On Decomposition of Bitopological (1,2)*-*A*- Continuity

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Abstract: *- The aim of this paper is to give decompositions of continuity, namely (1,2)*-A-continuity by providing the concepts of (1,2)*-semi-continuity, (1,2)*-C-continuity, (1,2)*-β-continuity and (1,2)*-LC-continuity.*

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1. Introduction

To give a decomposition of continuity, Tong[13] introduced the notions of A-set and A-continuous mappings and proved that a map f : X→Y is continuous if and only if it is both α-continuous and A-continuous. Again, Tong[14] introduced the notions of B-sets and B-continuous mappings, and together with the notion of precontinuity he proved another decomposition of continuity i.e., A mapping f : X→Y is continuous if and only if it is precontinuous and B-continuous. Ganster and Reilly[5] established a decomposition of A-continuity i.e., a mapping f : X→Y is A-continuous if and only if it is semi-continuous and LC-continuous.

In this paper, we obtain decompositions of bitopological (1,2)*-A-continuous. In most of the occasions, our ideas are illustrated and substantiated by suitable examples.

2. Preliminaries

Throughout this paper, X and Y denote bitopological spaces (X, τ_1, τ_2) and (Y, σ_1, σ_2), respectively, on which no separation axioms are assumed.

Definition 2.1

Let S be a subset of X. Then S is called $\tau_{1,2}$-open [10] if S = A ∪ B, where $A \in \tau_1$ and $B \in \tau_2$.

The complement of $\tau_{1,2}$-open set is called $\tau_{1,2}$ - closed.

Definition 2.2

Let A be a subset of X.

(i) The $\tau_{1,2}$-closure of A [10], denoted by $\tau_{1,2}$-cl(A), is defined by

$$\cap\{U : A \subseteq U \text{ and } U \text{ is } \tau_{1,2}\text{- closed}\};$$

(ii) The $\tau_{1,2}$-interior of A [10], denoted by $\tau_{1,2}$-int(A), is defined by

$$\cup\{U : U \subseteq A \text{ and } U \text{ is } \tau_{1,2}\text{-open}\}.$$

Remark 2.3 [10]

Notice that $\tau_{1,2}$-open sets need not necessarily form a topology.

Now we recall some definitions and results, which are used in this paper.

Definition 2.4

A subset A of X is said to be

(i) (1,2)*-semi-open [10] if $A \subseteq \tau_{1,2}$-cl($\tau_{1,2}$-int(A)),

(ii) (1,2)*- preopen [10] if $A \subseteq \tau_{1,2}$-int($\tau_{1,2}$-cl(A)),

(iii) (1,2)*-β-open [12] if $A \subseteq \tau_{1,2}$-cl($\tau_{1,2}$-int($\tau_{1,2}$-cl(A))),

(iv) (1,2)*-α-open [10] if $A \subseteq \tau_{1,2}$-int($\tau_{1,2}$-cl($\tau_{1,2}$-int(A))),

(v) regular (1,2)*-open [10] if $A = \tau_{1,2}$-int($\tau_{1,2}$-cl(A)).

The complements of the above- mentioned open sets are called their respective closed sets.

The family of all (1,2)*-semi-open (resp. (1,2)*-preopen, (1,2)*-α-open, (1,2)*- β-open, regular (1,2)*-open) sets of X will be denoted by (1,2)*-SO(X) (resp. (1,2)*-PO(X), (1,2)*-αO(X), (1,2)*-βO(X), (1,2)*-RO(X)).

The (1,2)*-preclosure, (1,2)*-pcl(A), of a subset A is the intersection of all (1,2)*-preclosed subsets of X that contain A.

Example 2.5

Let X = {a, b, c}, τ_1 = {φ, X, {a}} and τ_2 = {φ, X, {c}}. Then the sets in {φ, X, {a}, {c}, {a, c}} are $\tau_{1,2}$-open and the sets in {φ, X, {b}, {a, b}, {b, c}} are $\tau_{1,2}$- closed.

Definition 2.6

A subset S of X is said to be

(i) a (1,2)*-A- set [10] if $S = G \cap R$, where G is $\tau_{1,2}$-open and R is regular (1,2)*-closed,

(ii) a (1,2)*-t-set [10] if $\tau_{1,2}$-int($\tau_{1,2}$-cl(S)) = $\tau_{1,2}$-int(S),

(iii) a (1,2)*-B-set [10] if $S = G \cap R$, where G is $\tau_{1,2}$-open and R is a (1,2)*-t- set,

(iv) a locally (1,2)*-closed [9] if $S = G \cap R$, where G is $\tau_{1,2}$-open and R is $\tau_{1,2}$-closed.

