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Decompositions of $\mathcal{I}$-πg-continuity

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Abstract : In this paper, we introduce the notions of $\mathcal{I}$-π-open sets, $\mathcal{I}$-πg-open sets, $\mathcal{I}$-$\pi g\alpha$-open sets, $\mathcal{I}$-πgp-open sets, $\mathcal{I}$-E_r-sets and $\mathcal{I}$-E_r^*-sets in ideal topological spaces and investigate some of their properties and using these notions we obtain three decompositions of $\mathcal{I}$-πg-continuity.

Keywords : $\mathcal{I}$-$\pi g\alpha$-continuity, $\mathcal{I}$-πgp-continuity, $\mathcal{I}$-E_r-continuity, $\mathcal{I}$-E_r^*-continuity and $\mathcal{I}$-πg-continuity.

AMS Subject Classification: 54A05.

1 Introduction and Preliminaries

In 1968, Zaitsev [12] introduced the concept of π-closed sets and in 1970, Levine [5] initiated the study of so called g-closed sets in topological spaces. The concept of g-continuity was introduced and studied by Balachandran et. al. in 1991 [1]. Dontchev and Noiri [2] defined the notions of πg-closed sets and πg-continuity in topological spaces. Quite Recently Ravi et. al. [9] obtained three different decompositions of πg-continuity in topological spaces by providing two types of weaker forms of continuity, namely E_r-continuity and E_r^*-continuity and in [10], they also obtained three different decompositions of πg-continuity via idealization.

Recently, Rajamani et. al. [7] introduced $\mathcal{I}$-g-open sets, $\mathcal{I}$-gp-open sets, $\mathcal{I}$-gs-open sets and obtained three different decompositions of $\mathcal{I}$-g-continuity and in [8], they also introduced $\mathcal{I}$-rg-open sets, $\mathcal{I}$-gα^{**}-open sets, $\mathcal{I}$-gpr-open sets and obtained three different decompositions of $\mathcal{I}$-rg-continuity. In this paper, we introduce the notions of $\mathcal{I}$-π-open sets, $\mathcal{I}$-πg-open sets, $\mathcal{I}$-$\pi g\alpha$-open sets, $\mathcal{I}$-πgp-open sets, $\mathcal{I}$-E_r-sets and $\mathcal{I}$-E_r^*-sets to obtain three decompositions of $\mathcal{I}$-πg-continuity.

Let (X, τ) be a topological space. An ideal is defined as a nonempty collection $\mathcal{I}$ of subsets of X satisfying the following two conditions:

(i) If $A \in \mathcal{I}$ and $B \subseteq A$, then $B \in \mathcal{I}$

(ii) If $A \in \mathcal{I}$ and $B \in \mathcal{I}$, then $A \cup B \in \mathcal{I}$.

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For a subset $A \subseteq X$, $A^*(\mathcal{I}) = \{x \in X/U \cap A \notin \mathcal{I}$ for each neighborhood U of $x\}$ is called the local function of A with respect to $\mathcal{I}$ and τ [4]. We simply write A^* instead of $A^*(\mathcal{I})$ in case there is no chance for confusion. X^* is often a proper subset of X.

For every ideal topological space $(X, \tau, \mathcal{I})$ there exists a topology $\tau^*(\mathcal{I})$, finer than τ, generated by $\beta(\mathcal{I}, \tau) = \{U \setminus I : U \in \tau$ and $I \in \mathcal{I}\}$, but in general $\beta(\mathcal{I}, \tau)$ is not always a topology [11]. Also, $\text{cl}^*(A) = A \cup A^*$ defines a Kuratowski closure operator for $\tau^*(\mathcal{I})$ [11].

Additionally, $\text{cl}^*(A) \subseteq \text{cl}\ (A)$ for any subset A of X [3]. Throughout this paper, X denotes the ideal topological space $(X, \tau, \mathcal{I})$ and also $\text{cl}(A)$ and $\text{int}(A)$ denote the closure of A and the interior of A in (X, τ), respectively. $\text{int}^*(A)$ will denote the interior of A in $(X, \tau^*, \mathcal{I})$.

