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العدد التاسع عشر
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Totally Semi-open Functions in Topological Spaces

Amna Mohamed Abdelgader Ahmed

Department of Mathematics, Faculty of Sciences, Elmergib University

Abstract

In this paper, we introduce the concept of totally semi-open functions in topological spaces. Some interesting results and properties of totally semi-open functions are investigated and proven.

Keywords: *Semi-open function, Semi-open set, Semi-closed set, Semi-clopen set, Totally open function.*

1 Introduction

The notion of semi-open sets and semi-continuity was first introduced and investigated by Levine [8] in 1963. In 1969, Biswas [2] defined and studied semi-open functions. Irresolute functions and semi-homeomorphisms were introduced and studied by Crossley and Hildebrand [4]. Nour [11] defined totally semi-continuous and strongly semi-continuous functions. Benchalli and Neeli in [1] introduced and studied semi-totally continuous and semi-totally open functions. Garg and Shivaraj in [7] introduced the concept of preclosed mapping.

In this paper, a new generalization of semi-open functions is introduced and studied. We define totally semi-open functions and prove some interesting results and properties in this connection.

2 Preliminaries

Throughout this paper, X will always denote a topological space. If A is a subset of X , then \bar{A} and A° respectively denote the closure and the interior of A in X .

Definition 1. A subset A of a topological space (X, τ) is said to be

1) semi-open set [8] if there exists an open set U in X such that $U \subseteq A \subseteq \bar{U}$, i.e., $A \subseteq \bar{A}^\circ$.



2) semi-closed set [4] if A is the complement of a semi-open set, i.e., $(\bar{A})^\circ \subseteq A$. **Definition**

2. [4] (1) The semi-closure of a set A in X is the intersection of all semi-closed sets that contains A ; this set is denoted by \underline{A} .

2) The semi-interior of a set A in X is the union of all semi-open sets of X contained in A ; this set is denoted by A°

3) A point $x \in X$ is said to be a semi-limit point of a set A in X if every semi-open set containing x contains at least one point of A different from x itself.

Theorem 1. [8] If $\{A_i\}_{i \in I}$ a collection of semi-open sets in a topological space X then $\bigcup_{i \in I} A_i$ is semi-open.

Definition 3. A function $f : X \rightarrow Y$ is said to be

1) semi-continuous [8] if the inverse image of each open subset of Y is semi-open in X .

2) semi-open [2] if $f(U)$ is semi-open in Y for each open set U in X .

3) totally semi-continuous [11] if the inverse image of every open subset of Y is semi-clopen in X .

4) irresolute [4] if the inverse image of every semi-open set in Y is semi-open in X .

5) pre semi-open [4] if the image of every semi-open set in X is semi-open in Y .

6) semi-totally continuous [1] if the inverse image of every semi-open subset of Y is clopen in X .

7) semi-totally open [1] if the image of every semi-open set in X is clopen in Y .

Definition 4. [9] A topological space X is said to be

1) semi- T_0 if for each pair of distinct points in X , there exists a semi-open set containing one point but not the other.

2) semi- T_1 if for each pair of distinct points x and y of X , there exist semi-open sets U and V such that $x \in U, y \notin U$ and $x \notin V, y \in V$.

3) semi- T_2 if for each pair of distinct points x and y of X , there exist semi-open sets U and V such that $x \in U, y \in V$ and $U \cap V = \emptyset$.

Definition 5. [10] A topological space X is said to be semi-connected if X is not the union of two nonempty disjoint semi-open subsets of X .

Definition 6. [5] A topological space X is said to be semi-compact if any semi-open cover of X has a finite subcover.



3 Totally Semi-open Functions

In this section, we introduce the concept of totally semi-open functions. Further, we study many properties and prove some results.

Definition 7. A function $f : X \rightarrow Y$ is said to be totally semi-open if the image of every open set in X is semi-clopen in Y .

