# A Generalization of A Contra Pre Semi-Open Maps

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**ABSTRACT**

The concept of θ-semi-open sets in topological spaces was introduced in 1984 and 1986 by T. Noiri [9, 10]. In this paper we introduce and study a generalization of a contra pre semi-open maps due to (Caldas and Baker) [3], it is called contra pre θs-open maps, the maps whose images of a θ-semi-open sets is θ-semi-closed. Also, we introduce and study a new type of closed maps called contra pre θs-closed maps, which is stronger than contra pre semi-closed due to Caldas [2], the maps whose image of a θ-semi-closed sets is θ-semi-open.1991 Math. Subject Classification: 54 C10, 54 D 10.

**Keywords**: θ-semi-open sets, Contra pre θs-open and Contra pre θs-closed maps.

**تعميم تعميم للدوال شبه مفتوحة من النمط contra Pre**

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**الملخص**

عرف T. Noiri مفهوم مجموعة شبه مفتوحة من النمط θ في الفضاء التبولوجي في [9, 10] سنة 1984 و 1986 . في هذا البحث نعرف و ندرس تعميم للدوال شبه مفتوحة من النمط contra Pre المقدمة من قبل Caldas و Baker في [3] ، التي تسمى الدالة شبه المفتوحة من النمط contra Pre θ . وهي الدوال التي تكون صور المجموعات شبه المفتوحة من النمط θ ، شبه المغلقة من النمط θ ، كما نعرف و ندرس نمطاً جديداً من الدوال المغلقة تسمى الدوال شبه مغلقة من النمط contra Pre θ ، وهذه الدوال أقوى من الدوال شبه المغلقة من النمط contra المقدمة من قبل (caldas) في [2] ، وهي الدوال التي تكون صور المجموعات شبه المغلقة من النمط θ ، شبه مفتوحة من النمط θ .

**الكلمات المفتاحية:** مجموعة شبه مفتوحة من النمط θ، دوال شبه مفتوحة من النمط contra Pre، دوال شبه مغلقة من النمط contra Pre.

## 1. Introduction

The concept of θ-semi-open set in topological spaces was introduced in 1984 and 1986 by T. Noiri [9, 10], which depends on semi-open sets due to N. Levine [8]. When semi-open sets are replaced by θ-semi-open sets, new results are obtained. M. Caldas and C. Baker defined and studied the concept of contra pre semi-open maps [3], where the maps whose images of semi-open sets are semi-closed.

In this direction we shall define the concept of Pre θs-open maps. In this paper we introduce two new types of open and closed maps called contra pre θs-open and contra pre θs-closed maps via the concept of θ-semi-open sets and study some of their basic properties. We also establish relationships a mong these maps with other types of continuity, openness and closedness.

## 2. Preliminaries

Throughout the present paper, spaces always mean topological spaces on which no separation axiom is assumed unless explicitly stated. Let S be a subset of a space X. The closure and the interior of S are denoted by Cl(S) and Int(S), respectively. A subset S is said to be regular open(resp. semi-open[8]) if S = Int(Cl(S)) (resp. S $\subset$ Cl(Int((S))). A subset S is said to be θ-semi-open [9] if for each x $\in$ S, there exists a semi-open set U in X such that x $\in$ U $\subset$ Cl(U) $\subset$ S. The complement of each regular open (resp. semi-open and θ-semi-open) set is called regular closed (resp. semi-closed and θ-semi-closed). The family of all semi-open (resp. semi-closed, θ-semi-open and θ-semi-closed) sets of X is denoted by SO(X) (resp. SC(X), θSO(X) and θSC(X)). A point x is said to be in the θ-semi-closure [10] of S, denoted by $sCl_\theta(S)$, if S $\cap$ Cl(U) $\neq \phi$ for each U$\in$SO (X) containing x. If S = $sCl_\theta(S)$, then S is called θ-semi-closed. A point x is said to be in the θ-semi-interior [10] of S denoted by $sInt_\theta(S)$, if Cl(U) $\subset$ S for some U $\in$ SO (X) containing x. If S = $sInt_\theta(S)$, then S is called θ-semi-open. For each U $\in$SO (X), Cl(U) is θ-semi-open and hence every regular closed set is θ-semi-open. Therefore, x$\in sCl_\theta(S)$ if and only if S $\cap$ A $\neq \phi$ for each θ-semi-open set A containing x. A function $f$ : X$\to$Y is said to be contra pre semi-open [3] (resp. contra pre semi-closed [2]) if for each semi-open (resp. semi-closed) set U of X, $f$(U) $\in$ SC(Y) (resp. $f$(U) $\in$ SO(Y)).

