



ON PRE GENERALIZED PRE REGULAR WEAKLY INTERIOR AND PRE GENERALIZED PRE REGULAR WEAKLY CLOSURE IN TOPOLOGICAL SPACES

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ABSTRACT

In this paper, the notation of pgprw-interior and pgprw-closure are introduced and studied in topological spaces. It is proved that the complement of pgprw-interior of A is the closure of the complement of A and some properties of the new concepts have been studied.

**Keywords:** Pgprw closed sets, Pgprw open sets, Pgprw-closure, Pgprw-interior.

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1. INTRODUCTION

N.Levine[1] introduced the concept of generalized sets of a topological space in 1970. Dunham[2] defined generalized closure operator in 1982. Mashhour, Abd El-Monsef and Deeb[3] introduced the concept of pre-closed sets in 1982. Gnanambal[4] introduced and studied the concept of gpr closed sets in topological space. Gnanambal and Balachandran[5], introduced and studied the concept of gpr- interior and gpr-closure operator in topological space in 1999. Recently in the year 2015 Wali and Vivekananda Dembre [6] introduced and studied Pre generalized pre regular weakly closed sets (briefly-pgprw) and Pre generalized pre regular weakly open [7] sets in topological spaces.

2. PRELIMINARIES

A subset A of a topological space  $(X, \tau)$  is called

- (i) Generalized closed set (briefly g-closed) if  $cl(A) \subseteq U$  whenever  $A \subseteq U$  and U is open in X.
- (ii) Pre-open set if  $A \subseteq int(cl(A))$  and pre-closed set if  $cl(int(A)) \subseteq A$ .
- (iii) Generalized pre regular closed set (briefly gpr-closed) if  $pcl(A) \subseteq U$  whenever  $A \subseteq U$  and U is regular open in X.
- (iv) A subset A of topological space  $(X, \tau)$  is called a pre generalized pre regular weakly closed set (briefly pgprw-closed set) if  $pCl(A) \subseteq U$  whenever  $A \subseteq U$  and U is rga open in  $(X, \tau)$ .
- (v) A subset A in  $(X, \tau)$  is called Pre generalized pre regular weakly open set in X if  $A^c$  is Pre generalized pre regular weakly closed set in X.

Throughout this paper space  $(X, \tau)$  and  $(Y, \sigma)$  (or simply X and Y) always denote topological space on which no separation axioms are assumed unless explicitly stated. For a subset A of a space X,  $Cl(A)$ ,  $Int(A)$ ,  $A^c$ ,  $P-Cl(A)$  and  $P-int(A)$  denote the Closure of A, Interior of A, Compliment of A, pre closure of A and pre-interior of A in X respectively.

3. PGPRW-CLOSURE AND PGPRW- INTERIOR IN TOPOLOGICAL SPACES

In this section the notation of pgprw-closure and pgprw-Interior is defined and some of its basic properties are studied.

**Definition 3.1:** For a subset A of  $(X, \tau)$ , pgprw-closure of A is denoted by  $pgprw-cl(A)$  and defined as  $pgprw-cl(A) = \bigcap \{G: A \subseteq G, G \text{ is pgprw-closed in } (X, \tau)\}$  or  $\bigcap \{G: A \subseteq G, G \in pgprw-C(X)\}$

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**Theorem 3.2:** If A and B are subsets of space  $(X, \tau)$  then

- (i)  $\text{pgprw-cl}(X) = X, \text{pgprw-cl}(\phi) = \phi$
- (ii)  $A \subseteq \text{pgprw-cl}(A)$ .
- (iii) If B is any pgprw-closed set containing A, then  $\text{pgprw-cl}(A) \subseteq B$ .
- (iv) If  $A \subseteq B$  then  $\text{pgprw-cl}(A) \subseteq \text{pgprw-cl}(B)$
- (v)  $\text{pgprw-cl}(A) = \text{pgprw-cl}(\text{pgprw-cl}(A))$
- (vi)  $\text{pgprw-cl}(A \cup B) = \text{Pgprw-cl}(A) \cup \text{pgprw-cl}(B)$ .

