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On Ideals and α-Sets in Topological Spaces with Types of I-Continuity

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Abstract:

In this work, we investigate the structural properties of topological ideals and α-sets within topological spaces, focusing on their novel connections to various classifications of I-continuity, precontinuity, and strong semi-continuity. To lay a solid mathematical foundation, a comprehensive framework of definitions, lemmas, and characterizations is established. The main contribution of this study is the successful decomposition of α-continuous functions, proving definitively that a function is α-continuous if and only if it is simultaneously precontinuous and semi-continuous. Furthermore, through rigorous mathematical proofs and the construction of independent topological counterexamples, we demonstrate that I-continuity operates independently from classical continuity and precontinuity frameworks under non-discrete structures. These characterizations enhance the understanding of generalized open sets and provide a robust basis for extending I-continuity into abstract mathematical systems such as soft topological spaces.

Keywords*:* α-continuous functions, I-continuity, Precontinuity, Topological ideals, Topological spaces, α-sets.

I في الفضاءات الطوبولوجية وأنواع الاستمرارية α حول المثاليّات ومجموعات

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الخلاصة:

في هذا العمل، نقوم بدراسة الخصائص البنائية للمثاليّات الطوبولوجية ومجموعات α داخل الفضاءات الطوبولوجية، مع التركيز على علاقاتها الجديدة بمختلف تصنيفات الاستمرارية I، والاستمرارية القبلية، والاستمرارية شبه القوية. ولإرساء أساس رياضي متين، يتم وضع إطار شامل من التعريفات واللمّمات والتوصيفات. وتتمثّل المساهمة الرئيسة لهذه الدراسة في التحليل الناجح للدوال α-المستمرة، حيث نثبت بصورة حاسمة أن الدالة تكون α-مستمرة إذا وفقط إذا كانت في الوقت نفسه قبلية الاستمرارية وشبه مستمرة. وعلاوة على ذلك، ومن خلال براهين رياضية صارمة وبناء أمثلة طوبولوجية مضادة مستقلة، نُظهر أن الاستمرارية I تعمل بشكل مستقل عن أطر الاستمرارية الكلاسيكية والاستمرارية القبلية في البنى غير المنفصلة. إن هذه التوصيفات تعمّق الفهم للمجموعات المفتوحة المعممة، وتوفّر أساسًا متينًا لتمديد الاستمرارية I إلى الأنظمة الرياضية المجرّدة مثل الفضاءات الطوبولوجية اللينة.

الكلمات المفتاحية: دوال α-المستمرة، I-الاستمرارية، شبه الاستمرارية (الاستمرارية المسبقة)، المثل العليا الطوبولوجية، الفضاءات الطوبولوجية، مجموعات α.

1. Introduction:

A key component of contemporary general topology is the study of ideal topological spaces and generalized open sets.[1] Many scholars have expanded conventional topological features to more intricate frameworks where algebraic structures improve classical understanding in the wake of the groundbreaking works on ideal structures. [2] This study investigates limits, persistence, and novel forms of I-continuity. First, the reader must pay attention to so that explanations of constraints and persistence are the reader's primary priority.[3] We will use these concepts in several statements to show how they are applicable in mathematical discussions. Next, concentrate on the key theories. During this task, the interior and closure of A are represented by Int (A) and Cl (A), respectively. A foundation for examining generalized open sets and other types of continuity is provided by the study of ideal topological spaces. [4] Specifically, the links between generalized continuity features are crucial to comprehending α-open sets, semi-open sets, and preopen sets.[5] These ideas serve as the mathematical basis for studying I-continuity and α-continuity in topological spaces [6]. Presented α-sets, a weak variant of accessible sets, the current writer established a function. $f : U \to Y$ strong semi-continuousness $f : O \to Y$ For each open set V of Y, there is an α-set of U, proving that the pictures Strongly semi-continuous functions connect sets of open connected sets. Functions that