## 3. Contra pre θs-open and contra pre θs-closed maps

Let $f : (X, \tau) \to (Y, \sigma)$ be a map from a topological space (X, τ) into a topological space (Y, σ).

**Definition 3.1:** A map $f : (X, \tau) \to (Y, \sigma)$ is said to be contra pre θs-open (resp. contra pre θs-closed) if $f$(A) is θ-semi-closed (resp. θ-semi-open ) in (Y, σ), for each set A $\in$ θSO(X, τ) ( resp. A $\in$ θSC(X, τ)).

The proof of the following two lemmas follows directly from their definitions and, therefore, they are omitted.

**Lemma 3.1:** Every contra pre semi-open map is contra pre θs-open.

**Lemma 3.2:** Every contra pre θs-closed map is contra pre semi-closed.
The converse of the above lemmas is not true in general as it is shown by the following examples.

**Example 3.1:** Let X = {a, b, c} and τ = {ϕ, X, {a}, {b}, {a, b}, {a, c}}. Then the family of all semi-open subsets of X with respect to τ is:
SO(X) = {ϕ, X, {a}, {b}, {a, b}, {a, c}} and the family of all θ-semi-open subsets of X with respect to τ is θSO(X) = {ϕ, X, {b}, {a, c}}. The identity map
*f :* (X, τ) → (X, τ) is contra pre θs-open map, but it is not contra pre semi-open maps.

**Example 3.2:** Let X = {a, b, c} and τ = {ϕ, X, {a}, {b}, {a, b}}. Then, the family of all semi-open subsets of X with respect to τ is:
SO(X) = {ϕ, X, {a}, {b}, {a, b}, {a, c}, {b, c}} and the family of all θ-semi-open subsets of X with respect to τ is :
θSO(X) = {ϕ, X, {a, c}, {b, c}}. Define a function
*f :* (X, τ) → (X, τ) as follows:
*f* (a) =b, *f* (b) = *f* (c) = a. Then *f* is contra pre semi-closed, but it is not contra pre θs-closed.

**Remark 3.1:** Contra pre θs-openness and contra pre θs-closedness are equivalent if the map is bijective.

**Theorem 3.1:** For a map *f :* X → Y the following are equivalent:

**i)** *f* is contra pre θs-open;

**ii)** for every subset D of Y and for every θ-semi-closed subset G of X with

$f^{-1}(D) \subset G$, there exists a θ-semi-open subset B of Y with $D \subset B$ and

$f^{-1}(B) \subset G$;

**iii)** for every $y \in Y$ and for every θ-semi-closed subset G of X with

$f^{-1}(y) \subset G$, there exists a θ-semi-open subset B of Y with $y \in B$ and

$f^{-1}(B) \subset G$.

**Proof: (i)⇒(ii).** Let D be a subset of Y and let G be a θ-semi-closed subset of X with $f^{-1}(D) \subset G$. Set, $B = Y \setminus f(X \setminus G)$. Since $f$ is contra pre θs-open, then B is a θ-semi-open set of Y and since $f^{-1}(D) \subset G$ we have $f(X \setminus G) \subset Y \setminus D$ and hence $D \subset B$. Also,
$f^{-1}(B) = X \setminus [f^{-1}(f(X \setminus G))] \subset X \setminus (X \setminus G) = G$.