The family of all (1,2)*-A-sets (resp. locally (1,2)*-closed sets, (1,2)*-B-sets) of X will be denoted by (1,2)*-A(X) (resp. (1,2)*-LC(X), (1,2)*-B(X)).

The following Proposition is a direct consequence of the definition of (1,2)*-t-sets.

Proposition 2.7

A subset A of a space X is a (1,2)*-t-set if and only if it is (1,2)*-semi-closed.

Proof

Let A be a (1,2)*-semi-closed set. Then $\tau_{1,2}$-int($\tau_{1,2}$-cl(A)) $\subseteq$ A.Therefore $\tau_{1,2}$-int($\tau_{1,2}$-cl(A)) $\subseteq$ $\tau_{1,2}$-int(A). We know that $\tau_{1,2}$-int(A) $\subseteq$ $\tau_{1,2}$-int($\tau_{1,2}$-cl(A)). Hence $\tau_{1,2}$-int(A) = $\tau_{1,2}$-int($\tau_{1,2}$-cl(A)). Then A is (1,2)*-t-set.

Conversely, let A be a (1,2)*-t-set. Then $\tau_{1,2}$-int($\tau_{1,2}$-cl(A)) = $\tau_{1,2}$-int(A). We have $\tau_{1,2}$-int($\tau_{1,2}$-cl(A)) $\subseteq$ $\tau_{1,2}$-int(A) $\subseteq$ A. Hence $\tau_{1,2}$-int($\tau_{1,2}$-cl(A)) $\subseteq$ A. Therefore A is (1,2)*-semi-closed set.

From the definitions, we can see (1,2)*-LC(X) $\subseteq$ (1,2)*-B(X).

Example 2.8

Let X = {a, b, c}, τ_1 = {φ, X, {a}} and τ_2 = {φ, X}. We have (1,2)*-LC(X) = {φ, X, {a}, {b, c}} and (1,2)*-B(X) = {φ, X, {a}, {b}, {c}, {b, c}}. Clearly {b} is (1,2)*-B-set but it is not locally (1,2)*-closed.

Remark 2.9 [10]

(i) A (1,2)*-A-set is a (1,2)*-B-set but not conversely.

(ii) Every regular (1,2)*-open set is $\tau_{1,2}$ - open but not conversely.

Proposition 2.10

Let A be an $\tau_{1,2}$-open subset of a space X. Then $\tau_{1,2}$-cl(A) is regular (1,2)*-closed.

Proof

Clearly, $\tau_{1,2}$-cl($\tau_{1,2}$-int($\tau_{1,2}$-cl(A))) $\subseteq$ $\tau_{1,2}$-cl(A). So we need only to show that $\tau_{1,2}$-cl(A) $\subseteq$ $\tau_{1,2}$-cl($\tau_{1,2}$-int($\tau_{1,2}$-cl(A))). Now, from A $\subseteq$ $\tau_{1,2}$-cl(A), we have A $\subseteq$ $\tau_{1,2}$-int($\tau_{1,2}$-cl(A)). Therefore, $\tau_{1,2}$-cl(A) $\subseteq$ $\tau_{1,2}$-cl($\tau_{1,2}$-int($\tau_{1,2}$-cl(A))).

Proposition 2.11 [11]

Let A be a subset of a space X. Then (1,2)*-pcl(A) = A $\cup$ $\tau_{1,2}$-cl($\tau_{1,2}$-int(A)).

Remark 2.12 [9]

A subset S of X is locally (1,2)*-closed if and only if S = U ∩ $\tau_{1,2}$-cl(S), where U is $\tau_{1,2}$ -open.

Definition 2.13 [10, 12]

Let f : (X, τ_1, τ_2) → (Y, σ_1, σ_2) be a map. Then f is said to be (1,2)*-semi-continuous if f^{-1}(G) $\in$ (1,2)*-SO(X) for each $\sigma_{1,2}$-open set G of Y.

The (1,2)-β-continuity and (1,2)*-A-continuity are analogously defined.* **Remark 2.14 [10]**(1,2)*-A-sets and (1,2)*-semi-open sets are independent.

Let X = {a, b, c}, τ_1 = {φ, X, {a}, {b, c}} and τ_2 = { φ, X, {b}, {a, c}}. Then the sets in {φ, X, {a}, {b}, {a, b}, {b, c}} are $\tau_{1,2}$-open and the sets in {φ, X, {a}, {b}, {c}, {a, c}, {b, c}} are $\tau_{1,2}$-closed. We have {c} is (1,2)*-A-set but not (1,2)*-semi-open.