Definition 1.1. A subset A of an ideal topological space $(X, \tau, \mathcal{I})$ is said to be

(i) $\mathcal{I}$*-pre-open [6] if* $A \subseteq int^*(cl^*(A))$,

(ii) $\mathcal{I}$-α*-open [6] if* $A \subseteq int^*(cl^*(int^*(A)))$,

(iii) a $\mathcal{I}$*-t-set [7] if* $int^*(cl^*(A)) = int^*(A)$,

(iv) an $\mathcal{I}$-α^**-set [7] if* $int^*(cl^*(int^*(A))) = int^*(A)$,

(v) $\mathcal{I}$*-regular closed [8] if* $A = cl^*(int^*(A))$.

The complement of $\mathcal{I}$*-regular closed set is* $\mathcal{I}$*-regular open [8].*

Also, we have $\mathcal{I}$-$\alpha int(A) = A \cap int^*(cl^*(int^*(A)))$ *[6] and* $\mathcal{I}$-$pint(A) = A \cap int^*(cl^*(A))$ *[6], where* $\mathcal{I}$-$\alpha int(A)$ *denotes the* $\mathcal{I}$-α*-interior of A in* $(X, \tau, \mathcal{I})$ *which is the union of all* $\mathcal{I}$-α*-open sets of* $(X, \tau, \mathcal{I})$ *contained in A.* $\mathcal{I}$-$pint(A)$ *has similar meaning.*

2 $\mathcal{I}$-πg-open sets, $\mathcal{I}$-$\pi g\alpha$-open sets and $\mathcal{I}$-πgp-open sets

Definition 2.1. A subset A of an ideal topological space $(X, \tau, \mathcal{I})$ is called

(i) $\mathcal{I}$-π*-open if the finite union of* $\mathcal{I}$*-regular open sets,*
The complement of $\mathcal{I}$-π*-open set is* $\mathcal{I}$-π*-closed,*

(ii) $\mathcal{I}$-πg*-open if* $F \subseteq int^*(A)$ *whenever* $F \subseteq A$ *and F is* $\mathcal{I}$-π*-closed in X,*

(iii) $\mathcal{I}$-$\pi g\alpha$*-open if* $F \subseteq \mathcal{I}$-$\alpha int(A)$ *whenever* $F \subseteq A$ *and F is* $\mathcal{I}$-π*-closed in X,*

(iv) $\mathcal{I}$-πgp*-open if* $F \subseteq \mathcal{I}$-$pint(A)$ *whenever* $F \subseteq A$ *and F is* $\mathcal{I}$-π*-closed in X.*

Proposition 2.2. *For a subset of an ideal topological space, the following hold:*

(i) Every $\mathcal{I}$-πg*-open set is* $\mathcal{I}$-$\pi g\alpha$*-open.*

(ii) Every $\mathcal{I}$-$\pi g\alpha$*-open set is* $\mathcal{I}$-πgp*-open.*

(iii) Every $\mathcal{I}$-πg*-open set is* $\mathcal{I}$-πgp*-open.*

Proof.

(i) Let A be an $\mathcal{I}$-πg-open. Then, for any $\mathcal{I}$-π-closed set F with $F \subseteq A$, we have $F \subseteq \text{int}^*(A) \subseteq \text{int}^*((\text{int}^*(A))^*) \cup \text{int}^*(A) = \text{int}^*((\text{int}^*(A))^*) \cup \text{int}^*(\text{int}^*(A)) \subseteq \text{int}^*((\text{int}^*(A))^* \cup \text{int}^*(A)) = \text{int}^*(\text{cl}^*(\text{int}^*(A)))$. That is, $F \subseteq A \cap \text{int}^*(\text{cl}^*(\text{int}^*(A))) = \mathcal{I}\text{-}\alpha\text{int}(A)$ which implies that A is $\mathcal{I}$-$\pi g\alpha$-open.