Example 1. Let $X = \{1,2,3\}$, $\tau = \{\phi, X, \{1\}\}$ and $\tau' = \{\phi, X, \{2\}, \{1,3\}\}$. The function $g: (X, \tau) \rightarrow (X, \tau')$ defined by $g(1) = 2$, $g(2) = 1$, $g(3) = 3$ is totally semi-open.

Example 2. Let $I_{\mathbb{R}}: \mathbb{R} \rightarrow \mathbb{R}$ be the identity function. If $A = (-\infty, 0) \cup (0, \infty)$, then A is open, but $f(A) = A$ is not semi-clopen in \mathbb{R} . So, $I_{\mathbb{R}}$ is not totally semi-open.

Theorem 2. Let $f : X \rightarrow Y$ be a totally semi-open injective function and let $A \subseteq X$. For any $x \in X$, if $f(x)$ is a semi-limit point of $f(A)$ then x is a limit point of A .

Proof. Suppose that x is not a limit point of A , so there exists an open set U in X such that $x \in U$ and $U \cap A \setminus \{x\} = \phi$. But then $f(U) \cap f(A) \setminus \{f(x)\} = \phi$ and hence $f(x)$ is not a semi-limit point of $f(A)$ since $f(U)$ is semi-clopen in Y .

Definition 8. A function $f : X \rightarrow Y$ is said to be totally semi-closed if the image of every closed set in X is semi-clopen in Y .

Lemma 1. A bijection $f: X \rightarrow Y$ is totally semi-open if and only if it is totally semi-closed.

Proof. Suppose f is totally semi-open and let $A \subseteq X$ be a closed set, then $f(X \setminus A) = Y \setminus f(A)$ is semi-clopen in Y if and only if $f(A)$ is also semi-clopen in Y .

Theorem 3. If $f : X \rightarrow Y$ is a totally semi-open function then for all $A \subseteq X$:

1) $f(A^\circ) \subseteq (f(A))^\circ$.

2) $f(A) \subseteq f(\bar{A})$

Proof. 1) Since $A^\circ \subseteq A$, then $f(A^\circ) \subseteq f(A)$. Hence, $f(A^\circ) = (f(A^\circ))^\circ \subseteq (f(A))^\circ$, since $f(A^\circ)$ is semi-open in Y .

2) Since $A \subseteq \bar{A}$, then $f(A) \subseteq f(\bar{A})$. From Lemma 1 we have f is also totally semi-closed, so $f(\bar{A})$ is semi-clopen in Y . Hence, $f(A) \subseteq f(\bar{A}) = f(\bar{A})$.

Lemma 2. [8] Let $\{X_i\}_{i \in \mathbb{N}}$ be a collection of topological spaces and for each i , A_i is a semi-open (resp. semi-closed) set in X_i , then $A = \prod_{i \in I} A_i$ is semi-open (resp. semi-closed) in the product space $\prod_{i \in I} X_i$.



Theorem 4. Let $\{f_i: X \rightarrow X_i\}_{i \in \mathbb{N}}$ be a collection of totally semi-open functions. Then the function $f: X \rightarrow \prod_{i \in \mathbb{N}} X_i$ defined by $f(x) = (f_i(x))_{i \in \mathbb{N}}$ is totally semi-open.

Proof. Let U be an open set in X , then $f(U) = \prod_{i \in \mathbb{N}} f_i(U)$, where $f_i(U)$ is semi-clopen in X_i for all $i \in \mathbb{N}$, so the proof follows directly from Lemma 2.

Theorem 5. Let $f: X \rightarrow Y$ be a function and $g: X \rightarrow X \times Y$ the graph function of f where $g(x) = (x, f(x))$ for each $x \in X$. If g is totally semi-open then f is also totally semi-open.