Let X = {a, b, c}, τ_1 = {φ, X, {a}} and τ_2 = { φ, X}. Then the sets in {φ, X, {a}} are $\tau_{1,2}$-open and the sets in {φ, X, {b, c}} are $\tau_{1,2}$-closed. We have {a, b} is not (1,2)*-A-set but it is (1,2)*-semi-open.

3. PROPERTIES OF BITOPOLOGICAL (1,2)*-SETS

In this section, we provide three theorems concerning decompositions of bitopological (1,2)*-A-continuity. In the second theorem, a notion of (1,2)*-C-sets which is weaker than that of locally (1,2)*- closed sets is used.

Definition 3.1

A subset S of a space X is called (1,2)*-C-set if S = G ∩ R, where G is $\tau_{1,2}$-open and R is a (1,2)*-preclosed.

Remark 3.2

(i) The family of all (1,2)*-C-sets of X will be denoted by (1,2)*-C(X).

(ii) Every $\tau_{1,2}$-open set is (1,2)*-C-set.

(iii) Every (1,2)*-preclosed set is (1,2)*-C-set.

Remark 3.3

By definition 3.1, it is clear that (1,2)*-A(X) $\subseteq$ (1,2)*-LC(X) $\subseteq$ (1,2)*-C(X).

The following example shows that a (1,2)*-C-set need not be a locally (1,2)*- closed set and a locally (1,2)*-closed set need not be a (1,2)*-A-set.

Example 3.4

Let X = {a, b, c}, τ_1 = {φ, X, {a, b}} and τ_2 = {φ, X, {b, c}}. Then (1,2)*-A(X) = {φ, X, {a, b}, {b, c}}; (1,2)*-LC(X) = {φ, X, {a}, {c}, {a, b}, {b, c}} and (1,2)*-C(X) = P(X), where P(X) is the power set of X. Clearly, {b} is (1,2)*-C-set but it is not locally (1,2)*-closed. Moreover, {a} is locally (1,2)*-closed but it is not (1,2)*-A-set.

Definition 3.5

A bitopological space (X, τ_1, τ_2) equipped with the family of all $\tau_{1,2}$-open sets will be called DRT-space if int_{τ_1} (S) = int_{τ_2} (S) for each $\tau_{1,2}$-closed subset S of X.

Let X = {a, b, c}, τ_1 = {φ, X, {a}, {b, c}} and τ_2 = { φ, X, {b}, {a, c}}. Then (X, τ_1, τ_2) is not DRT-space since int_{τ_1} ({a}) = {a} ≠ φ = int_{τ_2} ({a}) for the $\tau_{1,2}$-closed subset {a} of X. However, in Example 3.4., (X, τ_1, τ_2) is DRT-space.

Theorem 3.6

Let X be a DRT-space. Then an (1,2)*-A-set in X is (1,2)*-semi-open.

Proof

Let S = U ∩ C be an (1,2)*-A-set, where U is $\tau_{1,2}$-open and C = $\tau_{1,2}$-cl($\tau_{1,2}$-int(C)). Since S = U ∩ C, we have $\tau_{1,2}$-int(S) ⊃ U ∩ $\tau_{1,2}$-int(C). It is easily seen that $\tau_{1,2}$-int(S) ⊂ S ⊂ C, hence $\tau_{1,2}$-int(S) = $\tau_{1,2}$-int($\tau_{1,2}$-int(S)) ⊂ $\tau_{1,2}$-int(C). But $\tau_{1,2}$-int(S) ⊂ S ⊂ U, hence $\tau_{1,2}$-int(S) ⊂ U ∩ $\tau_{1,2}$-int(C). Therefore $\tau_{1,2}$-int(S) = U ∩ $\tau_{1,2}$-int(C). Now we prove S ⊂ $\tau_{1,2}$-cl($\tau_{1,2}$-int(S)). Let x ∈ S and V be an arbitrary $\tau_{1,2}$-open set containing x. Then U ∩ V is also an $\tau_{1,2}$-open set containing x. Since x ∈ C = $\tau_{1,2}$-cl($\tau_{1,2}$-int(C)), there is a point z ∈ $\tau_{1,2}$-int(C) such that z ≠ x and z ∈ U ∩ V. Hence z ∈ U ∩ $\tau_{1,2}$-int(C) = $\tau_{1,2}$-int(S). Therefore x ∈ $\tau_{1,2}$-cl($\tau_{1,2}$-int(S)) and S $\tau_{1,2}$-cl($\tau_{1,2}$-int(S)). From $\tau_{1,2}$-int(S) ⊂ S ⊂ $\tau_{1,2}$-cl($\tau_{1,2}$-int(S)) we know that S is (1,2)*-semi-open.

