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Separation axioms via μ-Pre*-closed sets In GTS

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Abstract: In this expedition, we explored the idea of "separation axioms" via μ–pre*-closed set in GTS, investigate their vital traits, relationship and characterizations.

Key words: μ-pre$^*-$kernel; $\wedge_{p^*\mu}-$set; $\vee_{p^*\mu}-$set; $\wedge_{p^*\mu}-$closed; $\vee_{p^*\mu}-$open; μ-pre$^*-T_0$ space; μ-pre$^*-T_1$ space; μ-pre$^*-T_2$ space; $p^*kr_\mu(A)$; $\wedge_{p^*\mu}(X)$; $\vee_{p^*\mu}(X)$; $\wedge_{p^*\mu}C(X)$; $\vee_{p^*\mu}O(X)$; p^*_μ–T_0; p^*_μ–T_1; p^*_μ–T_2.

1. Introduction

The concept of generalized closed and open sets was first originated 1970 by N. Levin [8] in topological space (on briefly TS). The try – out generalized topological space (on briefly GTS) was initiated in 2002 by A. Csaszar [3]. By making use of their perception, the opinion of $\mu-$ pre*-closed sets is introduce and their attributes are discussed in GTS by us [18]. The idea of separation axioms in TS is introduced and considered by Felix Hausdroff (1869). The intention of this research, is to bring up the $\mu-$ pre*-kernel, $\wedge_{p^*\mu}$-set, $\wedge_{p^*\mu}$-closed and $\mu-$pre* separation axioms (μP^*SA) in GTS and probe fundamental traits. Also their correlations have been studied with several related counter examples.

2. Primary Needs

Here, we recall some notions and results on GTS. Henceforth, we mentioned GTS ($X,\ \mu$) as X. We know that $\tau \subseteq 2^x$ (power set) is called a topology on a set X if τ contains arbitrary union and finite intersection of members of τ and also void and whole space belong to τ (obviously arbitrary union of void set is void therefore, $\varphi \in \tau$) but in GTS, some of the above features do not valid. In a GTS, $\mu \subseteq 2^x$ that includes null space and $U_{i \in I} U_i \in \mu$ when $U_i \in \mu,\ i \in I$. In X, M_μ is delineated as $M_\mu = U_{i \in I} U_i$. A subset $A \subseteq X$ is known as a $\mu-$ pre*-open set (μP^*Os) if $A \subseteq i^*_\mu(c_\mu (A))$ and $X \setminus A$ is named as a $\mu-$ pre*-closed set (μP^*Cs). The collection of all $\mu-$ pre*-open sets and $\mu-$ pre*-closed sets are indicated as a symbol $P^*O_\mu(X)$ and $P^*C_\mu(X)$ respectively. $p^*i_\mu(A)$ is defined as union of all μP^*Os contained in A. $p^*c_\mu(A)$ is defined as the intersection of all μP^*Cs which contains A. On the whole paper, we call $p^*c_\mu(A)$

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as $\mathcal{C}(A)$ and $p^*i_\mu(A)$ as $\mathcal{J}(A)$.

Let for each $x \neq y \in M_\mu$. A space X is said to be a T_0 space [16] if $\exists$ a $\mu-$ open set $x \in U$, $y \notin U$ or $x \notin U$, $y \in U$. X is called as a T_1 space [10] if $\exists$ $\mu-$ open sets U_1 and U_2 such that $x \in U_1$, $y \notin U_1$ and $x \notin U_2$, $y \in U_2$. X is a T_2 space [16] if $\exists$ disjoint $\mu-$ open sets U_1 and U_2 such that $x \in U_1$ and $y \in U_2$. The forthcoming lemmas will be useful in the sequel.

Lemma 2.1. *If $x \in X$, then $x \in \mathcal{C}(A)$ iff $V \cap A \neq \varphi$ for every $V \in p^*O_\mu(X)$ and $x \in V$.*

Lemma 2.2. *If $A \subseteq X$, then the following statements hold.*

(i) Every μP^*Cs containing a μP^*Cs $(X \setminus M_\mu)$.

(ii) $\mathcal{C}(A \cap M_\mu) \cap M_\mu = \mathcal{C}(A) \cap M_\mu$.

(iii) If $A \in P^*C_\mu(X)$ then $\mathcal{C}(A \cap M_\mu) \cap M_\mu = A \cap M_\mu$.

(iv) $\mathcal{C}(A) = [\mathcal{C}(A) \cap M_\mu] \cup [X \setminus M_\mu]$.

(v) If $A \in P^*C_\mu(X)$ then $A = [A \cap M_\mu] \cup [X \setminus M_\mu]$.

Proof. (i) For every $U \in P^*O_\mu(X)$, $U \subseteq M_\mu$ so that $(X \setminus M_\mu) \subseteq X \setminus U$. Thus every μP^*Cs includes $(X \setminus M_\mu)$.

(ii) Since $A \cap M_\mu \subseteq A$, $\mathcal{C}(A \cap M_\mu) \cap M_\mu \subseteq \mathcal{C}(A) \cap M_\mu$. Let $x \in \mathcal{C}(A) \cap M_\mu$. Then $x \in \mathcal{C}(A)$ and $x \in M_\mu$, by lemma 2.1, $U \cap A \neq \varphi \; \forall \; U \; in \; P^*O_\mu(X)$ and $x \in U$. Since $U \subseteq M_\mu$, $U \cap (A \cap M_\mu) \neq \varphi$. Therefore, $x \in \mathcal{C}(A \cap M_\mu)$ and so $x \in \mathcal{C}(A \cap M_\mu) \cap M_\mu$. Hence $\mathcal{C}(A) \cap M_\mu \subseteq \mathcal{C}(A \cap M_\mu) \cap M\,\mu$.

(iii) If $A \in P^*C_\mu(X)$ and by (ii), $\mathcal{C}(A \cap M_\mu) \cap M_\mu = A \cap M_\mu$.