**Proof:**

- (i) By definition of pgprw-closure, X is only pgprw-closed set containing X. Therefore  $\text{pgprw-cl}(X) =$  Intersection of all the pgprw-closed set containing  $X = \bigcap \{X\} = X$  therefore  $\text{pgprw-cl}(X) = X$  and again by definition of pgprw-closure.  $\text{Pgprw-cl}(\phi) =$  Intersection of all pgprw-closed sets containing  $\phi = \phi \cap$  any pgprw-closed set containing  $\phi = \phi$ . Therefore  $\text{pgprw-cl}(\phi) = \phi$ .
- (ii) By definition of pgprw-closure of A, it is obvious that  $A \subseteq \text{pgprw-cl}(A)$ .
- (iii) Let B be any pgprw-closed set containing A. Since  $\text{pgprw-cl}(A)$  is the intersection of all pgprw-closed set containing A,  $\text{pgprw-cl}(A)$  is contained in every pgprw-closed set containing A. Hence in particular  $\text{pgprw-cl}(A) \subseteq B$
- (iv) Let A and B be subsets of  $(X, \tau)$  such that  $A \subseteq B$  by definition of pgprw-closure,  $\text{Pgprw-cl}(B) = \bigcap \{F : B \subseteq F \in \text{pgprw-C}(X)\}$ . If  $B \subseteq F \in \text{pgprw-C}(X)$ , then  $\text{pgprw-cl}(B) \subseteq F$ . since  $A \subseteq B, A \subseteq B \subseteq F \in \text{pgprw-C}(X)$ , we have  $\text{pgprw-cl}(A) \subseteq F, \text{pgprw-cl}(A) \subseteq \bigcap \{F : B \subseteq F \in \text{pgprw-C}(X)\} = \text{pgprw-cl}(B)$ . Therefore  $\text{pgprw-cl}(A) \subseteq \text{pgprw-cl}(B)$ .
- (v) Let A be any subset of X by definition of pgprw-closure,  $\text{pgprw-cl}(A) = \bigcap \{F : A \subseteq F \in \text{pgprw-C}(X)\}$ . If  $A \subseteq F \in \text{pgprw-C}(X)$  then  $\text{pgprw-cl}(A) \subseteq F$ , since F is pgprw-closed set containing  $\text{pgprw-cl}(A)$  by (iii)  $\text{pgprw-cl}(\text{pgprw-cl}(A)) \subseteq F$ ; Hence  $\text{pgprw-cl}(\text{pgprw-cl}(A)) = \bigcap \{F : A \subseteq F \in \text{pgprw-C}(X)\} = \text{pgprw-cl}(A)$ . Therefore;  $\text{pgprw-cl}(\text{pgprw-cl}(A)) = \text{pgprw-cl}(A)$ .
- (vi) Let A and B be subsets of X, Clearly  $A \subseteq A \cup B, B \subseteq A \cup B$  from (iv)  $\text{pgprw-cl}(A) \subseteq \text{pgprw-cl}(A \cup B), \text{pgprw-cl}(B) \subseteq \text{pgprw-cl}(A \cup B)$ ; hence,  $\text{pgprw-cl}(A) \cup \text{pgprw-cl}(B) \subseteq \text{pgprw-cl}(A \cup B)$ . .....(1) Now we have to prove that  $\text{pgprw-cl}(A \cup B) \subseteq \text{pgprw-cl}(A) \cup \text{pgprw-cl}(B)$ . Suppose  $x \notin \text{pgprw-cl}(A) \cup \text{pgprw-cl}(B)$  then  $\exists$  pgprw-closed set  $A_1$  and  $B_1$  with  $A \subseteq A_1, B \subseteq B_1$  and  $x \notin A_1 \cup B_1$ . We have  $A \cup B \subseteq A_1 \cup B_1$  and  $A_1 \cup B_1$  is the pgprw-closed set (we know that union of two pgprw closed subsets of X is pgprw closed set in X) such that  $x \notin A_1 \cup B_1$ . Thus  $x \notin \text{pgprw-cl}(A \cup B)$ .
- (vii) Hence  $\text{pgprw-cl}(A \cup B) \subseteq \text{pgprw-cl}(A) \cup \text{pgprw-cl}(B)$  -----(2). From (1) and (2) we have  $\text{pgprw-cl}(A \cup B) = \text{pgprw-cl}(A) \cup \text{pgprw-cl}(B)$ .