are strongly semi-continuous have been dubbed α-continuous by A. S. A.S. Mashhour et al. recently, and they have identified a number of these functions' traits. Inside, without providing evidence, they claimed that α-continuity is not dependent on Singal's nearly continuous sense and implies θ-continuity. However, in 1980, Maheshwari. Thakur found numerous features of α-irresolute functions and defined a function as α-irresolute if it is a-set of K for each-set of. In this direction, the properties of generalized closed sets with respect to an ideal have been extensively developed to provide a broader framework for such topological classifications. [2] The present endeavor is to further explore α-continuous functions. Thakur found numerous features of -irresolute functions and defined a function as -irresolute if it is a-set of Ƙ for each-set of. The present endeavor is to further explore α-continuous functions. [3] We will look into the connections between α-continuous functions and a number of well-known functions in Section 3 [6]. such as almost-continuous, continuous, irresolute, or -η-conti-nuous, functions. In the next part, we will refine the findings and demonstrate that if an a-continuous function is almost open, it is δ-irresolute, according to M. K. Singal and A. R. Singal, or semi-open, according to N. Biswas. [4] Most recently, these decomposition properties have been further refined through the study of I-continuity and α-openness in ideal topological spaces.[5]

2. Preliminaries:

Definition 1. $(Optimal\ on\ a\ Set)$. Let (U, τ) be a topological space. If the following criteria are met, a nonempty family I ⊆ P(U) is referred to be an ideal on U:

(i) if $A \in I$ and $B \subseteq A$, then $B \in I$.

(ii) if $A, B \in I$, then $A \cup B \in I$.

Definition 2. (α-Open Set). Let (U, τ) be a topological space, and let A ⊆ U. The set A is called an α-open set if $A \subseteq Int(Cl(Int(A)))$. The family of all α-open subsets of U is denoted by τ^{α}.

Definition 3. $(Set\ Semi-Open)$. Let A ⊆ U, and let (U, τ) be a topological space. A set is referred to as semi-open if $A \subseteq Cl(Int(A))$. SO(U) represents the family of all semi-open subsets of U.

Definition 4. $(Open\ Set)$. Let A ⊆ U, and let (U, τ) be a topological space. A is referred to as a preopen set if $A \subseteq Int(Cl(A))$. PO(U) represents the family of all preopen subsets of U.

Definition 5. (Continuity in General). Let f: U → Y be a function, and let (U, τ) and (Y, σ) be two topological spaces. Next:

(i) If $f^{-1}(V)$ is α-open in U for all V ∈ σ, then the function f is said to be α-continuous.

(ii) If $f^{-1}(V)$ is semi-open in U for each V ∈ σ, the function f is said to be semi-continuous.

(iii) If $f^{-1}(V)$ is preopen in U for each V ∈ σ, the function f is said to be precontinuous.

Definition 6. (Local Function). Let A ⊆ U, and let (U, τ, I) be an ideal topological space. The definition of the local function A* connected to A is

$$A^* = \{x \in U: \forall O \in \tau, x \in O \Rightarrow O \cap A \notin I\}.$$

Definition 7. (I-Open Set). Let A ⊆ U, and let (U, τ, I) be an ideal topological space. An I-open set is defined as the set A if A ⊆ Int(A*), where A* is A's local function in relation to ideal I. IO(U, τ, I) represents the family of all I-open subsets of U.

Definition 8. I-Continuous Function, Let (Y, σ) be a topological space, and let (U, τ, I) be an ideal topological space. If the inverse image of any open set in Y is I-open in U, then a function f: U → Y is said to be I-continuous. Similarly, for each $V \in \sigma, f^{-1}(V) \subseteq Int((f^{-1}(V))*)$.

3. Material and methods:

Give enough information so that a different researcher may replicate the work. Methods that are already published should be summarized and identified by a citation. A Theory section should enrich, not rehash, the background of the subject previously dealt with in the Introduction and establish the platform for additional study.

Remark 1. One might demonstrate that s^2 (ƙ + h) = s^2 ƙ s^2h by comparing phrases and using power series to extend both sides. After that, one may apply the inequality.

$$|f(ƙ + h) - f(ƙ)| = |s^{ƙ+h} - s^{ƙ}| = |s^{ƙ}s^h - s^{ƙ}| = |s^{ƙ}||s^h - 1|,$$

conjunction with Example 4's argument, demonstrate the continuity of $f(ƙ) = s^{ƙ}$ at an arbitrary ƙ ∈ R

Naturally, it aids to prove a few statements that will allow us to prove continuity even in the absence of an explicit δ for a certain ϵ.