(iv) $\mathcal{C}(A) = \mathcal{C}(A) \cap X = \mathcal{C}(A) \cap [M_\mu \cup (X \setminus M_\mu)] = [\mathcal{C}(A) \cap M_\mu] \cup [\mathcal{C}(A) \cap [X \setminus M_\mu]] = [\mathcal{C}(A) \cap M_\mu] \cup [X \setminus M_\mu]$ (by (i))

(v) If $A \in P^*C_\mu(X)$ and by (iv), $A = [A \cap M_\mu] \cup [X \setminus M_\mu]$.

□

3. $\mu-$pre$^*-$kernel in GTS

In this section, we present the concepts in GTS such as $\mu-$pre$^*-$kernel, $\wedge_{p^*\mu}-$set and $\wedge_{p^*\mu}-$closed and discuss their attributes. Also we investigate the relations among them.

Definition 3.1. Let $A \subseteq X$. Then $\mu-$pre$^*-$kernel of A is the intersection of all μP^*Os contains A and it's indicated by $p^*kr_\mu(A)$.

(ie) $p^*kr_\mu(A) = \cap\{U \in P^*_\mu O(X) : A \subseteq U\}$.

State that if there is no μP^*Os contains A then $p^*_\mu kr(A) = X$.

Proposition 3.1. *For A, $B \subseteq X$ and a subset A_α, $\alpha \in N$ of X, the following statements hold.*

(i) $A \subseteq p^*kr_\mu(A)$.

(ii) $A \subseteq B \Rightarrow p^*kr_\mu(A) \subseteq p^*kr_\mu(B)$.

(iii) $p^*kr_\mu(\ p^*kr_\mu(\ A\ )\ ) = p^*kr_\mu(\ A\ )$.

(iv) *If* $A \in P^*_\mu O(\ X\ )$ *then* $A = p^*kr_\mu(\ A\ )$.

(v) $p^*kr_\mu(\ \cup A_\alpha\ ) = \cup\, p^*kr_\mu(\ A_\alpha\ )$.

(vi) $p^*kr_\mu(\ \cap A_\alpha\ ) \subseteq \cap\, p^*kr_\mu(\ A_\alpha\ )$.

Remark 3.1. *In the above proposition, the inversion statement of* (iv) *and the reverse inclusion of* (vi) *may be valid. These conditions can be explored by the succeeding counter example.*

Example 3.1. *Consider* $X = \{\ 0.1_X,\ 0.2_X,\ 0.3_X,\ 0.4_X,\ 0.5_X,\ 0.6_X\ \}$ *with* $\mu = \{\ \varphi,\ \{\ 0.2_X\ \}, \{\ 0.4_X\ \}, \{\ 0.5_X\ \}, \{\ 0.1_X,\ 0.2_X\ \}, \{\ 0.1_X,\ 0.3_X\ \}, \{\ 0.2_X,\ 0.4_X\ \}, \{\ 0.2_X,\ 0.5_X\ \}, \{\ 0.2_X,\ 0.6_X\ \}, \{\ 0.4_X, 0.5_X\ \}, \{\ 0.1_X,\ 0.2_X,\ 0.3_X\ \}, \{\ 0.1_X,\ 0.2_X,\ 0.4_X\ \}, \{\ 0.1_X,\ 0.2_X,\ 0.5_X\ \}, \{\ 0.1_X,\ 0.2_X,\ 0.6_X\ \}, \{0.1_X,\ 0.3_X, 0.4_X\ \}, \{\ 0.1_X,\ 0.3_X,\ 0.5_X\ \}, \{\ 0.2_X,\ 0.4_X,\ 0.5_X\ \}, \{\ 0.2_X,\ 0.4_X,\ 0.6_X\ \}, \{\ 0.2_X,\ 0.5_X,\ 0.6_X\ \}, \{\ 0.1_X,\ 0.2_X, 0.3_X,\ 0.4_X\ \}, \{\ 0.1_X,\ 0.2_X,\ 0.3_X,\ 0.5_X\ \}, \{\ 0.1_X,\ 0.2_X,\ 0.3_X,\ 0.6_X\ \}, \{\ 0.1_X,\ 0.2_X,\ 0.4_X,\ 0.5_X\ \}, \{\ 0.1_X, 0.2_X,\ 0.4_X,\ 0.6_X\ \}, \{\ 0.1_X,\ 0.2_X,\ 0.5_X,\ 0.6_X\ \}, \{\ 0.1_X,\ 0.3_X,\ 0.4_X,\ 0.5_X\ \}, \{\ 0.2_X,\ 0.4_X,\ 0.5_X,\ 0.6_X\ \}, \{\ 0.1_X,\ 0.2_X,\ 0.3_X,\ 0.4_X,\ 0.5_X\ \}, \{\ 0.1_X,\ 0.2_X,\ 0.3_X,\ 0.4_X,\ 0.6_X\ \}, \{\ 0.1_X,\ 0.2_X,\ 0.3_X,\ 0.5_X,\ 0.6_X\ \}, \{\ 0.1_X,\ 0.2_X,\ 0.4_X,\ 0.5_X,\ 0.6_X\ \},\ X\ \}$.

For (iv), *Take* $A = \{\ 0.3_X\ \}$. *Here* $p^*_\mu ker(\ A\ ) = \{\ 0.3_X\ \}$ *but* $\{\ 0.3_X\ \}$ *is not* μP^*O. *For* (vi), *Let* $A = \{\ 0.2_X\ \}$ *and* $B = \{\ 0.1_X,\ 0.6_X\ \}$. *Then* $A \cap B = \varphi$. *Here* $p^*kr_\mu(\ A\ ) = \{\ 0.2_X\ \}$, $p^*kr_\mu(\ B\ ) = \{\ 0.1_X,\ 0.2_X,\ 0.6_X\ \}$ *and* $p^*kr_\mu(\ A \cap B\ ) = \varphi$. *Hence* $p^*kr_\mu(\ A \cap B\ ) \subset p^*kr_\mu(\ A\ ) \cap p^*kr_\mu(\ B\ )$. *Take* $A = \{\ 0.3_X,\ 0.4_X\ \}$ *and* $B = \{\ 0.1_X,\ 0.3_X,\ 0.5_X\ \}$. *Then* $A \cap B = \{\ 0.3_X\ \}$. *Here* $p^*kr_\mu(\ A\ ) = \{\ 0.3_X,\ 0.4_X\ \}$, $p^*kr_\mu(\ B\ ) = \{\ 0.1_X,\ 0.3_X,\ 0.5_X\ \}$ *and* $p^*kr_\mu(\ A \cap B\ ) = \{\ 0.3_X\ \}$. *Hence* $p^*kr_\mu(\ A \cap B\ ) = p^*kr_\mu(\ A\ ) \cap p^*kr_\mu(\ B\ )$. *From this,* $p^*kr_\mu(\ \cap A_\alpha\ ) \subseteq \cap\, p^*kr_\mu(\ A_\alpha\ )$.