Proof. Let U be an open set in X , then $g(U) = U \times f(U)$ is semi-clopen in $X \times Y$. Since $U \times f(U)$ is semi-open, $U \times f(U) \subseteq \overline{(U \times f(U))}^\circ = \overline{U}^\circ \times \overline{(f(U))}^\circ$, so $f(U) \subseteq \overline{(f(U))}^\circ$ and $f(U)$ is semi-open in Y . Similarly, we can prove that $f(U)$ is semi-closed in Y . Therefore, $f(U)$ is semi-clopen in Y and f is totally semi-open function.

Definition 9. A function $f: X \rightarrow Y$ is said to be totally open if the image of every open set in X is clopen in Y .

Theorem 6. Every totally open function is totally semi-open.

Proof. The proof follows directly from the fact that every clopen set is also semi-clopen.

Remark 1. The converse of Theorem 6 is not true as shown by the following example.

Example 3. Let $X = \{a, b, c\}$, $\tau = \{\emptyset, X, \{b, c\}\}$ and $\tau' = \{\emptyset, X, \{a\}, \{c\}, \{a, c\}\}$. The function $g: (X, \tau) \rightarrow (X, \tau')$ defined by $g(x) = x$ is a totally semi-open function, but g is not totally open.

Theorem 7. Every totally semi-open function is semi-open.

Proof. Let $f: X \rightarrow Y$ be a totally semi-open function and $U \subseteq X$ be an open set, then $f(U)$ is semi-clopen in Y , so $f(U)$ is semi-open in Y .

Remark 2. The converse of the above theorem is false as shown by:

Example 4. Let $X = \{1, 2, 3\}$ and $\tau = \{\emptyset, X, \{1\}\}$, then the identity function on X is semi-open but not totally semi-open.

Theorem 8. Every semi-totally open function is totally semi-open.

Proof. Let $f: X \rightarrow Y$ be a semi-totally open function and $U \subseteq X$ be an open set. So, U is also semi-open and then $f(U)$ is clopen in Y . Since a clopen set is also semi-clopen, the proof is complete.

Remark 3. The converse of Theorem 8 is not true, for example, the function g defined in Example 3 is totally semi-open but not semi-totally open.



Remark 4. A totally semi-open function need not be pre-semi-open. Also, a pre-semi-open function need not be totally-semi-open as is illustrated in the following examples:

Example 5. The identity function on \mathbb{R} is pre-semi-open but not totally semi-open.

Example 6. Let $X = \{1,2,3\}$, $\tau = \{\phi, X, \{2\}\}$ and $\tau' = \{\phi, X, \{2\}, \{1,3\}\}$. The function $g: (X, \tau) \rightarrow (X, \tau')$ defined by $g(x) = x$ is totally semi-open but not pre-semi-open.

Remark 5. Example 5 and Example 3 also illustrate that totally semi-open functions and open functions are independent notions.

Remark 6. The composition of two totally semi-open functions need not be a totally semi-open function as is illustrated in the following example.

Example 7. Let $X = \{1,2,3\}$, $\tau = \{\phi, X, \{2,3\}\}$ and $\tau' = \{\phi, X, \{1\}, \{3\}, \{1,3\}\}$ and let $X^* = \{1,2,3,4\}$ and $\tau^* = \{\phi, X, \{1\}, \{1,3\}, \{3\}\}$. Let $f: (X, \tau) \rightarrow (X^*, \tau^*)$ be defined as $f(1) = 2, f(2) = 1, f(3) = 4$ and let $g: (X^*, \tau^*) \rightarrow (X, \tau')$ be defined by $g(1) = g(3) = 1, g(2) = 2, g(4) = 3$, then both f and g are totally semi-open. But the composition $g \circ f$ is not a totally semi-open function because $(g \circ f)(\{2,3\}) = \{1,3\}$ and $\{1,3\}$ is not semi-clopen in Z although $\{2,3\}$ is open in X .

The proof of the following theorem is obvious.

Theorem 9. If $f: X \rightarrow Y$ is open and $g: Y \rightarrow Z$ is totally semi-open, then $g \circ f: X \rightarrow Z$ is totally semi-open.

