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Almost Irresolute Functions Via Generalized Topology

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Abstract: A function $f: (X,\mu) \rightarrow (Y,\sigma)$ is said to be almost (μ, σ) -irresolute if $f^{-1}(V) \in so(X,\mu)$ for every regular semi-open set *V* of *Y*. In this paper the authors introduce and investigate almost (μ, σ)-irresolute, quasi (μ, σ)-irresolute on generalized topological space (X,μ) into the topological space (Y,σ). Some characterizations and properties of such a type of functions are discussed.

Keywords : Generalized topological space; almost irresolute; quasi (μ, σ) -irresolute; μ-semipreopen; almost (μ, σ)-irresolute.

1. INTRODUCTION

In topology weak forms of open sets play an important role in the generalization of various forms of continuity. Using various forms of open sets, many authors have introduced and studied various types of continuity. In 1961, Levine [10] introduced the notion of weak continuity in topological spaces and obtained a decomposition of continuity.

Generalized topology (X,μ) was first introduced by csaszar [3]. We recall some notions defined in [3]and [7].

Let X be a set. A subset μ of expX is called a generalized topology on X and (X,μ) is called a generalized topological space [3] (GTS) if μ has the following properties

(i) $\phi \in \mu$

(ii) Any union of elements of belongs to .

For a GTS (X,μ), the elements of μ are called μ-open sets and the complement of μ-open sets are called μ-closed sets. For $A \subseteq X$, we denote by $c_\mu(A)$ the intersection of all μ-closed sets containing A, that is, the smallest μ- closed set containing A, and by $i_\mu(A)$ the union of all μ-open sets contained in A, that is, the largest μ-open set contained in A. Intensive research on the field of generalized topological space (X, μ) was done in the past ten years as the theory was developed by A. Csaszar[3], Ahana Balan[7]

It is easy to observe that i_μ and c_μ are idempotent and monotonic, where γ: exp X→exp X said to be idempotent if and only if $A \subseteq B \subseteq X$ implies $\gamma(\gamma(A)) = \gamma(A)$ and monotonic if and only if $\gamma(A) \subseteq \gamma(B)$. It is also well known that from [5,6] , that if μ is a GT on X and $A \subseteq X$, $x \in X$ then $x \in c_\mu(A)$ if and only if $x \in M \in \mu => M \cap A \neq \varnothing$ and $c_\mu(X\text{-}A) = X - i_\mu(A)$.

Let $B \subset \exp X$ and $\varnothing \in B$. Then B is called a base[4] for μ if $\{\cup B' : B' \subset B\} = \mu$. We also say that μ is generated by B. Consider X={a,b,c} and $\mu = \{\varnothing, \{a\}, \{b\}, \{a,b\}\}$. The μ-closed sets are X,{b,c},{a,c}and{c}. If A={a,b} then A is not μ-closed

A generalized topology (X, μ) is said to be strong[4] if $X \in \mu$. Throughout this paper a space (X, μ) or simply X for short, will always mean a strong generalized topological space with the strong generalized topology μ unless otherwise explicitly stated. A point $x \in X$ is called a μ-cluster point of $B \subset X$ if $U \cap (B\text{-}\{x\}) \neq \varnothing$ for each $U \in \mu$ with $x \in \mu$. The set of all μ-cluster point of B is denoted by d(B).

Let (Y, σ) be a topological space with topology σ. Let $A \subset (Y, \sigma)$. The closure and interior of A is denoted by cl(A) and int(A) respectively, where the closure of A is the intersection of all closed sets containing A and the interior of A is the union of all open sets contained in A.