Proposition 3.2. *Let* $A \subseteq X$ *and* $\forall\, x \in X$. *Then* $p^*kr_\mu(\ A\ ) = \{\ x\ :\ \mathcal{C}(\ \{\ x\ \}\ ) \cap A \neq \varphi\ \}$.

Proof. Suppose $\mathcal{C}(\ \{\ x\ \}\ ) \cap A = \varphi,\ x \notin X \setminus \mathcal{C}(\ \{\ x\ \}\ ) \in p^*O_\mu(\ X\ )$ and $A \subseteq X \setminus \mathcal{C}(\ \{\ x\ \}\ )$. Therefore, $x \notin p^*kr_\mu(\ A\ )$ and hence $p^*kr_\mu(\ A\ ) \subseteq \{\ x \in X : \mathcal{C}(\ \{\ x\ \}\ ) \cap A \neq \varphi\ \}$. On the other hand, let $x \notin p^*kr_\mu(\ A\ )$. Then $\exists\, U \in p^*O_\mu(\ X\ ),\ A \subseteq U$ and $x \notin U$ and hence $\mathcal{C}(\ \{\ x\ \}\ ) \cap U = \varphi$ so that $\mathcal{C}(\ \{\ x\ \}\ ) \cap A = \varphi$. This is a contradiction. Thus, $\{\ x \in X : \mathcal{C}(\ \{\ x\ \}\ ) \cap A \neq \varphi\} \subseteq p^*kr_\mu(\ A\ )$. □

Proposition 3.3. *For any* $x,\ y \in X,\ \ y \in p^*kr_\mu(\ \{\ x\ \}\ )$ *iff* $x \in \mathcal{C}(\ \{\ y\ \}\ )$.

Proof. **Essential Condition:** Let $y \notin p^*kr_\mu(\ \{\ x\ \}\ )$. Then, $\exists\, U \in P^*O_\mu(\ X\ )$ such that U contains x but not y so that $\exists\, \mu P^*Cs$ containing y but not x and hence $x \notin \mathcal{C}(\ \{\ y\ \}\ )$.
Sufficient Condition: Suppose $x \notin \mathcal{C}(\ \{\ y\ \}\ ),\ \exists\, V \in P^*O_\mu(\ X\ )$ such that V contains x but not y. Thus, $y \notin p^*kr_\mu(\ \{\ x\ \}\ )$. □

Proposition 3.4. *If* $A \subseteq X$ *then* $A \in P^*C_\mu(\ X\ )$ *iff* $\mathcal{C}(\ A\ ) \subseteq p^*kr_\mu(\ A\ )$.

Proposition 3.5. $p^*kr_\mu(\ \{\ x\ \}\ ) \neq p^*kr_\mu(\ \{\ y\ \}\ )$ *iff* $\mathcal{C}(\ \{\ x\ \}\ ) \neq \mathcal{C}(\ \{\ y\ \}\ ),\ \forall\, x,\ y \in X$.

Proof. **Essential Condition:** Assume $p^*kr_\mu(\ \{\ x\ \}\ ) \neq p^*kr_\mu(\ \{\ y\ \}\ ),\ \exists\, z \in X$ such that $z \in p^*kr_\mu(\ \{\ x\ \}\ )$ and $z \notin p^*kr_\mu(\ \{\ y\ \}\ )$. By proposition 3.3, $x \in \mathcal{C}(\ \{\ z\ \}\ )$ and $y \notin \mathcal{C}(\ \{\ z\ \}\ )$ and so $\{\ y\ \} \cap \mathcal{C}(\ \{\ z\ \}\ ) = \varphi$.

Since $\mathcal{C}(\{x\}) \subseteq \mathcal{C}(\{z\})$, $\{y\} \cap \mathcal{C}(\{x\}) = \varphi$. Thus, $\mathcal{C}(\{x\}) \neq \mathcal{C}(\{y\})$.
Sufficient Condition: Let $\mathcal{C}(\{x\}) \neq \mathcal{C}(\{y\})$. Then $\exists\, z \in X$ such that $z \in \mathcal{C}(\{x\})$ and $z \notin \mathcal{C}(\{y\})$ so that $\exists\, U \in P^*O_\mu(X)$ containing z but not y. Since $z \in \mathcal{C}(\{x\})$, $x \in U$. Therefore $y \notin p^*kr_\mu(\{x\})$ and hence $p^*kr_\mu(\{x\}) \neq p^*kr_\mu(\{y\})$. □

Proposition 3.6. $\cap_{x \in M_\mu} \mathcal{C}(\{x\}) = X \setminus M_\mu$ *iff* $p^*kr_\mu(\{x\}) \neq M_\mu$, $\forall\, x \in M_\mu$.