Theorem 10. If $f: X \rightarrow Y$ and $g: Y \rightarrow Z$ are functions and $g \circ f: X \rightarrow Z$ is totally semi-open then:

- (1) if f is continuous and surjective, then g is totally semi-open.
- (2) if g is semi-totally continuous and injective, then f is totally semi-open.

Proof. (1) Let U be an open set in Y then $f^{-1}(U)$ is open in X since f is continuous, Since f is surjective then $(g \circ f)(f^{-1}(U)) = g(U)$. Since $g \circ f$ is totally semi-open then $g(U)$ is semi-clopen in Z .

(2) Let U be an open set in X , then $(g \circ f)(U) = g(f(U))$ is semi-clopen (and hence semi-open) in Z since $g \circ f$ is totally semi-open. But g is totally semi-continuous and injective, so $g^{-1}((g \circ f)(U)) = f(U)$ is clopen and hence semi-clopen in Y .

The proof of the following theorem is obvious and hence omitted.



Theorem 11. If $f : X \rightarrow Y$ is a totally semi-open function and A is an open subset of X , then the restriction function $f|_A : A \rightarrow Y$ is also totally semi-open.

Remark 7. Let $f : X \rightarrow Y$ be a function and $X = A \cup B$ where A, B are open. If both $f|_A$ and $f|_B$ are totally semi-open, then f need not be totally semi-open since, from Theorem 1, the union of semi-clopen sets is not necessarily semi-clopen.

Theorem 12. If $f : X \rightarrow Y$ is a totally semi-open bijection and X is a T_0 space then Y is a semi- T_2 space.

Proof. Let $x, y \in Y$ and $x \neq y$ then $f^{-1}(x) \neq f^{-1}(y)$. Since X is a T_0 -space, then there exist an open set U such that $f^{-1}(x) \in U$ and $f^{-1}(y) \notin U$. Now, $f(U), Y - f(U)$ are disjoint semi-clopen sets (hence semi-open sets) and $x \in f(U), y \in Y - f(U)$. Therefore, Y is a semi- T_2 space.

Corollary 1. If $f : X \rightarrow Y$ is a totally semi-open bijection and X is a T_1 -space or a T_2 -space then Y is a semi- T_2 space.

The proof of the following theorem follows directly from the definitions of semi-connected spaces and totally semi-open maps.

Theorem 13. If $f : X \rightarrow Y$ is a totally semi-open bijection and Y is a semi-connected space, then X is connected.

Theorem 14. If $f : X \rightarrow Y$ is a totally semi-open bijection and Y is a semi-compact space, then X is compact.

Proof. Suppose that X is not compact, then there exists an open cover $\{U_i\}_{i \in I}$ of X which has no subcover. Since f is a totally semi-open bijection, then $\{f(U_i)\}_{i \in I}$ is a semi-open cover of Y and has not subcover, so Y is not semi-compact.

Conclusion

In the study, we have introduced the concept of totally semi-open functions in topological spaces and investigated several properties. Other properties of totally semi-open functions can be studied and totally semi-closed maps might also be defined and investigated.