(ii) Let A be $\mathcal{I}$-$\pi g\alpha$-open. Then, for any $\mathcal{I}$-π-closed set F with F $\subseteq A$, we have F $\subseteq \mathcal{I}\text{-}\alpha\text{int}(A) = A \cap \text{int}^*(\text{cl}^*(\text{int}^*(A))) \subseteq A \cap \text{int}^*(\text{cl}^*(A)) = \mathcal{I}\text{-}p\text{int}(A)$ which implies that A is $\mathcal{I}$-πgp-open.

(iii) It is an immediate consequence of (i) and (ii).

□

Remark 2.3. *The converses of Proposition 2.2 are not true, in general.*

Example 2.4. *Let $X = \{a, b, c, d\}$, $\tau = \{\emptyset, X, \{a\}, \{b, c\}, \{a, b, c\}\}$ and $\mathcal{I} = \{\emptyset, \{d\}\}$. Then $\{a, b, d\}$ is $\mathcal{I}$-πgp-open set but not $\mathcal{I}$-$\pi g\alpha$-open.*

Example 2.5. *In Example 2.4, $\{a, b, d\}$ is $\mathcal{I}$-πgp-open set but not $\mathcal{I}$-πg-open.*

Example 2.6. *Let $X = \{a, b, c, d, e\}$, $\tau = \{\emptyset, X, \{a\}, \{c, d\}, \{a, c, d\}, \{b, c, d\}, \{a, b, c, d\}\}$ and $\mathcal{I} = \{\emptyset\}$. Clearly $\{a, c, d, e\}$ is $\mathcal{I}$-$\pi g\alpha$-open set but not $\mathcal{I}$-πg-open.*

Remark 2.7. *By Proposition 2.2, we have the following diagram. In this diagram, there is no implication which is reversible as shown by examples above.*

$\mathcal{I}$-$\pi g\alpha$-open

↗

$\mathcal{I}$-πg-open ↓

↘

$\mathcal{I}$-πgp-open

3 $\mathcal{I}$-E_r-sets and $\mathcal{I}$-E_r^*-sets

Definition 3.1. *A subset A of an ideal topological space $(X, \tau, \mathcal{I})$ is called*

(i) a $\mathcal{I}$-E_r-set if $A = U \cap V$, where U is $\mathcal{I}$-πg-open and V is a $\mathcal{I}$-t-set,

(ii) a $\mathcal{I}$-E_r^*-set if $A = U \cap V$, where U is $\mathcal{I}$-πg-open and V is an $\mathcal{I}$-α^*-set.

We have the following proposition:

Proposition 3.2. *For a subset of an ideal topological space, the following hold:*

(i) Every $\mathcal{I}$-t-set is an $\mathcal{I}$-α^*-set [7] and a $\mathcal{I}$-E_r-set.

(ii) Every $\mathcal{I}$-α^*-set is a $\mathcal{I}$-E_r^*-set.

(iii) Every $\mathcal{I}$-E_r-set is a $\mathcal{I}$-E_r^*-set.

(iv) Every $\mathcal{I}$-πg-open set is both $\mathcal{I}$-E_r-set and $\mathcal{I}$-E_r^*-set.

From Proposition 3.2, We have the following diagram.

$$\begin{array}{ccccc} \mathcal{I}\text{-}\pi g\text{-open set} & \longrightarrow & \mathcal{I}\text{-}E_r\text{-set} & \longleftarrow & \mathcal{I}\text{-}t\text{-set} \\ & & \downarrow & & \downarrow \\ & & \mathcal{I}\text{-}E_r^*\text{-set} & \longleftarrow & \mathcal{I}\text{-}\alpha^*\text{-set} \end{array}$$

Remark 3.3. *The converses of implications in Diagram II need not be true as the following examples show.*

Example 3.4. *Let* $X = \{a, b, c, d\}$, $\tau = \{\emptyset, X, \{a\}, \{b\}, \{a, b\}, \{b, c\}, \{a, b, c\}\}$ *and* $\mathcal{I} = \{\emptyset, \{c\}\}$. *Then* $\{a, b\}$ *is* $\mathcal{I}$-E_r*-set but not a* $\mathcal{I}$-t*-set.*