Proof. **Essential condition:** Assume $\cap_{x \in M_\mu} \mathcal{C}(\{x\}) \cap M_\mu = \varphi$. Suppose $y \in M_\mu$ such that $p^*kr_\mu(\{y\}) = M_\mu$. Let $x \in M_\mu$ be an arbitrary point. Then for any μP^*Os containing y which also contains x so that $y \in \mathcal{C}(\{x\})$. Therefore, $y \in \mathcal{C}(\{x\})\ \forall\, x \in M_\mu$. This follows that $y \in \cap_{x \in M_\mu} \mathcal{C}(\{x\}) \cap M_\mu$, which is a contradiction. Thus, $p^*kr_\mu(\{x\}) \neq M_\mu$.
Sufficient condition: Assume $p^*kr_\mu(\{x\}) \neq M_\mu$. Let $y \in M_\mu$ such that $y \in \cap_{x \in M_\mu} \mathcal{C}(\{x\}) \cap M_\mu$. Then $\forall\, x \in M_\mu$, every μP^*Cs containing x also contains y. Therefore, every μP^*Os containing y must contains all point of M_μ so that M_μ is the only μP^*Os containing y. Therefore, $p^*kr_\mu(\{x\}) = M_\mu$ which is a contradiction. Therefore, $\cap_{x \in M_\mu} \mathcal{C}(\{x\}) \cap M_\mu = \varphi$. □

Definition 3.2. A subset A of X is said to be a $\wedge_{p^*\mu}-$set if $A = p^*kr_\mu(A)$. The complement of $\wedge_{p^*\mu}-$set is called a $\vee_{p^*\mu}-$set. Here after $\wedge_{p^*\mu}(X)$ and $\vee_{p^*\mu}(X)$ denotes the collection of all $\wedge_{p^*\mu}-$set and $\vee_{p^*\mu}-$set respectively.

Proposition 3.7. *If $A \subseteq X$, then the following statements hold.*

(i) φ *and* X *are* $\wedge_{p^*\mu}-$*sets.*

(ii) If $A \in P^*O_\mu(X)$ *then* $A \in \wedge_{p^*\mu}(X)$.

(iii) $p^*kr_\mu(A) \in \wedge_{p^*\mu}(X)$.

It can be easily seen that the converse of proposition 3.7 (ii) may be hold as well. Let us consider $X = \{e_{1X}, e_{2X}, e_{3X}, e_{4X}\}$ with $\mu = \{\phi, \{e_{1X}\}, \{e_{4X}\}, \{e_{1X}, e_{2X}\}, \{e_{1X}, e_{3X}\}, \{e_{1X}, e_{4X}\}, \{e_{2X}, e_{3X}\}, \{e_{2X}, e_{4X}\}, \{e_{1X}, e_{2X}, e_{3X}\}, \{e_{1X}, e_{2X}, e_{4X}\}, \{e_{1X}, e_{3X}, e_{4X}\}, \{e_{2X}, e_{3X}, e_{4X}\}, X\}$. Here $A = \{e_{3X}, e_{4X}\}$ is a $\wedge_{p*\mu}-$set but not μP^*O.

Proposition 3.8. *If* $A_\alpha \subseteq X$, $\alpha \in N$ *and* $A_\alpha \in \wedge_{p*\mu}(X)$, *then*

(i) $\cap A_\alpha \in \wedge_{p*\mu}(X)$.

(ii) $\cup A_\alpha \in \wedge_{p*\mu}(X)$.

Proof. (i) By proposition 3.1 (vi), $p^*kr_\mu(\cap A_\alpha) \subset \cap\, p^*kr_\mu(A_\alpha)$, $\alpha \in N$. Since $A_\alpha \in \wedge_{p*\mu}(X)$, $p^*kr_\mu(\cap A_\alpha) \subset \cap A_\alpha$. By proposition 3.1(i) $\cap A_\alpha \subseteq p^*kr_\mu(\cap A_\alpha)$. Thus we have $p^*kr_\mu(\cap A_\alpha) = \cap A_\alpha$ so that $\cap A_\alpha \in \wedge_{p*\mu}(X)$, $\alpha \in N$.

(ii) By proposition 3.1 (v) for all $\alpha \in N$, $p^*kr_\mu(\cup A_\alpha) \supseteq \cup\, p^*kr_\mu(A_\alpha)$. Since $A_\alpha \in \wedge_{p*\mu}(X)$, $p^*kr_\mu(\cup A_\alpha) \supseteq \cup A_\alpha$. We know that $A_\alpha \subseteq \cup A_\alpha$ and by proposition 3.1 (ii) $p^*kr_\mu(A_\alpha) \subseteq p^*kr_\mu(\cup A_\alpha)$, $\alpha \in N \Rightarrow \cup\, p^*kr_\mu(A_\alpha) \subseteq p^*kr_\mu(\cup A_\alpha) \Rightarrow \cup A_\alpha \subseteq p^*kr_\mu(\cup A_\alpha)$. Thus, $p^*kr_\mu(\cup A_\alpha) = \cup A_\alpha$.

□

Proposition 3.9. *Let* $A \in \wedge_{p*\mu}(X)$ *Then* $A \in P^*C_\mu(X)$ *iff* $p^*c_\mu(A) = p^*kr_\mu(A)$.

Proposition 3.10. *If* $A \in \wedge_{p*\mu}(X)$ *and* $p^*kr_\mu(A) \in P^*C_\mu(X)$ *then* $A \in P^*C_\mu(X)$.

Definition 3.3. A subset A of X is said to be $\wedge_{p^*\mu}-$closed if $A = \mathcal{K} \cap F$ where $\mathcal{K} \in \wedge_{p^*\mu}(X)$ and $F \in P^*C_\mu(X)$. The collection of $\wedge_{p^*\mu}-$closed is stand as a symbol for $\wedge_{p*_\mu}C(X)$.
A subset A of X is called a $\vee_{p*\mu}-$open set if $X \setminus A$ is $\wedge_{p*\mu}-$closed and $\vee_{p*\mu}O(X)$ denotes the collection of all $\vee_{p*\mu}-$open.

Proposition 3.11. *For any* X, *the following properties hold.*

(i) $\wedge_{p*\mu}(X) \subseteq \wedge_{p*\mu}C(X)$.

(ii) $P^*C_\mu(X) \subseteq \wedge_{p*\mu}C(X)$.

But the reverse statement of proposition 3.11 (i) and (ii) are not true. It can be described below with the aid of an example.