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الفهرس

الصفحة	اسم الباحث	عنوان البحث	ر.ت
1-23	يونس يوسف أبونايجي	وضع الضاهر موضع الضمير ودلالته على المعنى عند المفسرين	1
24-51	محمد خليفة صالح خليفة محمود الجداوي	دراسة استقصائية حول مساهمة تقنية المعلومات والاتصالات في نشر ثقافة الشفافية ومحاربة الفساد	2
52-70	Ebtisam Ali Haribash	An Interactive GUESS Method for Solving Nonlinear Constrained Multi-Objective Optimization Problem	3
71-105	احمد علي الهادي الحويج احمد محمد سليم معوال	العوامل الخمسة الكبرى للشخصية وعلاقتها بالذكاء الوجداني لدى طلبة مرحلة التعليم الثانوي	4
106-135	محمد عبد السلام دخيل	في المجتمع الليبي التحضر وانعكاساته على الحياة الاجتماعية "دراسة ميدانية في مدينة الخمس"	5
136-158	سالم فرج زوبيك	الاستعارة التهكمية في القرآن الكريم	6
159-173	أسماء جمعة القلعي	دور الرياضات العملية الصوفية في تهذيب السلوك	7
174-183	S. M. Amsheri N. A. Abouthferah	On Coefficient Bounds for Certain Classes of Analytic Functions	8
184-191	N. S. Abdanabi	Fibrewise Separation axioms in Fibrewise Topological Group	9
192-211	Samah Taleb Mohammed	Investigating Writing Errors Made by Third Year Students at the Faculty of Education El-Mergib University	10
212-221	Omar Ali Aleyan Eissa Husen Muftah AL remali	SOLVE NONLINEAR HEAT EQUATION BY ADOMIAN DECOMPOSITION METHOD [ADM]	11
222-233	حسن احمد قرقد عبدالباسط محمد قريصة مصطفى الطويل	قياس تركيز بعض العناصر الثقيلة في المياه الجوفية لمدينة مصراته	12
234-244	ربيعة عبد الله الشبير عائشة أحمد عامر عبير مصطفى الهصيك	تعادم الدوال الكروية المناظرة لقيم ذاتية على سطح الكرة	13
245-255	Khadiga Ali Arwini Entisar Othman Laghah	λ -Generalizations And g - Generalizations	14



256-284	خيري عبدالسلام حسين كليب عبدالسلام بشير اشتيوي بشير ناصر مختار كصارة	Impact of Information Technology on Supply Chain management	15
285-294	Salem H. Almadhun, Salem M. Aldeep, Aimen M. Rmis, Khairia Abdulsalam Amer	Examination of 4G (LTE) Wireless Network	16
295-317	نور الدين سالم فريوع	التجربة الجمالية لدى موريس ميرلوبوتي	17
318-326	ليلى منصور عطية الغويج هدى على التقبي	Effect cinnamon plant on liver of rats treated with trichloroethylene	18
327-338	Fuzi Mohamed Fartas Naser Ramdan Amaizah Ramdan Ali Aldomani Husamaldin Abdualmawla Gahit	Qualitative Analysis of Aliphatic Organic Compounds in Atmospheric Particulates and their Possible Sources using Gas Chromatography Mass Spectrometry	19
339-346	E. G. Sabra A. H. EL- Rifae	Parametric Tension on the Differential Equation	20
347-353	Amna Mohamed Abdelgader Ahmed	Totally Semi-open Functions in Topological Spaces	21
354-376	زينب إمام أبو راس حواء بشير بالنور	كتاب الخصائص لابن جني دراسة بعض مواضع الحذف من ت"392" المسمى: باب في شجاعة العربية	22
377-386	لطيفة محمد الدالي	Least-Squares Line	23
387-397	نادية محمد الدالي ايمان احمد اخميرة	THEORETICAL RESEARCH ON AI TECHNOLOGIES FOR LEARNING SYSEM	24
398-409	Ibrahim A. Saleh Tarek M. Fayez Mustafah M. A. Ahmad	Influence of annealing and Hydrogen content on structural and optoelectronic properties of Nano-multilayers of a-Si:H/a-Ge: H used in Solar Cells	25
410-421	أسماء محمد الحبشي	The learners' preferences of oral corrective feedback techniques	26
422-459	أمينة محمد العكاشي ربيعة عثمان عبد الجليل عفاف محمد بالحاج فتحية علي جعفر	التقدير الإيجابي المسبق لفاعلية الذات ودوره في التغلب على مصادر الضغوط النفسية " دراسة تحليلية "	27