**(ii)⇒(iii).** It is sufficient, set D = {y}, we get the result.

**(iii)⇒(i).** Let A be a θ-semi-open subset of X with $y \in Y \setminus f(A)$ and let $G = X \setminus A$. By(iii) , there exists a θ-semi-open subset $B_y$ of Y with $y \in B_y$ and $f^{-1}(B_y) \subset G$. Then, $y \in B_y \subset Y \setminus f(A)$.
Hence $Y \setminus f(A) = \cup \{ B_y : y \in Y \setminus f(A)\}$. Therefore, by [6, Lemma 2.2] that $Y \setminus f(A)$ is θ-semi-open. Thus, $f(A)$ is a θ-semi-closed subset in Y.

**Theorem 3.2:** For a map $f : X \rightarrow Y$ the following are equivalent:

i) $f$ is contra pre θs-closed;

ii) for every subset D of Y and for every θ-semi-open subset A of X with $f^{-1}(D) \subset A$, there exists a θ-semi-closed subset H of Y with $D \subset H$ and $f^{-1}(H) \subset A$.

**Proof: (i)⇒(ii).** Let D be a subset of Y and let A be a θ-semi-open subset of X with $f^{-1}(D) \subset A$. Set, $H = Y \setminus f(X \setminus A)$. Since $f$ is contra pre θs-closed, therefore, H is a θ-semi-closed set of Y and since $f^{-1}(D) \subset A$,
we have $f(X \setminus A) \subset X \setminus D$ and hence $D \subset H$. Also, $f^{-1}(H) \subset A$.

**(ii)⇒(i).** Let G be a θ-semi-closed subset of X. Set,
$D = Y \setminus f(G)$ and let $A = X \setminus G$.
Hence $f^{-1}(D) = f^{-1}(Y \setminus f(G)) = X \setminus f^{-1}(f(G)) \subset X \setminus G = A$. By assumption, there exists a θ-semi-closed set $H \subset Y$ for which $D \subset H$ and $f^{-1}(H) \subset A$. It follows that D = H. If $y \in H$ and $y \notin D$, then $y \in f(G)$.

therefore, $y = f(x)$ for some $x \in G$ and we have $x \in f^{-1}(H) \subset A = X \setminus G$ which is a contradiction. Since $D = H$, that is, $Y \setminus f(G) = H$, which implies that $f(G)$ is θ-semi-open and hence $f$ is contra pre θs-closed.

Taking the set D in Theorem 3.2 to be $\{y\}$ for $y \in Y$ we obtain the following result.

**Corollary 3.1:** If $f : X \to Y$ is contra pre θs-closed map, then for every $y \in Y$ and every θ-semi-open subset A of X with $f^{-1}(y) \subset A$, there exists a θ-semi-closed subset H of Y with $y \in H$ and $f^{-1}(H) \subset A$.

**Theorem 3.3:** A map $f : X \to Y$ is contra pre θs-open if and only if for each $x \in X$ and each semi-open set S in X containing x, there exists a θ-semi-closed set H in Y containing $f(x)$ such that $H \subset f(Cl(S))$.

**Corollary 3.2:** A map $f : X \to Y$ is contra pre θs-open if and only if for each $x \in X$ and each θ-semi-open subset A of X containing x, there exists a θ-semi-closed subset H of Y containing $f(x)$ such that $H \subset f(A)$.

**Corollary 3.3:** A map $f : X \to Y$ is contra pre θs-open, then for each $x \in X$ and each regular closed subset R of X containing x, there exists a θ-semi-closed subset H of Y containing $f(x)$ such that $H \subset f(R)$.

**Theorem 3.4:** A map $f : X \to Y$ is contra pre θs-closed if and only if for each $x \in X$ and each θ-semi-closed subset G of X containing x, there exists a semi-open subset W of Y containing $f(x)$ such that $Cl(W) \subset f(G)$.

**Corollary 3.4:** A map $f : X \to Y$ is contra pre θs-closed if and only if for each $x \in X$ and each θ-semi-closed subset G of X containing x, there exists a θ-semi-open subset B of Y containing $f(x)$ such that $B \subset f(G)$.