Example 3.2. *Let us consider* $X = \{0.2_X,\ 0.4_X,\ 0.6_X,\ 0.8_X\}$ *endowed with* $\mu = \{\varphi, \{0.2_X\}, \{0.8_X\}, \{0.2_X, 0.4_X\}, \{0.2_X, 0.6_X\}, \{0.2_X, 0.8_X\}, \{0.4_X, 0.8_X\}, \{0.2_X, 0.4_X, 0.6_X\}, \{0.2_X, 0.4_X, 0.8_X\}, \{0.2_X, 0.6_X, 0.8_X\}, X\}$. *Here,* $A = \{0.4_X, 0.6_X\} \in \wedge_{p*\mu}C(X)$ *but not in* $\wedge_{p*\mu}(X)$. *Also* $A = \{0.2_X, 0.4_X\} \in \wedge_{p*\mu}C(X)$ *but not in* $P*C_\mu(X)$.

Remark 3.2. *Every* μP^*Os *is* $\wedge_{p*\mu}-$ *closed.*

Proposition 3.12. *If* $S \subseteq X$, *then the following assertions are equivalent.*

(i) $S \in \wedge_{p*\mu}C(X)$.

(ii) $S = \mathcal{K} \cap \mathcal{C}(S)$ *where* $\mathcal{K} \in \wedge_{p*\mu}(X)$.

(iii) $S = p*kr_\mu(S) \cap \mathcal{C}(S)$.

Proof. (i) $\Rightarrow$ (ii) Let $S \in \wedge_{p*\mu}C(X)$, then $S = \mathcal{K} \cap F$ where $\mathcal{K} \in \wedge_{p*\mu}(X)$ and $F \in p^*C_\mu(X)$. Since $S \subseteq F$, $\mathcal{C}(S) \subseteq \mathcal{C}(F) = F$ and also $S \subseteq \mathcal{K}$. So we get $S \subseteq \mathcal{K} \cap \mathcal{C}(S) \subseteq \mathcal{K} \cap F = S$. Thus $S = \mathcal{K} \cap \mathcal{C}(S)$.
(ii) $\Rightarrow$ (iii) Since $S \subseteq p*kr_\mu(S)$ and also $S \subseteq \mathcal{K}$. By proposition 3.1 (ii) $p*kr_\mu(S) \subseteq p*kr_\mu(\mathcal{K}) = \mathcal{K}$. Now, $S \subseteq p*kr_\mu(S) \cap \mathcal{C}(S) \subseteq \mathcal{K} \cap \mathcal{C}(S) = S$. Therefore, $S = p*kr_\mu(A) \cap \mathcal{C}(S)$.
(iii) $\Rightarrow$ (i) Follows from proposition 3.7.
From (iii) we can say that a subset A is said to be $\wedge_{p*\mu}-$ closed if A can be represented as the intersection of all μP^*Os and all μP^*Cs containing it. □

Proposition 3.13. *If* $A \subseteq X$ *then* $A \in \vee_{p*\mu}O(X)$ *iff* $A = N \cup \mathcal{J}(G)$, *where* $N \in \vee_{p*\mu}(X)$ *and* $G \in P^*O_\mu(X)$.

4. Separation Axioms on $\mu-$ Pre*closed sets in GTS

In this part, we present a lower separation axioms such as $\mu-$pre$^* - T_0$, $\mu-$pre$^* - T_1$ and $\mu-$pre$^* - T_2$ using $P^*O_\mu(X)$. Also we speak about some results using such spaces.

Definition 4.1. A space X is called $\mu-\text{pre}^*-T_0$ (briefly $p*_\mu\text{–}T_0$) if $\forall\, x \neq y \in M_\mu$, $\exists\, U \in P{*}O_\mu(\,X\,)$ containing one but not the other.

Proposition 4.1. *Every μ–pre–T_0 space is $p^*_\mu\text{–}T_0$ space.*

Proposition 4.2. *X is $p*_\mu\text{–}T_0$ iff $\mathcal{C}(\,\{\,x\,\}\,)\cap M_\mu \neq \mathcal{C}(\,\{\,y\,\}\,)\cap M_\mu$, $\forall x \neq y \in M_\mu$.*

Proof. **Necessary Condition:** Assume X is $p^*_\mu\text{–}T_0$, $\exists\, U \in P^*O_\mu(\,X\,)$ such that $x \in U \subseteq M_\mu$ and $y \notin U$. Therefore, $X \setminus U \in P^*C_\mu(\,X\,)$ and $y \in X \setminus U$ but $x \notin X \setminus U$. Since $\mathcal{C}(\,\{\,y\,\}\,)$ is the smallest μP^*Cs containing y, $x \notin \mathcal{C}(\,\{\,y\,\}\,)$. Thus, $\mathcal{C}(\,\{\,x\,\}\,)\cap M_\mu \neq \mathcal{C}(\,\{\,y\,\}\,)\cap M_\mu$.
Sufficient Condition: Assume distinct points of M_μ have distinct $\mu-\text{pre}^*-$closures, $\exists\, z \in \mathcal{C}(\,\{\,x\,\}\,)\cap M_\mu$ and $z \notin \mathcal{C}(\,\{\,y\,\}\,)\cap M_\mu$ so that $\exists\, U \in P^*O_\mu(\,X\,)$ and $z \in U$, $y \notin U$. Suppose $x \notin U$, $\exists\, \mu P^*Cs$ containing x but not z and hence $z \notin \mathcal{C}(\,\{\,x\,\}\,)$. So that $x \in U$ but $y \notin U$. Hence X is $p^*_\mu\text{–}T_0$. ☐

Proposition 4.3. *A space X is $p^*_\mu\text{–}T_0$ iff $\{\,x\,\} \in \wedge_{p^*\mu}C(\,X\,)$, $\forall\, x \in M_\mu$.*

