-1}(V)\right) = (gof)^{-1}(V)$. Thus, (gof) is αf $-$iirresolute.

Theorem 3.2 Let f: $(X, \tau, \tau_f) \to (Y, \tau', \tau_f')$ and g: $(Y, \tau', \tau'_f) \to (Z, \tau'', \tau''_f)$ be functions. Then the composition gof: $(X, \tau, \tau_f) \to (Z, \tau'', \tau''_f)$ is βf $-$iirresolute if f is $\beta f\omega$ $-$ccontinuous and g is $\omega\beta f$ $-$ccontinuous.

Proof. Similar as of theorem 3.1.

Theorem 3.3 Let f: $(X, \tau, \tau_f) \to (Y, \tau', \tau_f')$ and g: $(Y, \tau', \tau'_f) \to (Z, \tau'', \tau''_f)$ be functions. Then the composition gof: $(X, \tau, \tau_f) \to (Z, \tau'', \tau''_f)$ is pf $-$iirresolute if f is $pf\omega$ $-$ccontinuous and g is ωpf $-$ccontinuous.

Proof. Similar as of theorem 3.1.

Theorem 3.4 Let f: $(X, \tau, \tau_f) \to (Y, \tau', \tau_f')$ and g: $(Y, \tau', \tau'_f) \to (Z, \tau'', \tau''_f)$ be functions. Then the composition gof: $(X, \tau, \tau_f) \to (Z, \tau'', \tau''_f)$ is sf $-$iirresolute if f is $sf\omega$ $-$ccontinuous and g is ωsf $-$ccontinuous.

Proof: Similar as of theorem 3.1.

Theorem 3.5 For a function f: $(X,\tau, \tau_f) \to (Y,\tau', \tau_f')$, the following propertiesare equivalent:
1. f is weakly ω-continuous;
2. $f^{-1}(V) \subset \omega Int(f^{-1}(\omega\, Cl(V)))$ for every fine-open set V of Y;
3. $\omega\, Cl(f^{-1}(\omega\, Int(F))) \subset f^{-1}(F)$ for every fine-closed set F of Y;
4. $\omega Cl(f^{-1}(\omega\, Int(Cl(B)))) \subset f^{-1}(Cl(B))$ for every subset B of Y;
5. $f^{-1}(Int(B)) \subset \omega\, Int(f^{-1}(\omega\, Cl(Int(B))))$ for every subset B of Y;
6. $\omega Cl(f^{-1}(V)) \subset f^{-1}(\omega\, Cl(V))$ for every fine-open set V of Y.