**Theorem 3.5:** For a map $f : X \to Y$, the following are equivalent:

**a)** $f$ is contra pre θs-open;

**b)** $f(sInt_\theta(A)) \subset sCl_\theta(f(A))$ for each subset A of X;

**c)** $sInt_\theta(f^{-1}(B)) \subset f^{-1}(sCl_\theta(B))$ for each subset B of Y;

**d)** $f^{-1}(sInt_\theta(B)) \subset sCl_\theta(f^{-1}(B))$ for each subset B of Y.

**Proof: (a)⇒(b).** Suppose $f$ is contra pre θs-open maps and $A \subset X$. Since $sInt_\theta(A) \subset A$, $f(sInt_\theta(A)) \subset f(A)$ and hence $f(sInt_\theta(A)) \subset sCl_\theta(f(A))$.
**(b)⇒(c).** Let B be any subset of Y. Then $f^{-1}(B) \subset X$. Therefore, we apply (b), we obtain $f(sInt_\theta(f^{-1}(B))) \subset sCl_\theta(f(f^{-1}(B))) \subset sCl_\theta(B)$. Thus, $sInt_\theta(f^{-1}(B)) \subset f^{-1}(sCl_\theta(B))$.
**(c)⇒(d).** In (c), we take $Y \setminus B$ instead of B, we get $sInt_\theta(f^{-1}(Y \setminus B)) \subset f^{-1}(sCl_\theta(Y \setminus B))$. Then, $sInt_\theta(X \setminus f^{-1}(B)) \subset f^{-1}(Y \setminus sCl_\theta(B))$, which implies that $X \setminus sCl_\theta(f^{-1}(B)) \subset X \setminus f^{-1}(sInt_\theta(B))$. Hence $f^{-1}(sInt_\theta(B)) \subset sCl_\theta(f^{-1}(B))$.
**(d)⇒(a).** Let A be any θ-semi-open subset of X and set $B = Y \setminus f(A) = f(X \setminus A)$. By (d), $f^{-1}(sInt_\theta(( f(X \setminus A))) \subset sCl_\theta(f^{-1}(f(X \setminus A))) = sCl_\theta(X \setminus A) = X \setminus A$. Therefore, $f(X \setminus A) = Y \setminus f(A)$ is θ-semi-open and hence $f(A)$ is θ-semi-closed subset of Y. Thus, $f$ is contra pre θs-open map.

The proof of the following theorem is similar to the above theorem for the contra pre θs-closed maps.

**Theorem 3.6:** For a map $f : X \rightarrow Y$, the following are equivalent:
**a)** $f$ is contra pre θs-closed;
**b)** $f(sCl_\theta(A)) \subset (sInt_\theta f(A))$ for each subset A of X;
**c)** $sCl_\theta(f^{-1}(B)) \subset f^{-1}(sInt_\theta(B))$ for each subset B of Y;
**d)** $f^{-1}(sCl_\theta(B)) \subset sInt_\theta(f^{-1}(B))$ for each subset B of Y.

**Theorem 3.7:** Let $f : (X, \tau) \rightarrow (Y, \sigma)$ be a map. Then,
i) If $f$ is contra pre θs-open, then $sCl_\theta(f(A)) \subset f(sCl_\theta(A))$ for every θ-semi-open subset A of X.
ii) If $f$ is contra pre θs-closed, then $f(A) \subset sInt_\theta(f(sCl_\theta(A)))$ for every subset A of X.
**Proof: i)** Since $f$ is contra pre θs-open, then $sCl_\theta(f(A)) = f(A) \subset f(sCl_\theta(A))$ for every $A \in \theta SO(X, \tau)$.
**ii)** Since $f$ is contra pre θs-closed and since $sCl_\theta(A)$ is θ-semi-closed, then $f(A) \subset f(sCl_\theta(A)) = sInt_\theta(f(sCl_\theta(A)))$ for every subset A of X.