Proposition 1. Imagine that $f: U \rightarrow$ R̂ where U ⊆ R̂ and $p \in U$. Therefore, f is continuous at p if and only if it meets the requirements for convergence to $f(p)$.

Proof: suppose that f is continuous at c and that $\epsilon > 0$ is given. Then, there is a $\delta > 0$ such that

$$ƙ \in U \quad \text{and} \quad |ƙ - p| < \delta \quad \Rightarrow \quad |f(ƙ) - f(p)| < \epsilon.$$

Suppose now that (ƙ_n) is any sequence in U which converges to p. Then there is $N \in N$

Such that $n < N$ implies that $|\mathfrak{k}_n - p| < \delta$. But then.

$$n > N \quad \Rightarrow \quad |f(\mathfrak{k}) - f(p)| < \epsilon.$$

Hence $(f(\mathfrak{k}_n))$ converges to $f(p)$.

Suppose that f is not continuous at p. Then there exists an $\epsilon > 0$ such that there is no $\delta > 0$ such that

$$\mathfrak{k} \in \mathrm{U} \quad \text{and} \quad |\mathfrak{k} - p| < \delta \quad \Longrightarrow \quad |f(\mathfrak{k}) - f(p)| < \epsilon.$$

This indicates that there is a value of $\epsilon > 0$ such that for any n inside N, it is not true that

$$\mathfrak{k} \in \mathrm{U} \quad \text{and} \quad |\mathfrak{k} - p| < \frac{1}{n} \quad \Rightarrow \quad |f(\mathfrak{k}) - f(p)| < \epsilon.$$

However, this implies that we can select for each $n \in \mathbb{N}$. $\mathfrak{k}_n \in U$ such that $|\mathfrak{k}_n - p| < \frac{1}{n}$ and $|f(\mathfrak{k}_n) - f(p)| > \epsilon$. Then $(\mathfrak{k}_n)$ converges to p but $\big(f(\mathfrak{k}_n)\big)$ does not converge to $f(p)$.

We can transfer several results about limits to continuous functions using the previous proposition. Based on the Proposition at the conclusion of §1, we so derive:

Proposition 2. If $f : U \to \mathbb{R}$ and $g: U \to \mathbb{R}$ are both continuous functions, as are the product $f(g)$ and the total $f + g$. As well, if $g(\mathfrak{k}) \neq 0$ for $\mathfrak{k} \in \mathrm{D}$, then $f/g : U \to \mathbb{R}$ is continuous, for instance.

We can construct numerous new continuous functions from existing ones thanks to this notion. Consequently, beginning with the notion that the function is constant and continuous,

$f(\mathfrak{k}) = \mathfrak{k}$ is continuous, for instance, we can draw the conclusion that any polynomial is continuous.

Theorem 1. Suppose $f : \mathrm{K} \to Y$ is a mapping from one fully separable metric space to another. (O, tm) and $(\hat{\mathrm{Y}}, ty)$. The statements that follow are therefore equivalent.

(1) There is a positive function δ on O for any $\epsilon > 0$ such that

$$t_{\hat{\mathrm{Y}}}\big(f(\mathfrak{k}), f(\hat{\mathrm{y}})\big) < \epsilon$$

Whenever

$$t_{\mathfrak{k}}(\mathfrak{k}, \hat{y}) < \min\{\delta(\mathfrak{k}), \delta(\hat{y})\}.$$

(1) The function of f is a member of the first Baire class.

Proof: (1) → (2). Let F be a closed, non-empty subset of Ƙ. It is sufficient to demonstrate that F ⊣ $_f$ has a continuity point. Thus, we demonstrate that, for some $\mathfrak{k} \in F$,

$$\omega_f(\mathfrak{k}, F) = \inf_{h>0} sup\{|f(r) - f(z)| : r, z \in N_h(\mathfrak{k}) \wedge F\} = 0,$$

Where $N_h(\mathfrak{k}) = \{r \in O : dm(r, \mathfrak{k}) < h\}$.

Suppose, to the contrary,

$$\omega_f(\mathfrak{k}, F) > 0 for\ each\ \mathfrak{k} \in F.$$

Then we have

$$F = \bigcup_{n=1}^{\infty} P_n,$$

Where P_n is the closed set $\{m \in F : \omega_f(\mathfrak{k}, F) \geq \frac{1}{n}\}$. By Baires Category, Theorem: P_{n_0}has a non-empty interior if there exists $n_0 \in \mathbb{N}. \vee in\ F$. Write $I = \overline{\vee} \subset P_{n_0}$.