460-481	Aisha Mohammed Ageal Najat Mohammed Jaber	English Pronunciation problems Encountered by Libyan University Students at Faculty of Education, Elmergib University	28
482-499	الحسين سليم محسن	The Morphological Analysis of the Quranic Texts	29
500-507	Ghada Al-Hussayn Mohsen	Cultural Content in Foreign Language Learning and Teaching	30
508-523	HASSAN M. ALI Mostafa M Ali	The relationship between <i>slyA</i> DNA binding transcriptional activator gene and <i>Escherichia coli</i> fimbriae and related with biofilm formation	31
524-533	Musbah A. M. F. Abduljalil	Molecular fossil characteristics of crude oils from Libyan oilfields in the Zalla Trough	32
534-542	سعدون شهبوب محمد	تلوث المياه الجوفية بالنترات بمنطقة كعام، شمال غرب ليبيا	33
543-552	Naima M. Alsharif Mahmoud M. Buazzi	Analysis of Genetic Diversity of <i>Escherichia Coli</i> Isolates Using RAPD PCR Technique	34
553-560	Hisham mohammed alnaib alshareef aisha mohammed elfagaeh aisha omran alghawash abdualaziz ibrahim lawej safa albashir hussain kaka	The Emergence of Virtual Learning in Libya during Coronavirus Pandemic	35
561-574	Abdualaziz Ibrahim Lawej Rabea Mansur Milad Mohamed Abduljalil Aghnayah Hamza Aabeed Khalafllaa ³	ATTITUDES OF TEACHERS AND STUDENTS TOWARDS USING MOTHER TONGUE IN EFL CLASSROOMS IN SIRTE	36
575-592	صالحة التومي الدروقي أمال محمد سالم أبوسته	دافع الانجاز وعلاقته بالرضا الوظيفي لدى معلمي مرحلة التعليم الأساسي "ببلدية ترهونة"	37
593-609	آمنة سالم عبد القادر قدورة نجية علي جبريل انبية	الإرشاد النفسي ودوره في مواجهة بعض المشكلات الأخرية الراهنة	38
610-629	Hanan B. Abousittash, Z. M. H. Kheiralla Betiha M.A.	Effect Mesoporous silica silver nanoparticles on antibacterial agent Gram- negative <i>Pseudomonas</i> <i>aeruginosa</i> and Gram-positive <i>Staphylococcus</i> <i>aureus</i>	39
630-652	حنان عمر بشير الرمالي	برنامج التربية العملية وتطويره	40
653-672	Abdualla Mohamed Dhaw	Towards Teaching CAT tools in Libyan Universities	41



673-700	عثمان علي أميمن سليمة رمضان الكوت زهرة عثمان البرق	سبل إعادة أعمار وتأهيل سكان المدن المدمرة بالحرب ومعوقات المصالحة الوطنية في المجتمع الليبي: مقارنة نفس-اجتماعية	42
701-711	Abdulrhman Mohamed Egnebr	Comparison of Different Indicators for Groundwater Contamination by Seawater Intrusion on the Khoms city, Libya	43
712-734	Elhadi A. A. Maree Abdualah Ibrahim Sultan Khaled A. Alurffi	Hilbert Space and Applications	44
735-759	معتوق علي عون عمار محمد الزليطني عرفات المهدي قرينات	الموارد الطبيعية اللازمة لتحقيق التنمية الاقتصادية بشمال غرب ليبيا وسبل تحقيق الاستدامة	45
760-787	سهام رجب العطوي هدى المبروك موسى	الخلج وعلاقته بمفهوم الذات لدى تلاميذ الشق الثاني بمرحلة التعليم الاساسي بمنطقة جنزور	46
788-820	هنية عبدالسلام بالوص زهرة المهدي أبو راس	الصلابة النفسية ودورها الوقائي في مواجهة الضغوط النفسية	47
821-847	عبد الحميد مفتاح أبو النور محي الدين علي المبروك	ودوره في الحد من التمر التوجيه التربوي والإرشاد النفسي المدرسي	48
848	الفهرس		52