Proof. **Necessary Condition:** Assume X is $p^*_\mu\text{–}T_0$. Since $\{\,x\,\} \subseteq p^*kr_\mu(\,\{\,x\,\}\,)\cap \mathcal{C}(\,\{\,x\,\}\,)$. If $y \neq x$, by hypothesis (i) $\exists\, U \in P^*O_\mu(\,X\,)$ such that $x \in U$ and $y \notin U$ (or) (ii) $\exists\, V \in P^*O_\mu(\,X\,)$ such that $y \in V$ and $x \notin V$. In case of (i), $y \notin p^*kr_\mu(\,\{\,x\,\}\,)$. In case of (ii) we have $\exists\, F \in P^*C_\mu(\,X\,)$ such that $x \in F$ and $y \notin F$. Consequently, $y \notin \mathcal{C}(\,\{\,x\,\}\,)$ and hence $y \notin p^*kr_\mu(\,\{\,x\,\}\,)\cap \mathcal{C}(\,\{\,x\,\}\,)$. In either cases, $p^*kr_\mu(\,\{\,x\,\}\,)\cap \mathcal{C}(\,\{\,x\,\}\,) \subseteq \{\,x\,\}$. Therefore, $\{\,x\,\} = p^*kr_\mu(\,\{\,x\,\}\,)\cap \mathcal{C}(\,\{\,x\,\}\,)$ and by proposition 3.12 (iii), $\{\,x\,\} \in \wedge_{p^*\mu}C(\,X\,)$.
Sufficient Condition: Let $\{\,x\,\} \in \wedge_{p^*\mu}C(\,X\,)$. Then by proposition 3.12 (iii), $\{\,x\,\} = p^*kr_\mu(\,\{\,x\,\}\,)\cap \mathcal{C}(\,\{\,x\,\}\,)$. If X is not $p^*_\mu\text{–}T_0$, $\forall\, x \neq y \in M_\mu$ (i) $y \in U$, $\forall\, U \in P^*O_\mu(\,X\,)$ containing x and (ii) $x \in V$, $\forall\, V \in P^*O_\mu(\,X\,)$ containing y. From (i) and (ii), $y \in p^*kr_\mu(\,\{\,x\,\}\,)$ and $y \in \mathcal{C}(\,\{\,x\,\}\,)$ and hence $y \in p^*kr_\mu(\,\{\,x\,\}\,)\cap \mathcal{C}(\,\{\,x\,\}\,)$ which is a inconsistency. Thus, X is $p^*_\mu\text{–}T_0$. ☐

Proposition 4.4. *X is $p^*_\mu\text{–}T_0$ iff either $y \notin p^*kr_\mu(\,\{\,x\,\}\,)$ or $x \notin p^*kr_\mu(\,\{\,y\,\}\,)$, $\forall\, x \neq y \in M_\mu$.*

Proof. **Necessary Condition:** Assume X is $p^*_\mu\text{–}T_0$, $\forall\, U \in P^*O_\mu(\,X\,)$ such that $x \in U$, $y \notin U$ or $x \notin U$, $y \in U$. If $x \in U$, $y \notin U \Rightarrow y \notin p^*kr_\mu(\,\{\,x\,\}\,)$. Similarly, we have $x \notin p^*kr_\mu(\,\{\,y\,\}\,)$.
Sufficient Condition: Assume $y \notin p^*_\mu\ ker(\,\{\,x\,\}\,)$ or $x \notin p^*_\mu ker(\,\{\,y\,\}\,)$, $\exists\, U \in P^*O_\mu(\,X\,)$ such that $x \in U$, $y \notin U$ or $x \notin U$, $y \in U$. Thus, X is $p^*_\mu\text{–}T_0$. ☐

Definition 4.2. A space X is called $\mu-\text{pre}^*-T_1$ (briefly $p^*_\mu\text{–}T_1$) if $\forall\, x \neq y \in M_\mu$, $\exists\, U, V \in P^*O_\mu(\,X\,)$, such that $x \in U$, $y \notin U$ and $x \notin V$, $y \in V$.

Clearly, every $p^*_\mu\text{–}T_1$ space is $p^*_\mu\text{–}T_0$. But the reverse statement is not valid in general. It will be exuded in the forthcoming example.

Example 4.1. *Let $X = \{\,u_X, v_X, w_X, z_X\,\}$ with $\mu = \{\,\varphi, \{\,u_X\,\}, \{\,z_X\,\}, \{\,u_X, v_X\,\}, \{\,u_X, w_X\,\}, \{\,u_X, z_X\,\}, \{\,v_X, z_X\,\}, \{\,u_X, v_X, w_X\,\}, \{\,u_X, v_X, z_X\,\}, \{\,u_X, w_X, z_X\,\}, X\,\}$. Here there is no $U, V \in P^*O_\mu(\,X\,)$ such that $u_X \in U$, $w_X \notin U$ and $w_X \in V$, $u_x \notin V$. Thus, X is $p^*_\mu\text{–}T_0$ but not $p^*_\mu\text{–}T_1$.*

Proposition 4.5. *A space X is p^*_μ–T_1 iff $\{ x \} \cup (X \setminus M_\mu) \in P^*C_\mu(X)$, $\forall\, x \in M_\mu$.*

Proof. **Necessary Part:** Let X be p^*_μ–T_1. Then $\exists\, U,\ V \in P^*O_\mu(X)$ such that $y \in V \subseteq M_\mu$ and $x \notin V$ so that $M_\mu \setminus \{ x \} \in P^*O_\mu(X)$. Hence, $X \setminus [M_\mu \setminus \{ x \}] = \{ x \} \cup (X \setminus M_\mu) \in P^*C_\mu(X)$.
Sufficient Part: Let $x \neq y \in M_\mu$. By hypothesis, $\{ x \} \cup (X \setminus M_\mu)$, $\{ y \} \cup (X \setminus M_\mu) \in P^*C_\mu(X)$. Take $V = X \setminus [\{ x \} \cup (X \setminus M_\mu)] = M_\mu \setminus \{ x \}$ and $U = X \setminus [\{ x \} \cup (X \setminus M_\mu)] = M_\mu \setminus \{ y \}$. So that U and $V \in P^*O_\mu(X)$ such that $x \in U$, $y \notin U$ and $x \notin V$, $y \in V$. Hence X is $p^*\mu$–T_1. □

Proposition 4.6. *The following assertions are equivalent, $\forall x \neq y \in M_\mu$.*

(i) X *is* $p{*}_\mu$–T_1.

(ii) $\{ x \} = \mathcal{C}(\{ x \}) \cap M_\mu$.

(iii) $\mathcal{C}(\{ x \}) \cap \mathcal{C}(\{ y \}) = X \setminus M_\mu$.