Example 3.7

Let X = {a, b, c}, τ_1 = {φ, X, {a}} and τ_2 = { φ, X}. Then the sets in {φ, X, {a}} are $\tau_{1,2}$-open and the sets in {φ, X, {b, c}} are $\tau_{1,2}$-closed. In this DRT-space, we have {a, b} is not (1,2)*-A-set but it is (1,2)*-semi-open.

Theorem 3.8

Let X be a DRT-space. Then (1,2)*-A(X) = (1,2)*-SO(X) ∩ (1,2)*-LC(X).

Proof

Let S ∈ (1,2)*-A(X). Then S = G ∩ R where G is $\tau_{1,2}$-open and R is regular (1,2)*-closed. Clearly S is locally (1,2)*- closed. Now $\tau_{1,2}$ -int(S) = G ∩ $\tau_{1,2}$-int(R), so that S = G ∩ $\tau_{1,2}$-cl($\tau_{1,2}$-int(R)) ⊆ $\tau_{1,2}$-cl(G ∩ $\tau_{1,2}$-int(R)) = $\tau_{1,2}$-cl($\tau_{1,2}$-int(S)) and hence S is (1,2)*-semi-open.

Conversely, let S be (1,2)*-semi-open and locally (1,2)*-closed, so that S ⊆ $\tau_{1,2}$-cl($\tau_{1,2}$-int(S)) and S = U ∩ $\tau_{1,2}$-cl(S), where U is $\tau_{1,2}$-open. Then $\tau_{1,2}$-cl(S) = $\tau_{1,2}$-cl($\tau_{1,2}$-int(S)) and so is regular (1,2)*-closed. Hence S is an (1,2)*-A-set.

Proposition 3.9

Let A be a subset of X. Then A is (1,2)*-preclosed if and only if $\tau_{1,2}$- cl($\tau_{1,2}$-int(A)) ⊆ A.

Lemma 3.10

Let (X, τ_1, τ_2) be a DRT-space and G be a subset of X. Then G ∈ (1,2)*-C(X) if and only if G = R ∩ (1,2)*-pcl(G) for some $\tau_{1,2}$-open set R.

Proof

Suppose that G = R ∩ (1,2)*-pcl(G) for some $\tau_{1,2}$-open set R. It is obvious that G ∈ (1,2)*-C(X), since (1,2)*-pcl(G) is (1,2)*- preclosed.

Conversely , let G ∈ (1,2)*-C(X). Then G = R ∩ A where R is $\tau_{1,2}$-open and A is (1,2)*-preclosed. From G ⊆ A, we have (1,2)*-pcl(G) ⊆ (1,2)*-pcl(A) = A ∪ $\tau_{1,2}$-cl($\tau_{1,2}$-int(A)). Since A is (1,2)*-preclosed, by Proposition 3.9, we have (1,2)*-pcl(G) ⊆ A. Thus, R ∩ (1,2)*-pcl(G) ⊆ R ∩ A = G ⊆ R ∩ (1,2)*-pcl(G), which shows that G = R ∩ (1,2)*-pcl(G) with R is $\tau_{1,2}$-open.

Lemma 3.11

Let (X, τ_1, τ_2) be a DRT-space and G be a subset of X. Then G = R ∩ $\tau_{1,2}$-cl($\tau_{1,2}$-int(G)) for some $\tau_{1,2}$-open set R if and only if G ∈ (1,2)*-C(X) ∩ (1,2)*- SO(X).

Proof

Suppose that G = R ∩ $\tau_{1,2}$-cl($\tau_{1,2}$-int(G)) where R is $\tau_{1,2}$-open. Then G ⊆ $\tau_{1,2}$-cl($\tau_{1,2}$-int(G)) which shows that G ∈ (1,2)*-SO(X). Moreover, $\tau_{1,2}$-cl($\tau_{1,2}$-int(G)) is $\tau_{1,2}$ -closed and therefore (1,2)*-preclosed. So, G ∈ (1,2)*-C(X).

Conversely, let G ∈ (1,2)*-C(X) ∩ (1,2)*-SO(X). From G ∈ (1,2)*-C(X), we have from Lemma 3.10, that G = R ∩ (1,2)*-pcl(G), where R is $\tau_{1,2}$-open. From G ∈ (1,2)*-SO(X), we have G ⊆ $\tau_{1,2}$-cl($\tau_{1,2}$-int(G)). But (1,2)*-pcl(G) = G ∪ $\tau_{1,2}$-cl($\tau_{1,2}$-int(G)) (see Proposition 2.11). Thus G = R ∩ $\tau_{1,2}$ -cl($\tau_{1,2}$ -int(G)) with R is $\tau_{1,2}$ -open.