**Theorem 3.3:** If  $A \subseteq X$  is pgprw-closed set then  $\text{pgprw-cl}(A) = A$

**Proof:** Let A be pgprw-closed subset of X. we know that  $A \subseteq \text{pgprw-cl}(A)$  -(1) Also  $A \subseteq A$  and A is pgprw-closed set by theorem 3.2 (iii)  $\text{pgprw-cl}(A) \subseteq A$  -(2) Hence  $\text{pgprw-cl}(A) = A$ .

The Converse of the above need not be true as seen from the following example.

**Example 3.4:** Let  $X = \{a, b, c, d\}, \tau = \{X, \phi, \{a\}, \{c, d\}, \{a, c, d\}\}$ .  $A = \{a, c\}$   $\text{pgprw-cl}(A) = \{a, c\} = A$  then A is not pgprw-closed set.

**Theorem 3.5:** If A and B are subsets of space X then  $\text{pgprw-cl}(A \cap B) \subseteq \text{pgprw-cl}(A) \cap \text{pgprw-cl}(B)$ .

**Proof:** Let A and B be subsets of X, Clearly  $A \cap B \subseteq A, A \cap B \subseteq B$  by theorem 3.2(iv)  $\text{Pgprw-cl}(A \cap B) \subseteq \text{pgprw-cl}(A), \text{Pgprw-cl}(A \cap B) \subseteq \text{pgprw-cl}(B)$ ; hence  $\text{pgprw-cl}(A \cap B) \subseteq \text{pgprw-cl}(A) \cap \text{pgprw-cl}(B)$ .

**Remark 3.6:** In-general;  $\text{pgprw-cl}(A) \cap \text{pgprw-cl}(B) \not\subseteq \text{pgprw-cl}(A \cap B)$  as seen from the following example.

**Example 3.7:** Consider  $X = \{a, b, c, d\}, \tau = \{X, \phi, \{a\}, \{b\}, \{a, b\}, \{a, b, c\}\}$ ,  $A = \{b, c\}, B = \{c, d\}, A \cap B = \{c\}$ ,  $\text{pgprw-cl}(A) = \{b, c, d\}, \text{pgprw-cl}(B) = \{c, d\}, \text{pgprw-cl}(A \cap B) = \{c\}$  and  $\text{pgprw-cl}(A) \cap \text{pgprw-cl}(B) = \{c, d\}$  therefore  $\text{pgprw-cl}(A) \cap \text{pgprw-cl}(B) \not\subseteq \text{pgprw-cl}(A \cap B)$ .

**Theorem 3.8:** For an  $x \in X, x \in \text{pgprw-cl}(A)$  if and if  $A \cap V \neq \phi$  for every pgprw-open set V containing x.

**Proof:** Let  $x \in \text{pgprw-cl}(A)$ . To prove  $A \cap V \neq \phi$  for every pgprw-open set V containing x by contradiction.

Suppose  $\exists$  pgprw-open set  $V$  containing  $x$  s.t  $A \cap V = \emptyset$ . Then  $A \subseteq X-V$ ,  $X-V$  is pgprw-closed set,  $\text{pgprw-cl}(A) \subseteq X-V$ . This shows that  $x \notin \text{pgprw-cl}(A)$  which is contradiction. Hence  $A \cap V \neq \emptyset$  for every pgprw-open set  $V$  containing  $x$ . Conversely: Let  $A \cap V \neq \emptyset$  for every pgprw-open set  $V$  containing  $x$ . To prove  $x \in \text{pgprw-cl}(A)$ . we prove the result by contradiction. Suppose  $x \notin \text{pgprw-cl}(A)$  then there exist a pgprw-closed subset  $F$  containing  $A$  s.t  $x \notin F$ . Then  $x \in X-F$  is pgprw-open. Also  $(X-F) \cap A = \emptyset$  which is contradiction. Hence  $x \in \text{pgprw-cl}(A)$ .

**Theorem 3.9:** If  $A$  is subset of space  $X$  then

- (i)  $\text{Pgprw-cl}(A) \subseteq \text{cl}(A)$ .
- (ii)  $\text{Pgprw-cl}(A) \subseteq \text{pcl}(A)$ .