Proof. (i) $\Rightarrow$ (ii) By (i) and proposition 4.5 $\{ x \} \cup (X \setminus M_\mu) \in P^*C_\mu(X)$ and by lemma 2.2(iii), $[\{ x \} \cup \{ X \setminus M_\mu \}] \cap M_\mu = \mathcal{C} [[\{ x \} \cup \{ X \setminus M_\mu \}] \cap M\mu] \cap M_\mu \Rightarrow \{ x \} \cap M_\mu = \mathcal{C} [\{ x \} \cap M_\mu] \cap M_\mu = \mathcal{C} [\{ x \}] \cap M_\mu$. Thus, $\mathcal{C}(\{ x \}) \cap M_\mu = \{ x \}$.
(ii) $\Rightarrow$ (i) By (ii), $\{ x \} \cup (X \setminus M_\mu) = \mathcal{C}(\{ x \}) \in P^*C_\mu(X)$ and by proposition 4.5, X is p^*_μ–T_1.
(ii) $\Rightarrow$ (iii) By (ii), $\{ x \} = \mathcal{C}(\{ x \}) \cap M_\mu$ and $\{ y \} = \mathcal{C}(\{ y \}) \cap M_\mu \Rightarrow \mathcal{C}(\{ x \}) \cap \mathcal{C}(\{ y \}) \cap M_\mu = \{ x \} \cap \{ y \} = \varphi$. Therefore, $\mathcal{C}(\{ x \}) \cap \mathcal{C}(\{ y \}) = X \setminus M_\mu$.
(iii) $\Rightarrow$ (ii) Since $y \in \mathcal{C}(\{ y \}) \cap M_\mu$, by (iii) $y \notin \mathcal{C}(\{ x \}) \cap M_\mu$. Therefore, $\mathcal{C}(\{ x \}) \cap M_\mu \subseteq \{ x \}$ and also $\{ x \} \subseteq \mathcal{C}(\{ x \}) \cap M_\mu$. Thus, $\{ x \} = \mathcal{C}(\{ x \}) \cap M_\mu$. □

Proposition 4.7. *If X is p^*_μ–T_1 then $\cap_{x \in M_\mu} C (\{ x \}) = X \setminus M_\mu$.*

Proof. Given that X is p^*_μ–T_1. By proposition 4.6, $\mathcal{C}(\{ x \}) \cap M_\mu = \{ x \}$, $\forall x \in M_\mu$ and so as $\mathcal{C}(\{ x \}) = \{ x \} \cup (X \setminus M_\mu)$. Now, $\cap_{x \in M_\mu} \mathcal{C}(\{ x \}) = \cap_{x \in M_\mu} [\{ x \} \cup (X \setminus M_\mu)] = X \setminus M_\mu$. □

Corollary 4.1. *If X is p^*_μ–T_1 then $p{*}kr_\mu(\{ x \}) \neq M_\mu$, $\forall x \in M_\mu$.*

Remark 4.1. *The succeeding example can be explained the reverse of proposition 4.7 and corollary 4.1 are invalid in general. In example 4.1, $\cap_{x \in M_\mu} \mathcal{C}(\{ x \}) = X \setminus M_\mu$ and $p^*_\mu ker(\{ x \}) \neq M_\mu$, $\forall x \in M_\mu$ but X is not p^*_μ–T_1.*

Proposition 4.8. *A space X is p^*_μ–T_1 iff $A \in \wedge_{p^*\mu}(X)$, $\forall\, A \subseteq M_\mu$.*

Proof. **Necessary Part:** Suppose X is p^*_μ–T_1. Let $A \subseteq M_\mu$ and $y \notin A\, \forall y \in M_\mu$. Therefore, $A \subseteq X \setminus \{ y \}$ and by proposition 4.5, $\{ y \} \cup (X \setminus M_\mu) \in P^*C_\mu(X)$, $X \setminus [\{ y \} \cup (X \setminus M_\mu)] = (X \setminus \{ y \}) \cap M_\mu \in P^*O_\mu(X)$. Therefore, $A = \cap \{ (X \setminus \{ y \}) \cap M_\mu : y \in X \setminus A \}$ and hence $A = p^*kr_\mu(A)$.
Sufficient Part: Let $A \in \wedge_{p^*\mu}(X)\, \forall A \subseteq M_\mu$. By hypothesis, $\{ x \} \in \wedge_{p^*\mu}(X)$ and $\{ y \} \in \wedge_{p^*\mu}(X)$ so that $\exists\, U,\ V \in P^*O_\mu(X)$ such that $x \in U$, $y \notin U$ and $x \notin V$, $y \in V$. Thus, X is p^*_μ–T_1. □

Remark 4.2. *From proposition 4.8, In particular, each singleton set of M_μ is a $\wedge_{p^*\mu}-$set.*

Proposition 4.9. *X is p_μ^*–T_1 iff $y \notin p^*kr_\mu(\{x\})$ and $x \notin p^*kr_\mu(\{y\})$, $\forall x \neq y \in M_\mu$.*

Proof. **Necessary Part:** Assume X is p_μ^*–T_1, $\exists\, U, V \in P^*O_\mu(X)$ such that $x \in U$, $y \notin U$ and $x \notin V$, $y \in V$. Since $p^*kr_\mu(\{x\}) \subseteq U$ and $p^*kr_\mu(\{y\}) \subseteq V$, $y \notin p^*kr_\mu(\{x\})$ and $x \notin p^*kr_\mu(\{y\})$.

Sufficient Part: Assume $y \notin p^*kr_\mu(\{x\})$ and $x \notin p^*kr_\mu(\{y\})$, $\forall x \neq y \in M_\mu$. So that $\exists\, U, V \in P^*O_\mu(X)$ such that $x \in U$, $y \notin U$ and $x \notin V$, $y \in V$. Thus, X is p_μ^*–T_1. □

Proposition 4.10. *X is p_μ^*–T_1 iff $p^*kr_\mu(\{x\}) \cap p^*kr_\mu(\{y\}) = \varphi$, $\forall x \neq y \in M_\mu$.*

Proof. **Necessary Part:** Assume X is p_μ^*–T_1, by proposition 4.8 $p^*kr_\mu(\{x\}) \cap p^*kr_\mu(\{y\}) = \varphi$.