Example 3.5. *In Example 3.4,* $\{b, c, d\}$ *is* $\mathcal{I}$-E_r*-set but not an* $\mathcal{I}$-πg*-open set.*

Example 3.6. *In Example 2.4,* $\{a, b, d\}$ *is* $\mathcal{I}$-E_r^**-set but not a* $\mathcal{I}$-E_r*-set.*

Example 3.7. *In Example 3.4,* $\{a, b\}$ *is* $\mathcal{I}$-E_r^**-set but not an* $\mathcal{I}$-α^**-set.*

Example 3.8. *In Example 2.4,* $\{b\}$ *is* $\mathcal{I}$-α^**-set but not a* $\mathcal{I}$-t*-set.*

Proposition 3.9. *A subset* A *of* X *is* $\mathcal{I}$-πg*-open if and only if it is both* $\mathcal{I}$-πgp*-open and a* $\mathcal{I}$-E_r*-set in* X.

Proof. Necessity is trivial. We prove the sufficiency. Assume that A is $\mathcal{I}$-πgp-open and a $\mathcal{I}$-E_r-set in X. Let $F \subseteq A$ and F is $\mathcal{I}$-π-closed in X. Since A is a $\mathcal{I}$-E_r-set in X, $A = U \cap V$, where U is $\mathcal{I}$-πg-open and V is a $\mathcal{I}$-t-set. Since A is $\mathcal{I}$-πgp-open, $F \subseteq \mathcal{I}\text{-pint}(A) = A \cap \text{int}^*(\text{cl}^*(A)) = (U \cap V) \cap \text{int}^*(\text{cl}^*(U \cap V)) \subseteq (U \cap V) \cap \text{int}^*(\text{cl}^*(U) \cap \text{cl}^*(V)) = (U \cap V) \cap \text{int}^*(\text{cl}^*(U)) \cap \text{int}^*(\text{cl}^*(V))$. This implies $F \subseteq \text{int}^*(\text{cl}^*(V)) = \text{int}^*(V)$ since V is a $\mathcal{I}$-t-set. Since F is $\mathcal{I}$-π-closed, U is $\mathcal{I}$-πg-open and $F \subseteq U$, we have $F \subseteq \text{int}^*(U)$. Therefore, $F \subseteq \text{int}^*(U) \cap \text{int}^*(V) = \text{int}^*(U \cap V) = \text{int}^*(A)$. Hence A is $\mathcal{I}$-πg-open in X. □

Corollary 3.10. *A subset* A *of* X *is* $\mathcal{I}$-πg*-open if and only if it is both* $\mathcal{I}$-$\pi g\alpha$*-open and a* $\mathcal{I}$-E_r*-set in* X.

Proof. This is an immediate consequence of Proposition 3.9. □

Proposition 3.11. *A subset* A *of* X *is* $\mathcal{I}$-πg*-open if and only if it is both* $\mathcal{I}$-$\pi g\alpha$*-open and a* $\mathcal{I}$-E_r^**-set in* X.