**Proof:**

- (i) Let  $A$  be subset of space  $X$  by definition of Closure  $\text{Cl}(A) = \bigcap \{F : A \subseteq F \in C(X)\}$ . If  $A \subseteq F \in C(X)$  then  $A \subseteq F \in \text{pgprw-C}(X)$  because every closed set is pgprw-closed that is  $\text{pgprw-cl}(A) \subseteq F$  therefore  $\text{pgprw-cl}(A) \subseteq \bigcap \{F : A \subseteq F \in C(X)\} = \text{cl}(A)$ . Hence  $\text{pgprw-cl}(A) \subseteq \text{cl}(A)$ .
- (ii) Let  $A$  be subset of space  $X$  by definition of  $p$ -closure  $\text{pcl}(A) = \bigcap \{F : A \subseteq F \in p-C(X)\}$ . If  $A \subseteq F \in p-C(X)$  then  $A \subseteq F \in \text{pgprw-C}(X)$  because every  $p$ -closed set is pgprw-closed that is  $\text{pgprw-cl}(A) \subseteq F$  therefore  $\text{pgprw-cl}(A) \subseteq \bigcap \{F : A \subseteq F \in p-C(X)\} = \text{pcl}(A)$ . Hence  $\text{pgprw-cl}(A) \subseteq \text{p-cl}(A)$

**Remark 3.10:** Containment relation in the above theorem 3.9 may be proper as seen from following example.

**Example 3.11:** Let  $X = \{a, b, c, d\}$ ,  $\tau = \{X, \emptyset, \{a\}, \{b\}, \{a, b\}, \{a, b, c\}\}$ ,  $A = \{a\}$   $\text{cl}(A) = \{a, c, d\}$   $\text{pgprw-cl}(A) = \{a, d\}$ ,  $\text{pcl}(A) = \{a, c, d\}$  It follows that  $\text{pgprw-cl}(A) \subset \text{cl}(A)$  and  $\text{pgprw-cl}(A) \subset \text{pcl}(A)$

**Theorem 3.12:** If  $A$  is subset of space  $X$  then  $\text{gpr-cl}(A) \subseteq \text{pgprw-cl}(A)$  where  $\text{gpr-cl}(A) = \bigcap \{F : A \subseteq F \in \text{GPR-C}(X)\}$

**Proof:** Let  $A$  be a subset of  $X$  by definition of pgprw-closure,  $\text{pgprw-cl}(A) = \bigcap \{F : A \subseteq F \in \text{pgprw-C}(X)\}$  If  $A \subseteq F \in \text{pgprw-C}(X)$  then  $A \subseteq F \in \text{GPR-C}(X)$ , because every pgprw-closed is gpr-closed i.e  $\text{gpr-cl}(A) \subseteq F$  therefore  $\text{gpr-cl}(A) \subseteq \bigcap \{F : A \subseteq F \in \text{pgprw-C}(X)\} = \text{pgprw-cl}(A)$ . Hence  $\text{gpr-cl}(A) \subseteq \text{pgprw-cl}(A)$ .

**Theorem 3.13:** Pgprw-closure is a Kuratowski closure operator on a space  $X$ .

**Proof:** Let  $A$  and  $B$  be the subsets space  $X$ .

- (i)  $\text{pgprw-cl}(X) = X$ ,  $\text{pgprw-cl}(\emptyset) = \emptyset$
- (ii)  $A \subseteq \text{pgprw-cl}(A)$
- (iii)  $\text{pgprw-cl}(A) = \text{pgprw-cl}(\text{pgprw-cl}(A))$
- (iv)  $\text{pgprw-cl}(A \cup B) = \text{Pgprw-cl}(A) \cup \text{pgprw-cl}(B)$  by theorem 3.2  
Hence pgprw-closure is a Kuratowski closure operator on a space  $X$ .

**Definition 3.14:** For a subset  $A$  of  $(X, \tau)$ , pgprw-interior of  $A$  is denoted by  $\text{pgprw-int}(A)$  and defined as  $\text{pgprw-int}(A) = \bigcup \{G : G \subseteq A \text{ and } G \text{ is pgprw-open in } X\}$  or  $\bigcup \{G : G \subseteq A \text{ and } G \in \text{pgprw-O}(X)\}$  i.e  $\text{pgprw-int}(A)$  is the union of all pgprw-open set contained in  $A$ .