Proof. We prove this theorem in following implications:
(1)⇒(2): Let V be an open subset of Y and $x \in f^{-1}(V)$. Then$(x) \in V$. There exists $U \in \omega O(X, x)$ such that $f(U) \subset \mathrm{f}\omega_{cl}(V)$.
Thus, $x \in U \subset f^{-1}(\mathrm{f}\omega_{cl}(V))$.Hence, $x \in \mathrm{f}\omega_{Int}(f^{-1}(\mathrm{f}\omega_{cl}(V)))$.
Then,$f^{-1}(V) \subset \mathrm{f}\omega_{Int}(f^{-1}(\mathrm{f}\omega_{cl}(V)))$.
(2)⇒(3): Let F be any closed set of Y . Then $Y \setminus F$ is openin Y. By (2), $\mathrm{f}\omega_{cl}(f^{-1}(\mathrm{f}\omega_{Int}(F))) \subset f^{-1}(F)$.
(3)⇒(4): Let B be any subset ofY . Then $\mathrm{f}\omega_{cl}$(B) is closed in Y and by (3), we obtain $\mathrm{f}\omega_{cl}(f^{-1}(\mathrm{f}\omega_{Int}(\mathrm{f}\omega_{cl}(B)))) \subset f^{-1}(\mathrm{f}\omega_{cl}(B))$.
(4)⇒(5): Let B be any subset of Y . Then we have $f^{-1}(\mathrm{f}\omega_{Int}(B)) = X \setminus f^{-1}(\mathrm{f}\omega_{cl}(Y \setminus B)) \subset \mathrm{f}\omega_{Int}(f^{-1}(\mathrm{f}\omega_{cl}(Int(B))))$.
(5)⇒(6): Let V be anyopen subset of Y . Suppose that$x \notin f^{-1}(\mathrm{f}\omega_{cl}(V))$. Then $f(x) \notin \mathrm{f}\omega_{cl}(V)$and there exists $U \in \omega O(Y, f(x))$ such that U ∩ V $=\phi$; hence$\mathrm{f}\omega_{cl}(U) \cap V = \emptyset$. By (5), $x \in f^{-1}(U) \subset \mathrm{f}\omega_{Int}(f^{-1}(\mathrm{f}\omega_{cl}(U)))$ and hence there exists$W \in \omega O(X, x)$ such that$W \subset f^{-1}(\mathrm{f}\omega_{cl}(U))$. Since$\mathrm{f}\omega_{cl}(U) \cap V = \emptyset$, $W \cap f^{-1}(V) = \emptyset$and by Lemma 3 $x \notin \mathrm{f}\omega_{cl}(f^{-1}(V))$. Therefore, $\mathrm{f}\omega_{cl}(f^{-1}(V)) \subset f^{-1}(\mathrm{f}\omega_{cl}(V))$.
(6)⇒(1): Let $x \in X$ and V any open subset of Y containingf(x). By (6), $x \in f^{-1}(V) \subset f^{-1}(\mathrm{f}\omega_{Int}(\mathrm{f}\omega_{cl}(V))) \subset f^{-1}(\mathrm{f}\omega_{Int}(\mathrm{f}\omega_{cl}(V))) \subset X \setminus \mathrm{f}\omega_{cl}(f^{-1}(Y \setminus \mathrm{f}\omega_{cl}(V))) = \mathrm{f}\omega_{Int}(f^{-1}(\mathrm{f}\omega_{cl}(V)))$. Therefore, there exists $U \in \omega O(X, x)$ such that$U \subset \mathrm{f}\omega_{cl}(V)$. This shows that f is weakly $f\omega$-continuous.

4. fω −Connected Space

In this section we define $f\omega$ $-$connected space in fine-topological space.
Definition 4.1 A fine-topological space (X, τ) is called fωconnected if Xcannot be written as the disjoint union of two nonempty $f\omega$-open sets.

Definition 4.2 A topological space (X, τ) is said to be $f\omega$-regular if foreach fine-closed set F and each $x \notin F$, there exist disjoint $f\omega$-open sets U and Vsuch that x ∈U and F ⊂V .

Theorem 4.1 Let f : $(X, \tau) \to (Y, \tau')$ be a weakly $f\omega$-continuous surjectivefunction. If X is $f\omega$-connected, then Y is fine-connected.

Proof. Suppose that (Y, τ') is not fine-connected. Then there exist nonemptydisjoint fine-open sets V_1 and V_2 in Y such that $V_1 \cup V_2 = Y$. Since f is surjective,$f^{-1}(V_1)$ and $f^{-1}(V_2)$ are nonempty disjoint subsets of X such that $f^{-1}(V_1) \cup f^{-1}(V_2) = X$. By Theorem 3.1, we have $f^{-1}(V_i) \subseteq f\omega_{Int}(f^{-1}(f\omega_{cl}(V_i))), i = 1,2$. Since V_i is fine-open and closed and every fine-closed set is$f\omega$-closed, we obtain$f^{-1}(V_i) \subseteq f\omega_{Int}(f^{-1}(V_i))$ and hence $f^{-1}(V_i)$ is $f\omega$-open for i = 1,2. This impliesthat (X, τ) is not $f\omega$-connected.This shows that if X is $f\omega$-connected, then Y is fine-connected.

5. Conclusion

By using the concepts of $f\omega$-closed sets on fine-topological space, we may define a generalized form of continuity i.e. called weakly$f\omega$-continuous, $\alpha f\omega$ −continuous, $\beta f\omega$ −continuous, $pf\omega$ −continuous, $sf\omega$ −continuous, $\omega\alpha f$ −continuous, $\omega\beta f$ −continuous, ωpf −continuous and ωsf −continuousin fine-topological space and investigated some of their fundamental properties. Also, by defining some irresolute maps, the more general form of homeomorphism can be studied which is widely used in quantum physics.

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