Let (X, τ) be a topological Space. The δ-closure[20] of a subset A of a topological space (X, τ) is defined by$\{x \in X : A \cap U \neq \varnothing$ for all regular open set U containing $x\}$,where a subset A is called regular open if $A = int(cl(A))$. A subset A of a topological space (X, τ) is called semi-open[11] (resp., pre-open[13], α-open[15], β-open[14], b-open[1], δ-pre open [18], δ-semi open[17], and e-open[8]) if $A \subseteq cl(int(A))$ (resp., $A \subseteq int(cl(A))$, $A \subseteq int(cl(int(A))$, $A \subseteq cl(int(cl(A)))$, $A \subseteq cl(int(A)) \cup int(cl(A))$, $A \subseteq int(cl_\delta(A))$, $A \subseteq cl(\mathrm{int}_\delta(A))$ and $A \subseteq int(cl_\delta(A)) \cup cl(\mathrm{int}_\delta(A))$). A point $x \in X$ is in $sl(A)$ (resp., $pcl(A)$) if for each semi open (resp., pre open) set U containing x, $U \cap A \neq \varnothing$. A point $x \in X$ is called a θ-cluster[20] (resp., semi θ-cluster[12],P(θ)-cluster[16]) point of A denoted by $cl_\theta(A)$ (resp., $s.\ cl_\theta(A)$, p(θ)-$cl(A)$) if $cl(A) \cap U \neq \varnothing$ (resp., $sl(A) \cap U \neq \varnothing$, $pl(A) \cap U \neq \varnothing$) for every open (resp., semi-open, pre-open) set U containing x. A subset A is called θ-closed (resp., semi θ-closed, P(θ)-closed) if $cl_\theta(A) = A$ (resp., $s.cl_\theta(A)) = A$, p(θ)-$cl(A) = A$). The complement of a θ-closed (resp., semi-θ-closed, p(θ)-closed) set is called θ-open(resp., semi-θ-open, p(θ)-open). θ-open sets in a topological space forms a topology which is weaker than the original topology.

For any topological space(X,τ), the collection of all semi open (resp., pre-open, α-open, β-open, b-open, e-open, θ-open, p(θ)-open) sets are denoted by so(X) (resp., po(X), α-o(X), β-o(X), Bo(X), eo(X), θ-o(X), pθ-o(X)). We note that each of these collections forms a generalized topology on (X,τ). The end or omission of a proof will be denoted by ■

A subset A of (X,τ) is θ-open if for each $x \in A$ there exists an open set U such that $x \in U \subset cl(U) \subset A$.

Recall that, A subset A of X is said to be regular semi-open if there exists a regular open set U of X such that $U \subset A \subset cl(U)$

A function $f: X \to Y$ is said to be irresolute if $f^{-1}(V)$ is semiopen in X for every semiopen set V of Y.

A function $f: X \to Y$ is said to be almost irresolute if $f^{-1}(V)$ is semiopen in X for every regular open set V of Y.

A function $f: X \to Y$ is said to be θ-irresolute if for each $x \in X$ and each semi neighbourhood V of $f(x)$ there exists a semi neighbourhood U of x such that $f(s.cl(V)) \subset s.cl(V)$

A function $f: X \to Y$ is said to be quasi irresolute if for each $x \in X$ and each $V \in so(Y, f(x))$ there exists $U \in so(X,x)$ such that $f(U) \subset s.cl(V)$

A subset A of X is μ-semiopen (abbr. μ-so) in X if $A \subset c_\mu i_\mu(A)$. μ-so sets in X is denoted by so(X, μ). A subset A of X is μ-preopen (abbr. μ-po) in X if $A \subset i_\mu c_\mu(A)$. The family of all μ-po sets in X is denoted by po(X, μ). For a subset A of X, the intersection of all μ-semi-closed sets containing A is called the μ-semi-closure of A and is denoted by $s.c_\mu(A)$. For a subset A of X, the union of all μ-semi-open sets contained in A is called the μ-semi-interior of A and is denoted by $s.i_\mu(A)$

2. ALMOST (μ-σ)–IRRESOLUTE AND RELATED FUNCTIONS

We recall the following definitions from[2], A function $f: (X,\mu) \to (Y,\sigma)$ is said to be quasi (μ,σ) continuous at $x \in X$ if for each $U \in \mu$ containing x and each $V \in \sigma$ containing $f(x)$,there exists $G \in \mu$ such that $\varnothing \neq G \subset U$ and $f(G) \subset V$. If f is quasi (μ,σ) continuous at every point $x \in X$, then it is called quasi (Y,σ)-continuous.