A map $f : (X, \tau) \rightarrow (Y, \sigma)$ is said to be pre θs-open, if $f(A)$ is θ-semi-open in $(Y, \sigma)$, for every $A \in \theta SO(X, \tau)$.
Recall, that a map $f : (X, \tau) \rightarrow (Y, \sigma)$ is called S-closed [4] if $sCl_\theta(f(A)) \subset f(sCl_\theta(A))$ for every subset A of X.

**Theorem 3.8:** For a map $f : (X, \tau) \rightarrow (Y, \sigma)$ ,the following properties hold,

i) $f$ is S-closed, whenever $f$ is contra pre θs-closed and $sCl_\theta\,(sInt_\theta\,(f(A))) \subset f(A)$ for every θ-semi-closed set A of X.
ii) $f$ is pre θs-open, whenever $f$ is contra pre θs-open and $f(A) \subset sInt_\theta\,(sCl_\theta\,(f(A)))$ for every θ-semi-open set A of X.

**Proof: i)** Let G be a θ-semi-closed subset of X. Since $sCl_\theta\,(sInt_\theta\,(f(G))) \subset f(G)$ and $f(G)$ is θ-semi-open, then $sCl_\theta\,(sInt_\theta\,(f(G))) = sCl_\theta\,(f(G)) \subset f(G)$. So, by [1, Remark 1.2.6], $f(G)$ is θ-semi-closed. Therefore, by [10, Theorem 3.1], $f$ is S-closed map.
ii) Let A be a θ-semi-open subset of X. But $f(A) \subset sInt_\theta\,(sCl_\theta\,(f(A)))$ and $f(A)$ is θ-semi-closed, then $sInt_\theta\,(sCl_\theta\,(f(A))) = sInt_\theta\,(f(A))$ and hence $f(A) \subset sInt_\theta\,(f(A))$. Therefore, $f(A) = sInt_\theta\,(f(A))$. So, by [1, Proposition 1.2.2(4)], $f(A)$ is θ-semi-open.

**Lemma 3.3[7]:** If Y is a regular closed subset of a space X and $A \subset Y$, then A is θ-semi-open in X if and only if A is θ-semi-open in Y.

Regarding the restriction $f|_R$ of a map $f: (X, \tau) \to (Y, \sigma)$ to a subset R of X we have the following:

**Theorem 3.9:** If $f: (X, \tau) \to (Y, \sigma)$ is contra pre θs-open and R is a regular closed set of $(X, \tau)$, then the map $f|_R : (R, \tau_R) \to (Y, \sigma)$ is also contra pre θs-open.

**Proof:** Let A be a θ-semi-open set in the subspace R. Since R is regular closed in X, then by Lemma 3.3, A is θ-semi-open set in X. Since $f$ is contra pre θs-open. Therefore, $f(A)$ is θ-semi-closed in Y. Thus, $f|_R$ is contra pre θs-open map.

The proof of the following result is not hard, therefore, it is omitted.

**Theorem 3.10:** Let $f: (X, \tau) \to (Y, \sigma)$ and $g: (Y, \sigma) \to (Z, \gamma)$ be two maps such that $g \circ f : (X, \tau) \to (Z, \gamma)$. Then,
a) $g \circ f$ is contra pre θs-open, if $f$ is pre θs-open and $g$ is contra pre θs-open.
b) $g \circ f$ is contra pre θs-open, if $f$ is contra pre θs-open and $g$ is S-closed.
c) $g \circ f$ is contra pre θs-closed, if $f$ is S-closed and $g$ is contra pre θs-closed.
d) $g \circ f$ is contra pre θs-closed, if $f$ is contra pre θs-closed and $g$ is pre θs-open.

Recall, that a map $f : (X, \tau) \rightarrow (Y, \sigma)$ is S-continuous [10], if and only if for each θ-semi-open subset A of Y, $f^{-1}(A)$ is θ-semi-open in X.

**Theorem 3.11:** Let $f : (X, \tau) \rightarrow (Y, \sigma)$ and $g: (Y, \sigma) \rightarrow (Z, \gamma)$ be two maps such that $g \circ f : (X, \tau) \rightarrow (Z, \gamma)$ is contra pre θs-closed.
a) If $f$ is S-continuous surjection, then $g$ is contra pre θs-closed.
b) If $g$ is S-continuous injection, then $f$ is contra pre θs-closed.