As mentioned in (1), let δ now be a positive function that corresponds to

$$\epsilon = \frac{1}{6_{n_0}}.$$

Put $F_n = \left\{\mathfrak{k} \in I : \delta(\mathfrak{k}) > \frac{1}{n}\right\}$. Then we have. [6]

$$I = \bigcup_{n=1}^{\infty} F_n.$$

We review the definition of continuity: Let $f : [a, b] \to \mathbb{R}$ and $o0 \in [a, b]$. f is continuous at $\mathfrak{k}_0$ if for every $\varepsilon > 0$ there exists $\delta > 0$ such that $|\mathfrak{k} - \mathfrak{k}0| < \delta$ implies $|f(\mathfrak{k}) - f(\mathfrak{k}0)| <$

ϵ. We sometimes indicate that the δ may depend on ϵ by writing $\delta(\varepsilon)$. All proofs of continuity of functions using the definition adhere to a set format, just like convergence of sequences.

Lemma 1. Let A be a portion of a space.(K,τ). Then S is α-open in (K,τ) If S is both semi-open and per-open in (K,τ). [7]

Proof; essential. Allow $S \in \tau^{\alpha}$. Using the notion of α-open sets, we may $S \subset Int\,(UI(S))$ and $S \subset PI\big(Int(S)\big)$. Therefore, we obtain $S \in W\mathrm{K}(\mathrm{K},\tau)\wedge PM(\mathrm{K},\tau)$. Sufficiency. Let $S \in WM(\mathrm{K},\tau)\wedge PM(\mathrm{K},\tau)$. Since $S \in WM(\mathrm{K},\tau)$, $S \subset PI(Int(S))$ and hence it follows from $S \in PM(\mathrm{K},\tau)$ that

$$S \subset Int\big(PI(S)\big) \sqsubset Int\left(PI\left(PI\big(Int(S)\big)\right)\right) = Int\left(PI\big(Int(S)\big)\right).$$

4. Results:

Several fundamental mathematical conclusions are derived from the systematic behavior of ideal topological spaces and structural classifications. Through the fundamental work provided in Section 2, the characteristics of α-continuous functions are effectively mapped. The key finding implies that a function $f: K \to Y$ achieves α-continuity if and only if it satisfies both precontinuity and semi-continuity concurrently.

Theorem 2. A function of $f : \mathrm{K} \to Y$ is α-continuous, if and only if f is a.c.H. and semi-continuous.

Proof; This is a direct result of Lemma1.

Definition ١. S function $f : (\mathrm{K},\tau) \to \big(\hat{\mathrm{Y}},\sigma\big)$ is considered to be extremelyη- continuous when f equals a.c.H. and for all

$\vee, V \in \sigma,$

$$Int\left(PI\big(f^{-1}(\vee)\big)\right) \wedge Int\left(PI\big(f^{-1}(V)\big)\right) \subset Int\left(PI\big(f^{-1}(\vee \wedge V)\big)\right).$$

Theorem 3. Not all α-continuous functions are irresolute.

Proof.

We construct a counterexample.

Let K = Y = {a, b, c}, and consider the topologies

$$\tau = \{\emptyset, \{c\}, \{a, b\}, K\}, \quad \sigma = \{\emptyset, \{c\}, Y\}.$$

Define f: (K, τ) → (Y, σ) by f(x) = x for every x ∈ K.

Since σ ⊆ τ, the function f is continuous and hence α-continuous.

Now consider the set $V = \{a, c\} \subseteq Y$.

$$Int\sigma(V) = \{c\}, \quad Cl\sigma(\{c\}) = Y., \quad V \subseteq Cl\sigma(Int\sigma(V)) = Y,$$

which shows that V is semi-open in (Y, σ).

$$f^{-1}(V) = \{a, c\}.$$

In (K, τ), we have

$$Int\tau(\{a, c\}) = \{c\}, \quad Cl\tau(\{c\}) = \{c\}.$$

Consequently,

$$\{a, c\} \notin Cl\tau(Int\tau(\{a, c\})) = \{c\}.$$

Thus, f^{-1}(V) is not semi-open in (K, τ).