A function $f: (X,\mu) \to (Y,\sigma)$ is said to be almost (μ-σ)-continuous if for each $x \in X$ and each $V \in \sigma$ containing $f(x)$,there exists $U \in \mu$ containing x such that $f(U) \subset int(cl(V))$.

A function $f: (X,\mu) \to (Y,\sigma)$ is said to be almost quasi (μ-σ)-continuous at $x \in X$ if for each μ-open set U in X containing x and each $V \in \sigma$ containing $f(x)$,there exists μ-open set G in X such that $\varnothing \neq G \subset U$ and $f(G) \subset int(cl(V))$. If f is almost quasi (μ-σ)continuous at every $x \in X$, then it is called almost quasi(μ-σ)-continuous.(simply a.q. (μ-σ).c)

Theorem 2.1: The following are equivalent for a function $f:(X,\mu)\to(Y,\sigma)$
(i) f is a.q. $(\mu\text{-}\sigma)$.c
(ii) for each $x\in X$ and $V\in\sigma$ containing $f(x)$, there exists $U\in so(X,\mu)$ containing x such that $f(U)\subset int(cl(V))$
(iii) for each $x\in X$ and $V\in Ro(Y,\sigma)$ containing $f(x)$, there exists $U\in so(X,\mu)$ containing x such that $f(U)\subset V$
(iv) $s.c_\mu(f^{-1}(cl(int(cl(B)))))\subset f^{-1}(cl(B))$ for each subset B of Y
(v) $f^{-1}(F)\in s.c_\mu(X)$ for every $F\in Rc(Y,\sigma)$
(vi) $s.c_\mu f^{-1}(V))\subset f^{-1}(cl(V))$ for every $V\in so(Y,\sigma)$
(vii) $f^{-1}(V)\in so(X,\mu)$ for every $V\in Ro(Y,\sigma)$

Proof: (i) ⇒(ii) Let x X.$\sum_x=\{N|x\in N\in\mu\}$ and V be any open set of (Y,σ) containing $f(x)$. For each $N\in\sum_x$, there exists $G_N\in\mu$ such that $\varnothing\neq G_N\subset N$ and $f(G_N)\subset int(cl(V))$. For
$G=\{G_N|N\sum_x\}$, then we have $x\in c_\mu(G)$ and $G\in\mu$. Set $U=G\cup\{x\}$, then $G\subset U\subset c_\mu(G)$ and hence $x\in U$ so(X,μ). Also we obtain $f(U)\subset int(cl(V))$
(ii) ⇒(iii) Obvious
(iii) ⇒(iv) Let B be any subset of Y and suppose that $x\notin f^{-1}(cl(B))$. Then $f(x)\notin cl(B)$ and there exists $V\in\sigma$ containing $f(x)$ such that $V\cap B=\varnothing$. Therefore we have $V\cap int(cl(B))=\varnothing$ and $int(cl(V))\cap cl(int(cl(B)))=\varnothing$. By (iii), there exists $U\in so(X,\mu)$ containing x such that $f(U)\cap cl(int(cl(B)))=\varnothing$; hence $U\cap f^{-1}(cl(int(cl(B))))=\varnothing$. This implies that $x\notin s.c_\mu(f^{-1}(cl(int(cl(B)))))$. Clearly, we obtain $s.c_\mu(f^{-1}(cl(int(cl(B)))))\subset f^{-1}(cl(B))$
(iv) ⇒(v) Let $F\in Rc(Y,\sigma)$. By (iv), we have $s.c_\mu(f^{-1}(F))\subset f^{-1}(F)$ and hence $f^{-1}(F)\in s.c_\mu(X)$
(v) ⇒(vi) Let $V\in so(Y,\sigma)$. Since $cl(V)\in Rc(Y,\sigma)$, by (v) we have $f^{-1}(cl(V))\in s.c_\mu(X)$ and hence $f^{1}(V)\in so(X,\mu)$
(vi) ⇒(vii) Let $V\in Ro(Y,\sigma)$. Since $Y\text{-}V\in Rc(Y,\sigma)\subset so(Y,\sigma)$, as regular closed sets are semi-open, by (vi), we have $s.c_\mu(f^{-1}(Y\text{-}V))\subset f^{-1}(cl(Y\text{-}V))=f^{-1}((Y\text{-}V)$. Therefore, $f^{-1}(Y\text{-}V)\in s.c_\mu(X)$ and $f^{-1}(V)\in so(X,\mu)$
(vii) ⇒(i) Let x be any point of X, $x\in U\in\mu$ and $f(x)\in V\in\sigma$. Since $int(cl(V))\in Ro(Y,\sigma)$ by (vii) we obtain $x\in f^{-1}(int(cl(V)))\in so(X,\mu)$ and hence $x\in U\cap f^{-1}(int(cl(V)))\in so(X,\mu)$. Put $G=i_\mu[U\cap f^{-1}(int(cl(V)))]$, then we obtain $\varnothing\neq G\in\mu$ and $f(G)\subset int(cl(V))$. This shows that f is a.q.$(\mu\text{-}\sigma)$.c ■