Theorem 3.12

Let (X, τ_1, τ_2) be a DRT-space. Then (1,2)*-A(X) = (1,2)*-C(X) ∩ (1,2)*-SO(X).

Proof

It is clear that (1,2)*-A(X) ⊆ (1,2)*-C(X) ∩ (1,2)*-SO(X).

Conversely, let G ∈ (1,2)*-C(X) ∩ (1,2)*-SO(X). Then by Lemma 3.11, G = R ∩ $\tau_{1,2}$-cl($\tau_{1,2}$ -int(G)), where R is $\tau_{1,2}$ -open. Since $\tau_{1,2}$-int(G) is $\tau_{1,2}$ -open, by Proposition 2.10, $\tau_{1,2}$-cl($\tau_{1,2}$-int(G)) is regular (1,2)*-closed. Therefore G ∈ (1,2)*-A(X).

Remark 3.13

It is clear from the definition 2.4 that (1,2)*-SO(X) ⊆ (1,2)*-βO(X). However, the converse is not true.

Example 3.14

Let X = {a, b, c}, τ_1 = {φ, X, {a}} and τ_2 = {φ, X, {b, c}}. Then the sets in {φ, X, {a}, {b, c}} are $\tau_{1,2}$-open and $\tau_{1,2}$-closed. Clearly, {b} ∈ (1,2)*-βO(X), but it is not (1,2)*- semi-open.

Theorem 3.15

Let (X, τ_1, τ_2) be a DRT-space. Then (1,2)*-A(X) = (1,2)*-βO(X) ∩ (1,2)*-LC(X).

Proof

If G ∈ (1,2)*-A(X), then, obviously, G ∈ (1,2)*-βO(X) ∩ (1,2)*-LC(X). Conversely, let G ∈ (1,2)*-βO(X) ∩ (1,2)*-LC(X). From G ∈ (1,2)*-βO(X), we have G ⊆ $\tau_{1,2}$-cl($\tau_{1,2}$-int($\tau_{1,2}$-cl(G))). From G ∈ (1,2)*-LC(X), we have, by Remark 2.12, G = U ∩ $\tau_{1,2}$-cl(G), where U is $\tau_{1,2}$-open. So G ⊆ U, which implies G ⊆ U ∩ $\tau_{1,2}$-cl($\tau_{1,2}$-int($\tau_{1,2}$-cl(G))) ⊆ U ∩ $\tau_{1,2}$-cl(G) = G. Hence we have G = U ∩ $\tau_{1,2}$-cl($\tau_{1,2}$-int($\tau_{1,2}$-cl(G))). By Proposition 2.10, $\tau_{1,2}$-cl($\tau_{1,2}$-int($\tau_{1,2}$-cl(G))) is regular (1,2)*-closed, since $\tau_{1,2}$-int($\tau_{1,2}$-cl(G)) is $\tau_{1,2}$-open. Therefore, G ∈ (1,2)*-A(X).

4. DECOMPOSITIONS OF (1,2)*-A-CONTINUITY

Definition 4.1

A mapping f : X→Y is said to be (1,2)*-continuous [9] if f^{-1} (V) is $\tau_{1,2}$-open in X for every $\sigma_{1,2}$ -open set V of Y.

Definition 4.2

A mapping f : X→Y is said to be (1,2)* -C-continuous if f^{-1} (V) $\in$ (1,2)*-C(X) for every $\sigma_{1,2}$ -open set V of Y.

Definition 4.3

A mapping f : X→Y is said to be (1,2)*-LC-continuous [9] if f^{-1}(V) $\in$ (1,2)*-LC(X) for every $\sigma_{1,2}$ -open set V of Y.

Theorem 4.4

Let (X, τ_1, τ_2) be a DRT-space. Then a mapping f : X→Y is (1,2)*-A-continuous if and only if it is (1,2)*-semi-continuous and (1,2)* -C-continuous.

Proof

It follows from Theorem 3.12.

Theorem 4.5

Let (X, τ_1, τ_2) be a DRT-space. Then a mapping f : X→Y is (1,2)*-A-continuous if and only if it is (1,2)*-semi-continuous and (1,2)*-LC-continuous.

Proof

It follows from Theorem 3.8.

Theorem 4.6

Let (X, τ_1, τ_2) be a DRT-space. Then a mapping f : X→Y is (1,2)*-A-continuous if and only if it is (1,2)*-β-continuous and (1,2)*-LC-continuous.

Proof

It follows from Theorem 3.15.

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