**Theorem 3.15:** Let  $A$  and  $B$  be subset of space  $X$  then

- (i)  $\text{pgprw-int}(X) = X$ ,  $\text{pgprw-int}(\emptyset) = \emptyset$
- (ii)  $\text{pgprw-int}(A) \subseteq A$
- (iii) If  $B$  is any pgprw-open set contained in  $A$ , then  $B \subseteq \text{pgprw-int}(A)$
- (iv) If  $A \subseteq B$  then  $\text{pgprw-int}(A) \subseteq \text{pgprw-int}(B)$
- (v)  $\text{pgprw-int}(A) = \text{pgprw-int}(\text{pgprw-int}(A))$
- (vi)  $\text{pgprw-int}(A \cap B) = \text{pgprw-int}(A) \cap \text{pgprw-int}(B)$

**Proof :** (i) and (ii) by definition of pgprw-interior of  $A$ , it is obvious.

(iii) Let  $B$  be any pgprw-open set s.t  $B \subseteq A$ . Let  $x \in B$ ,  $B$  is an pgprw-open set contained in  $A$ ,  $x$  is an pgprw-interior of  $A$  i.e.  $x \in \text{pgprw-int}(A)$ . Hence  $B \subseteq \text{pgprw-int}(A)$  & (iv), (v), (vi) similar proof as theorem 3.2 and definition of pgprw-interior.

**Theorem 3.16:** If a subset  $A$  of  $X$  is pgprw-open then  $\text{pgprw-int}(A) = A$

**Proof:** Let  $A$  be pgprw-open subset of  $X$ . We know that  $\text{pgprw-int}(A) \subseteq A$  --(1) Also  $A$  is pgprw-open set contained in  $A$  from Theorem 3.15 (iii)  $A \subseteq \text{pgprw-int}(A)$  --(2). Hence From (1) and (2)  $\text{pgprw-int}(A) = A$

**Theorem 3.17:** If A and B are subsets of space X then  $pgprw-int(A) \cup pgprw-int(B) \subseteq pgprw-int(A \cup B)$

**Proof:** We know that  $A \subseteq A \cup B$  and  $B \subseteq A \cup B$ , We have Theorem 3.15(iv)  $pgprw-int(A) \subseteq pgprw-int(A \cup B)$  and  $pgprw-int(B) \subseteq pgprw-int(A \cup B)$ . This implies that  $pgprw-int(A) \cup pgprw-int(B) \subseteq pgprw-int(A \cup B)$

**Remark 3.18:** The converse of the above theorem need not be true as seen from the following example.

**Example 3.19:** Let  $X = \{a, b, c, d\}$  and  $\tau = \{X, \phi, \{a\}, \{b\}, \{a, b\}, \{a, b, c\}\}$ ,  $A = \{b, c\}$ ,  $B = \{a, d\}$ ,  $A \cup B = \{a, b, c, d\}$ ,  $pgprw-int(A) = \{b, c\}$ ,  $pgprw-int(B) = \{a\}$ ,  $pgprw-int(A \cup B) = X$ ,  $pgprw-int(A) \cup pgprw-int(B) = \{a, b, c\}$ ; therefore  $pgprw-int(A \cup B) \not\subseteq pgprw-int(A) \cup pgprw-int(B)$ .

**Theorem 3.20:** If A is a subset of X then (i)  $int(A) \subseteq pgprw-int(A)$  (ii)  $p-int(A) \subseteq pgprw-int(A)$ .