Sufficient Part: Let $p^*kr_\mu(\{x\}) \cap p^*kr_\mu(\{y\}) = \varphi$, $\forall x \neq y \in M_\mu$. Suppose X is not p_μ^*–T_1. By proposition 4.9, $x \in p^*kr_\mu(\{y\})$ and $y \in p^*kr_\mu(\{x\})$ so that $p^*kr_\mu(\{x\}) \cap p^*kr_\mu(\{y\}) \neq \varphi$ which is a inconsistency. Thus, X is p_μ^*–T_1. □

Definition 4.3. A space X is called $\mu-$pre$^*-T_2$ (briefly p_μ^*–T_2) if $\forall x \neq y \in M_\mu$, $\exists\, U$ and $V \in P^*O_\mu(X)$ such that $x \in U$, $y \in V$ and $U \cap V = \varphi$.

Remark 4.3. *In general, we get the relationship between the above spaces is given in the following diagram: p_μ^*–$T_2 \Rightarrow p_\mu^*$–$T_1 \Rightarrow p_\mu^*$–T_0.*
(i.e) Every p_μ^*–T_k space is p_μ^*–T_{k-1}, $k = 1, 2$. But the reverse statement is invalid in general. Now, we expressed through the help of a counter example.

Example 4.2. *Consider $X = \{i_X, j_X, k_X, l_X, m_X\}$ with $\mu = \{\varphi, \{i_X, j_X\}, \{k_X, l_X\}, \{l_X, m_X\}, \{k_X, l_X, m_X\}, \{i_X, j_X, k_X, l_X\}, \{i_X, j_X, l_X, m_X\}, X\}$. Then X is p_μ^*–T_0 and p_μ^*–T_1 but there are no disjoint $U, V \in P^*O_\mu(X)$ containing k_X and m_X respectively. Therefore, X is not p_μ^*–T_2.*

Proposition 4.11. *If X is p_μ^*–T_2 then $\{x\}$ and $\{y\}$ are $\mu-$pre$^*-$separated, $\forall\, x \neq y \in M_\mu$.*

Proposition 4.12. *X is p_μ^*–T_2 iff $\{x\} = \cap\{N : N \in P^*C_\mu(X)$ and $N \in p_\mu^*Nbd(x)\}$, $\forall x \in M_\mu$.*

Proof. **Necessary Part:** Assume X is $\mu-$pre$^*-T_2$, $\exists$ disjoint $U, V \in P^*O_\mu(X)$ such that $x \in U$, $y \in V$. Since $x \in U \subseteq X \setminus V$, $X \setminus V \in P^*C_\mu(X)$ so that $X \setminus V \in p_\mu^*Nbd(x)$. Therefore, $y \notin X \setminus V$ and hence $\{x\} = \cap\{X \setminus V : X \setminus V \in P^*C_\mu(X)$ and $X \setminus V \in p_\mu^*Nbd(x)\}$.

Sufficient Part: Suppose $\{x\} = \cap\{N : N \in P^*C_\mu(X)$ and $N \in p_\mu^*Nbd(x)\}$. Then $\exists\, N$ such that $N \in P^*C_\mu(X)$ and $N \in p_\mu^*Nbd(x)$ so that $y \notin N$ and hence $\exists\, U \in P^*O_\mu(X)$, $x \in U \subseteq N$. Hence U and $X \setminus N$ are required disjoint μP^*Os containing x and y respectively. Thus, X is $p_\mu^* - T_2$. □

Proposition 4.13. *The following properties are equivalent, $\forall x \neq y \in M_\mu$.*

(i) X is p_μ^*–T_2.

(ii) $\exists\, U \in P^*O_\mu(X)$ and $x \in U$ such that $y \notin \mathcal{C}(U)$.

(iii) $\cap\{\mathcal{C}(U) \mid x \in U$ and $U \in P^*O_\mu(X)\} = \{x\} \cup (X \setminus M_\mu)$.

Proof. (i) $\Rightarrow$ (ii) By (i), $\exists\ U,\ V \in P^*O_\mu(X)$ such that $x \in U$, $y \in V$ and $U \cap V = \varphi$. Since $V \in P^*O_\mu(X)$ and $y \in V$ and by lemma 2.1, we have $y \notin \mathcal{C}(U)$.
(ii) $\Rightarrow$ (iii) By (ii) and lemma 2.2 (i), $\cap\{\mathcal{C}(U): x \in U$ and $U \in P^*O_\mu(X)\} \supseteq (X \setminus M_\mu)$ not containing y. Thus, $\cap\{\mathcal{C}(U): x \in U$ and $U \in P^*O_\mu(X)\} = \{x\} \cup (X \setminus M_\mu)$.
(iii) $\Rightarrow$ (i) By (iii), $y \notin \{x\} \cup (X \setminus M_\mu) = \cap\{\mathcal{C}(U): x \in U$ and $U \in P^*O_\mu(X)\}$. Therefore $y \notin \mathcal{C}(U)$ for some μP^*Cs containing x so that $\exists\ V \in P^*O_\mu(X)$ such that $y \in V$ and $x \notin V$. Therefore, U and V are the required disjoint μP^*Os containing x and y respectively. ☐

Corollary 4.2. *X is p^*_μ–T_2 iff $\forall x \neq y \in M_\mu$, either $x \notin \mathcal{C}(\{y\}) \cap M_\mu$ or $y \notin \mathcal{C}(\{x\}) \cap M_\mu$.*

Corollary 4.3. *If X is p^*_μ–T_2 then $\{x\} \cup (X \setminus M_\mu) \in P^*C_\mu(X)$, $\forall x \in M_\mu$.*

Corollary 4.4. *Let X is p^*_μ–T_2. Then $\forall x \neq y \in M_\mu$ have disjoint $\mu-$pre$^*-$closure.*

5. Conclusion

In this journey, we have scrutinized some sets such as $\wedge_{p^*\mu}-$set and $\wedge_{p^*\mu}-$closed set through $\mu-$pre$^*-$kernel and their features were examined. The separation axioms of $\mu-$pre$^*-$closed set in GTS were discovered and their natures were contemplated and also discussed their correlations between them.

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