**Proof:** a) Suppose G is any arbitrary θ-semi-closed set in Y. Since $f$ is S-continuous. Therefore, by [10, Theorem 1.1], $f^{-1}(G)$ is θ-semi-closed in X. Since $g \circ f$ is contra pre θs-closed and $f$ is surjective $(g \circ f)(f^{-1}(G)) = g(G)$ is θ-semi-open in Z. This implies that $g$ is a contra pre θs-closed map.
b) Suppose G is any arbitrary θ-semi-closed set in X. Since $g \circ f$ is contra pre θs-closed, $(g \circ f)(G)$ is θ-semi-open in Z. Since $g$ is S-continuous injection, $g^{-1}((g \circ f))(G) = f(G)$ is θ-semi-open in Y. This implies that $f$ is a contra pre θs-closed map.

Arguing as in the proof of Theorem 3.11, we obtain the following result.

**Theorem 3.12:** Let $f : (X, \tau) \rightarrow (Y, \sigma)$ and $g: (Y, \sigma) \rightarrow (Z, \gamma)$ be two maps such that $g \circ f : (X, \tau) \rightarrow (Z, \gamma)$ is contra pre θs-open.
a) If $f$ is S-continuous surjection, then $g$ is contra pre θs-open.
b) If $g$ is S-continuous injection, then $f$ is contra pre θs-open.

**Lemma 3.4[10]:** Let $(X, \tau)$ be a topological space and D be a subset of X. Then $x \in sCl_\theta(D)$ if and only if for every θ-semi-open A of x such that $A \cap D \neq \phi$.

**Definition 3.2[5]:** A subset D of a topological space $(X, \tau)$ is called θ-semi-dense if $sCl_\theta(D) = X$.

**Theorem 3.13:** For a map $f : (X, \tau) \rightarrow (Y, \sigma)$, the following properties hold:
a) If $f$ is contra pre θs-open and $B \subset Y$ has the property that B is not contained in proper θ-semi-open sets, then $f^{-1}(B)$ is θ-semi-dense in X.

b) If $f$ is contra pre θs-closed and A is θ-semi-dense subset of Y, then $f^{-1}$ (A) is not contained in a proper θ-semi-dense set.

**Proof:** a) Let $x \in X$ and let A be a θ-semi-open subset of X containing x. Then $f$ (A) is θ-semi-closed and $Y \setminus f$ (A) is a proper θ-semi-open subset of Y. Thus, $B \not\subset Y \setminus f(A)$ and hence there exists $y \in B$ such that $y \in f$ (A). Let $z \in A$ for which $y = f$ (z). Then $z \in A \cap f^{-1}(B)$. Hence $A \cap f^{-1}(B) \neq \phi$ and thus by Lemma 3.4, $x \in sCl_\theta(f^{-1}(B))$. Hence $f^{-1}(B)$ is θ-semi-dense in X.
b) Assume that $f^{-1}(A) \subset O$ where O is a proper θ-semi-open subset of X. Then, we have that $f(X \setminus O)$ is a non-empty θ-semi-open set such that $f(X \setminus O) \cap A = \phi$, which a contradicts the fact that A is θ-semi-dense.

**Lemma 3.5[6]:** Let $X_1$ and $X_2$ be two topological spaces and $X = X_1 \times X_2$. Let $A_i \in \theta SO(X_i)$ for i = 1,2, then $A_1 \times A_2 \in \theta SO(X_1 \times X_2)$.

**Definition 3.3[7]:** A space X is said to be strongly semi-$T_2$ if and only if for each two distinct points x and y in X, there exists two disjoint θ-semi-open sets A and B in X containing x and y, respectively.

**Theorem 3.14:** If X is a strongly semi-$T_2$ space and $f: X \to Y$ is contra pre θs-open map, then the set $A = \{(x_1, x_2) : f(x_1) = f(x_2)\}$ is θ-semi-closed in the product space $X \times X$.

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