**Proof:**

- (i) Let A be a subset of a space X. Let  $x \in int(A) \Rightarrow x \in \cup \{G : G \text{ is open, } G \subseteq A\} \Rightarrow \exists$  an open set G s.t.  $x \in G \subseteq A \Rightarrow \exists$  an  $pgprw$ -open set G s.t.  $x \in G \subseteq A$ , as every open set is an  $pgprw$ -open set in  $X \Rightarrow x \in \cup \{G : G \text{ is } pgprw\text{-open set in } X\} \Rightarrow x \in pgprw-int(A)$ . Thus  $x \in int(A) \Rightarrow x \in pgprw-int(A)$ . Hence  $int(A) \subseteq pgprw-int(A)$ .
- (ii) Let A be a subset of a space X. Let  $x \in p-int(A) \Rightarrow x \in \cup \{G : G \text{ is } p\text{-open, } G \subseteq A\} \Rightarrow \exists$  a p-open set G s.t.  $x \in G \subseteq A \Rightarrow \exists$  an  $pgprw$ -open set G s.t.  $x \in G \subseteq A$ , as every p-open set is an  $pgprw$ -open set in  $X \Rightarrow x \in \cup \{G : G \text{ is } pgprw\text{-open set in } X\} \Rightarrow x \in pgprw-int(A)$ . Thus  $x \in p-int(A) \Rightarrow x \in pgprw-int(A)$ . Hence  $p-int(A) \subseteq pgprw-int(A)$ .

**Remark 3.21:** Containment relation in the above theorem may be proper as seen from the following example

**Example 3.22** Let  $X = \{a, b, c, d\}$   $\tau = \{X, \phi, \{a\}, \{b\}, \{a, b\}, \{a, b, c\}\}$ ;  $A = \{b, c\}$ ,  $int(A) = \{b\}$ ,  $p-int(A) = \{b\}$ ,  $pgprw-int(A) = \{b, c\}$  therefore  $int(A) \subseteq pgprw-int(A)$  and  $p-int(A) \subseteq pgprw-int(A)$

**Theorem 3.23:** If A is subset of X, then  $pgprw-int(A) \subseteq gpr-int(A)$ , where  $gpr-int(A)$  is given by  $gpr-int(A) = \cup \{G \subseteq X : G \text{ is } gpr\text{-open, } G \subseteq A\}$

**Proof:** Let A be a subset of a space X. Let  $x \in pgprw-int(A) \Rightarrow x \in \cup \{G : G \text{ is } pgprw\text{-open, } G \subseteq A\} \Rightarrow \exists$  an  $pgprw$ -open set G s.t.  $x \in G \subseteq A$ , as every  $pgprw$ -open set is an  $gpr$ -open set in  $X \Rightarrow x \in \cup \{G : G \text{ is } gpr\text{-open, } G \subseteq A\} \Rightarrow x \in gpr-int(A)$ . Thus  $x \in pgprw-int(A) \Rightarrow x \in gpr-int(A)$  Hence  $pgprw-int(A) \subseteq gpr-int(A)$ .

**Theorem 3.24:** For any subset A of X

- (i)  $X - pgprw-int(A) = pgprw-cl(X - A)$
- (ii)  $pgprw-int(A) = X - pgprw-cl(X - A)$
- (iii)  $pgprw-cl(A) = X - pgprw-int(X - A)$
- (iv)  $X - pgprw-cl(A) = pgprw-int(X - A)$

**Proof:**

- (i)  $x \in X - pgprw-int(A)$  then x is not in  $pgprw-int(A)$  i.e. every  $pgprw$ -open set G containing x s.t.  $G \not\subseteq A$ . This implies every  $pgprw$  open set G containing x intersects  $(X - A)$  i.e.  $G \cap (X - A) \neq \phi$ . Then by theorem 3.8  $x \in pgprw-cl(X - A)$  therefore  $X - pgprw-int(A) \subseteq pgprw-cl(X - A)$  (1) and Let,  $x \in pgprw-cl(X - A)$ , then every  $x \in pgprw$  open set, G containing x intersects  $X - A$  i.e.  $G \cap (X - A) \neq \phi$ , i.e. every  $pgprw$ -open G containing x s.t.  $G \subseteq A$ . Then by definition 3.14, x is not in  $pgprw-int(A)$ , i.e.  $x \in X - pgprw-int(A)$  and so  $pgprw-cl(X - A) \subseteq X - pgprw-int(A)$  (2). Thus  $X - pgprw-int(A) = pgprw-cl(X - A)$ .
- (ii) Follows by taking complements in (i).
- (iii) Follows by replacing A by X-A in (i)
- (iv) Follows by taking complements in (iii).

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