Definition 2.1: A function $f:(X,\mu)\to(Y,\sigma)$ is said to be almost $(\mu\text{-}\sigma)$-irresolute if $f^{-1}(V)\in so(X,\mu)$ for every regular semiopen set V of Y.

Definition 2.2: A function $f:(X,\mu)\to(Y,\sigma)$ is said to be quasi $(\mu\text{-}\sigma)$-irresolute if for each $x\in X$ and each $V\in so(Y,f(x))$ there exists $U\in so(X,\mu)$ containing x such that $f(U)\subset scl(V)$.

Definition 2.3: A subset A of a space (X, μ) is said to be μ-semipreopen if there exists a μ- preopen set U in X such that $U \subset A \subset c_\mu(U)$. The family of all μ-semipreopen sets in X is denoted by $spo(X, \mu)$. The complement of a μ-semipreopen set is called μ-semipreclosed.

Lemma 2.1: The following are equivalent for a subset A of a space (X, μ)

a) $A \in spo(X, \mu)$

b) $A \subset c_\mu(i_\mu(c_\mu(A)))$

c) $A \subset s.i_\mu(s.c_\mu(A))$

Proof : Obvious. ■

Definition 2.4: A function $f : (X, \mu) \to (Y, \sigma)$ is said to be weakly $(\mu - \sigma)$ - irresolute (resp. $(\mu - \sigma)$-θ-irresolute) if for each $x \in X$ and each semi-open set V of $f(x)$,there exists a μ-semiopen set U containing x such that $f(U) \subset s.cl(V)$ (resp. $f(s.c_\mu(U)) \subset s.cl(V)$).

Lemma 2.2: Let $f : (X, \mu) \to (Y, \sigma)$ be a function. Then the following are equivalent: a) f is quasi $(\mu - \sigma)$ - irresolute

b) for each $x \in X$ and each $V \in so(Y, f(x))$ there exists $U \in \mu$-$so(X)$ containing x such that $f(s.c_\mu(U)) \subset s.cl(V)$.

c) $f^{-1}(V)$ is semi-clopen in (X, μ) for every semi-clopen set V of Y.

d) $f^{-1}(V) \subset s.i_\mu(f^{-1}(s.cl(V)))$ for every $V \in so(Y)$.