Proof. Necessity is trivial. We prove the sufficiency. Assume that A is $\mathcal{I}$-$\pi g\alpha$-open and a $\mathcal{I}$-E_r^*-set in X. Let $F \subseteq A$ and F is $\mathcal{I}$-π-closed in X. Since A is a $\mathcal{I}$-E_r^*-set in X, $A = U \cap V$, where U is $\mathcal{I}$-πg-open and V is an $\mathcal{I}$-α^*-set. Now since F is $\mathcal{I}$-π-closed, $F \subseteq U$ and U is $\mathcal{I}$-πg-open, $F \subseteq \text{int}^*(\text{U})$. Since A is $\mathcal{I}$-$\pi g\alpha$-open, $F \subseteq \mathcal{I}\text{-}\alpha\text{int}(A) = A \cap \text{int}^*(\text{cl}^*(\text{int}^*(A))) = (U \cap V) \cap \text{int}^*(\text{cl}^*(\text{int}^*(U \cap V))) = (U \cap V) \cap \text{int}^*(\text{cl}^*(\text{int}^*(U) \cap \text{int}^*(V))) \subseteq (U \cap V) \cap \text{int}^*(\text{cl}^*(\text{int}^*(U)) \cap \text{cl}^*(\text{int}^*(V))) = (U \cap V) \cap \text{int}^*(\text{cl}^*(\text{int}^*(U))) \cap \text{int}^*(\text{cl}^*(\text{int}^*(V))) = (U \cap V) \cap \text{int}^*(\text{cl}^*(\text{int}^*(U))) \cap \text{int}^*(V)$, since V is an $\mathcal{I}$-α^*-set. This implies $F \subseteq \text{int}^*(V)$. Therefore, $F \subseteq \text{int}^*(U) \cap \text{int}^*(V) = \text{int}^*(U \cap V) = \text{int}^*(A)$. Hence A is $\mathcal{I}$-πg-open in X. □

Remark 3.12.

(i) The concepts of $\mathcal{I}$-πgp*-open sets and* $\mathcal{I}$-E_r*-sets are independent of each other.*

(ii) *The concepts of $\mathcal{I}$-$\pi g\alpha$-open sets and $\mathcal{I}$-E_r-sets are independent of each other.*

(iii) *The concepts of $\mathcal{I}$-$\pi g\alpha$-open sets and $\mathcal{I}$-E_r^*-sets are independent of each other.*

Example 3.13. *Consider the Example 2.4. Then*

(i) $\{d\}$ *is $\mathcal{I}$-E_r-set but not a $\mathcal{I}$-πgp-open.*

(ii) $\{a, b, d\}$ *is $\mathcal{I}$-πgp-open but not a $\mathcal{I}$-E_r-set.*

Example 3.14.

(i) *In Example 2.4,* $\{b, c, d\}$ *is $\mathcal{I}$-E_r-set but not an $\mathcal{I}$-$\pi g\alpha$-open set.*

(ii) *In Example 2.6,* $\{a, c, d, e\}$ *is $\mathcal{I}$-$\pi g\alpha$-open set but not a $\mathcal{I}$-E_r-set.*

Example 3.15.

(i) *In Example 2.5,* $\{b, c, d\}$ *is $\mathcal{I}$-E_r^*-set but not an $\mathcal{I}$-$\pi g\alpha$-open set.*

(ii) *In Example 2.6,* $\{a, c, d, e\}$ *is $\mathcal{I}$-$\pi g\alpha$-open set but not a $\mathcal{I}$-E_r^*-set.*

4 Decompositions of $\mathcal{I}$-πg-continuity

Definition 4.1. *A mapping $f : (X, \tau, \mathcal{I}) \to (Y, \sigma)$ is said to be $\mathcal{I}$-$\pi g\alpha$-continuous (resp. $\mathcal{I}$-πg-continuous, $\mathcal{I}$-πgp-continuous, $\mathcal{I}$-E_r-continuous and $\mathcal{I}$-E_r^*-continuous) if for every $V \in \sigma$, $f^{-1}(V)$ is $\mathcal{I}$-$\pi g\alpha$-open (resp. $\mathcal{I}$-πg-open, $\mathcal{I}$-πgp-open, a $\mathcal{I}$-E_r-set and a $\mathcal{I}$-E_r^*-set) in $(X, \tau, \mathcal{I})$. From Propositions 3.9 and 3.11 and Corollary 3.10 we have the following decompositions of $\mathcal{I}$-πg-continuity.*

Theorem 4.2. *Let $(X, \tau, \mathcal{I})$ be an ideal topological space. For a mapping $f : (X, \tau, \mathcal{I}) \to (Y, \sigma)$, the following properties are equivalent:*

(i) *f is $\mathcal{I}$-πg-continuous;*

(ii) *f is $\mathcal{I}$-πgp-continuous and $\mathcal{I}$-E_r-continuous;*

(iii) *f is $\mathcal{I}$-$\pi g\alpha$-continuous and $\mathcal{I}$-E_r-continuous;*

(iv) *f is $\mathcal{I}$-$\pi g\alpha$-continuous and $\mathcal{I}$-E_r^*-continuous.*

Remark 4.3.