e) $s.c_\mu(f^{-1}(V)) \subset f^{-1}(s.cl(V))$ for every $V \in so(Y)$ ■

Lemma 2.3: If $A \in so(X, \mu)$ then $s.c_\mu(A)$ is semiclopen in (X, μ). ■

Theorem 2.2: The following are equivalent for a function $f : (X, \mu) \to (Y, \sigma)$

a) f is quasi $(\mu - \sigma)$ -irresolute

b) f is weakly $(\mu - \sigma)$ irresolute

c) f is $(\mu - \sigma)$ - θ -irresolute

d) f is almost $(\mu - \sigma)$ -irresolute

Proof:This follows from definitions 2.1,2.2,2.3 and lemma 2.2. ■

Theorem 2.3: Let $f : (X, \mu) \to (Y, \sigma)$ be a function. Then the following are equivalent :

(i) f is almost $(\mu - \sigma)$-irresolute

(ii) $f^{-1}(V) \subset s.i_\mu(s.c_\mu(f^{-1}(V)))$ for every $V \in so(Y)$.

(iii) $f^{-1}(V) \subset c_\mu(i_\mu(c_\mu(f^{-1}(V))))$ for every $V \in so(Y)$.

(iv) $f^{-1}(V) \in spo(X, \mu)$ for every $V \in so(Y)$.

Proof : (i) $\Rightarrow$ (ii): Let $V \in so(Y)$ and $x \in f^{-1}(V)$

Since V is a semiopen set of Y containing $f(x)$, $s.c_\mu(f^{-1}(V))$ is a semiopen set of (X, μ) containing x and hence there exist $U \in so(X, \mu)$ containing x such that

$U \subset s.c_{\mu}(f^{-1}(V))$. Therefore we have $x \in U$ $s.i_{\mu}(s.c_{\mu}(f^{-1}(V)))$. This implies that $f^{-1}(V) \subset s.i_{\mu}(s.c_{\mu}(f^{-1}(V)))$.

(ii) $\Rightarrow$ (i) : Let $x \in X$ and V be any semiopen set of $f(x)$. There exists W $\in$ so($Y,f(x)$) contained in V. Therefore we obtain $x \in f^{-1}(W) \subset s.i_{\mu}(s.c_{\mu}(f^{-1}(W))) \subset s.c_{\mu}(f^{-1}(W)) \subset s.c_{\mu}(f^{-1}(V))$. This implies that $s.c_{\mu}(f^{-1}(V))$ is a μ-semiopen set of X.

It follows from Lemma 2.1 that (ii), (iii) and (iv) are equivalent. ■

Theorem 2.4:A function $f : (X, \mu) \rightarrow (Y, \sigma)$ is said to be almost $(\mu\text{-}\sigma)$-irresolute if and only if $f(s.c_{\mu}(U)) \subset s.cl(f(U))$ for every $U \in so(X, \mu)$.

Proof: Let $U \in so(X\mu,)$. Suppose that $y \notin s.cl(f(U))$,there exists $V \in so(Y, y)$ such that $V \cap f(U) = \varnothing$ Hence $f^{-1}(V) \cap U = \varnothing$. Since $U \in so(X, \mu)$,we have $s.i_{\mu}(s.c_{\mu}(f^{-1}(V))) \cap s.c_{\mu}(U) = \varnothing$. By theorem 2.3, $f^{-1}(V) \cap s.c_{\mu}(U) = \varnothing$ and hence $V \cap f(s.c_{\mu}(U)) = \varnothing$. Therefore we obtain $y \notin f(s.c_{\mu}(U))$. This shows that $f(s.c_{\mu}(U)) \subset s.cl\, f(U)$. Now let $V \in so(Y)$. Since $X\text{-}s.c_{\mu}(f^{-1}(V)) \in so(X, \mu)$,we have $f(s.c_{\mu}(X\text{-}s.c_{\mu}\, f^{-1}(V))) \subset s.cl(f(X\text{-}s.c_{\mu}\, f^{-1}(V)))$ and hence $X\text{-}s.i_{\mu}(s.c_{\mu}\, f^{-1}(V))) \subset f^{-1}(s.cl(f(X\text{-}s.c_{\mu}(f^{-1}(V))))) \subset f^{-1}(s.cl(f(X\text{-}f^{-1}(V)))) \subset f^{-1}(s.cl(Y\text{-}V)) = X\text{-}f^{-1}(V)$. Therefore we obtain $f^{-1}(V) \subset s.i_{\mu}(s.c_{\mu}(f^{-1}(V)))$. It follows from Theorem 2.3 that f is almost $(\mu\text{-}\sigma)$ - irresolute. ■