(i) *The concepts of $\mathcal{I}$-πgp-continuity and $\mathcal{I}$-E_r-continuity are independent of each other.*

(ii) *The concepts of $\mathcal{I}$-$\pi g\alpha$-continuity and $\mathcal{I}$-E_r-continuity are independent of each other.*

(iii) *The concepts of $\mathcal{I}$-$\pi g\alpha$-continuity and $\mathcal{I}$-E_r^*-continuity are independent of each other.*

Example 4.4.

(i) *Let $X = Y = \{a, b, c, d\}$, $\tau = \{\emptyset, X, \{a\}, \{b, c\}, \{a, b, c\}\}$, $\mathcal{I} = \{\emptyset, \{d\}\}$ and $\sigma = \{\emptyset, Y, \{b, c, d\}\}$. Let $f : (X, \tau, \mathcal{I}) \to (Y, \sigma)$ be the identity function. Then f is $\mathcal{I}$-E_r-continuous but not $\mathcal{I}$-πgp-continuous.*

(ii) In Example 4.4(1), if σ *is replaced by* $\sigma = \{\emptyset,\ Y,\ \{a,\ b,\ d\}\}$*, then* f *is* $\mathcal{I}$*-*πgp*-continuous but not* $\mathcal{I}$*-*E_r*-continuous.*

Example 4.5.

(i) In Example 4.4(1), f *is* $\mathcal{I}$*-*E_r*-continuous but not* $\mathcal{I}$*-*$\pi g\alpha$*-continuous.*

(ii) Let $X = Y = \{a,\ b,\ c,\ d,\ e\}$, $\tau = \{\emptyset,\ X,\ \{a\},\ \{c,\ d\},\ \{a,\ c,\ d\},\ \{b,\ c,\ d\},\ \{a,\ b,\ c,\ d\}\}$, $\mathcal{I} = \{\emptyset\}$ *and* $\sigma = \{\emptyset,\ Y,\ \{a,\ c,\ d,\ e\}\}$*. Let* $f : (X,\ \tau,\ \mathcal{I}) \rightarrow (Y,\ \sigma)$ *be the identity function. Then* f *is* $\mathcal{I}$*-*$\pi g\alpha$*-continuous but not* $\mathcal{I}$*-*E_r*-continuous.*

Example 4.6.

(i) In Example 4.4(1), f *is* $\mathcal{I}$*-*E_r^**-continuous but not* $\mathcal{I}$*-*$\pi g\alpha$*-continuous.*

(ii) In Example 4.5(2), f *is* $\mathcal{I}$*-*$\pi g\alpha$*-continuous but not* $\mathcal{I}$*-*E_r^**-continuous.*

5 Conclusion

Recently, Rajamani et. al. [7] introduced $\mathcal{I}$-g-open sets, $\mathcal{I}$-gp-open sets, $\mathcal{I}$-gs-open sets and obtained three different decompositions of $\mathcal{I}$-g-continuity and in [8], they also introduced $\mathcal{I}$-rg-open sets, $\mathcal{I}$-gα^{**}-open sets, $\mathcal{I}$-gpr-open sets and obtained three different decompositions of $\mathcal{I}$-rg-continuity. In this paper, we introduced the notions of $\mathcal{I}$-π-open sets, $\mathcal{I}$-πg-open sets, $\mathcal{I}$-$\pi g\alpha$-open sets, $\mathcal{I}$-πgp-open sets, $\mathcal{I}$-E_r-sets and $\mathcal{I}$-E_r^*-sets to obtain three decompositions of $\mathcal{I}$-πg-continuity.

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