Theorem 2.5: Let $f : (X, \mu) \rightarrow (Y, \sigma)$ be a function. Then the following are equivalent

(i) f is almost $(\mu\text{-}\sigma)$ -irresolute.

(ii) for each $x \in X$ and each $V \in so(Y, \sigma)$ containing $f(x)$,there exists U $\in$ spo(X, μ) containing x such that $f(U) \subset V$.

(iii) $f^{-1}(F)$ is semi preclosed in (X, μ) for every semiclosed set F of Y.

(iv) $i_{\mu}(c_{\mu}(i_{\mu}(f^{-1}(B)))) \subset f^{-1}(s.cl(B))$ for every subset B of Y.

(v) $f(i_{\mu}(c_{\mu}(i_{\mu}(A)))) \subset s.cl(f(A))$ for every subset A of X

Proof :(i)$\Rightarrow$(ii) **:** Let $x \in X$ and $V \in so(Y,f(x))$

Set $U = f^{-1}(V)$, then by theorem 2.3,U is μ-semipreopen set containing x and $f(U) \subset V$

(ii)$\Rightarrow$(i)**:**Let $V \in so(Y)$ and $x \in f^{-1}(V)$ there exists $U \in spo(X, \mu)$ containing x such that $f(U) \subset V$. By Lemma 2.1, we obtain x $U \subset s.i_{\mu}(s.c_{\mu}(U)) \subset s.i_{\mu}(s.c_{\mu}(f^{-1}(V)))$. Hence $f^{-1}(V) \subset s.i_{\mu}(s.c_{\mu}(f^{-1}(V)))$. It follows from Theorem 2.3 that f is almost $(\mu\text{-}\sigma)$ -irresolute.

(i)$\Rightarrow$ (iii) This is obvious from Theorem 2.3

(iii)$\Rightarrow$(iv) Let B be any subset of Y.Since s.cl(B) is semiclosed, we have $f^{-1}(s.cl(B))$ is μ-semipreclosed. By using Lemma 2.1,we have $X - f^{-1}(s.cl(B)) \subset c_{\mu}(i_{\mu}(c_{\mu}(X - f^{-1}(s.cl(B))))) = X - i_{\mu}(c_{\mu}(i_{\mu}(f^{-1}(s.cl(B)))))$

Therefore we obtain, $i_{\mu}(c_{\mu}(i_{\mu}(f^{-1}(B))) \subset f^{-1}(s.cl(B))$

(iv)⇒(v) Let A be any subset of (X, μ)
We have $i_\mu(c_\mu(i_\mu(A))) \subset i_\mu(c_\mu(i_\mu(f^{-1}(f(A))))) \subset f^{-1}(s.cl(f(A))$. Therefore we obtain $f(i_\mu(c_\mu(i_\mu(A))) \subset s.cl_\sigma(f(A))$.
(v)⇒(i) Let $U \in so(X, \mu)$. Since $s.c_\mu(U)=U \cap i_\mu(c_\mu(U))=U \cap i_\mu(c_\mu(i_\mu U)))$,we obtain $f(s.c_\mu(U))=f(U) \cup f(i_\mu(c_\mu(i_\mu(U)))) \subset f(U) \cup s.cl(f(U))=s.cl(f(U))$
It follows from Theorem 2.4 that f is almost $(\mu - \sigma)$ -irresolute. ■

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