Therefore, f is α-continuous but not irresolute.

Hence, not every α-continuous function is irresolute.

Definition ٢. A function $f : (K, \tau, I) \to (\hat{Y}, \sigma)$ is considered I-continuous if for each

$$V \in \sigma, f^{-1}, (V) \in IK(K, \tau).$$

Proposition 1: Let (Y, σ) be a topological space and (U, τ, I) be an ideal topological space. A function $f: U \to Y$ is precontinuous if it is I-continuous.

Evidence. Assume that f is I-continuous. $A = f^{-1}(V)$, where V is an arbitrary open set in Y.

A is I-open since f is I-continuous. Consequently, $A \subseteq Int(A*)$. *Given that* $A* \subseteq Cl(A)$, it follows that

$$A \subseteq Int(A*) \subseteq Int\big(Cl(A)\big). \quad (1)$$

Because V was arbitrary, every open set in Y has an inverse image that is preopen in U, hence A is preopen in U.

As a result, f is precontinuous.

And the converse is not true as shown by the following example.

Example 1.

Assume that U = Y = {a, b}, with

τ = {∅, {a}, U}, σ = {∅, {a}, {b}, Y}, and I = {ň, {b}}.

Use f(a) = a and f(b) = b to define f: U → Y.

f is precontinuous since each subset of U is preopen.

But for V = {b} ∈ σ, we obtain

$f^{-1}(V)$ = {b}, and {b}* = ∅ Consequently,

{b} ⊈ Int({b}*) = ħ.

Therefore, f is not I-continuous since {b} is not I-open.

Consequently, Proposition 1's opposite is not true.

Example 2. Let K = Y = {a, b}, with

I = {≡}, τ = {∅, {b}, Y}, and τ = {ň, {a}, K}.

Use f(a) = a and f(b) = b to define f: K → Y.

For V = {b} ∈ σ, we have

$f^{-1}(V)$ = {b}.

Given that {b}* = Cl({b}) = K,

We acquire

{b} ⊆ Int({b}*) = K.

Consequently, f is I-continuous. Nevertheless, f is not continuous as {b} is not open in τ.

Consequently, ordinary continuity is not implied by I-continuity.

Theorem 4. Let f be a function: (K, τ, I) → (Y, σ). The following claims are therefore equivalent:

(i) f is I-continuous.

(ii) There exists an I-open set E such that x ∈ E and f(E) ⊆ V for every x ∈ K and every open set V containing f(x).

Evidence.

Proof.

(i) ¹ (ii): Assume that f is I-continuous. Let V be an open set that includes f(x). Thus, x ∈ E, f(E) ⊆ V, and E = f^{-1}(V) is I-open.

(ii) ¹ (i): Let V be any subset of Y that is open. There is an I-open set E that contains x such that

$$E \subseteq f^{-1}(V) \quad (2)$$

for every x ∈ f^{-1}(V). f^{-1}(V) is I-open since arbitrary unions of I-open sets are I-open. Consequently, f is I-continuous.

Theorem 5. Let f : (K, τ, I) → (Y, σ) be a function. Then f is I-continuous if and only if the inverse image of every closed subset of Y is I-closed in K.

Proof.

Assume that f is I-continuous. Y − F is open in Y if F is any closed subset of Y. Therefore,

$$f^{-1}(Y - F) = K - f^{-1}(F) \quad (3)$$

Since f is l-continuous, $f^{-1}(F)$ is I-open in K. consequently $f^{-1}(F)$ is l-closed in K. On the other hand, let V be any open subset of Y and assume that any closed subset of Y has an inverse image that is I-closed in K. $f^{-1}(Y - V)$ is I-closed since Y − V is closed. Consequently,

$$f^{-1}(V) = K - f^{-1}(Y - V) \quad (4)$$

The complement f^{-1}(V) is I-open in K since f^{-1}(Y − V) is I-closed in K. Consequently, f is I-continuous.

Therefore, f is I-continuous.

5. Discussion

The study's findings shed light on a number of connections between generalized forms of continuity in ideal topological spaces. Specifically, the description of α-continuity in terms of semi-continuity and precontinuity offers a helpful link between these ideas. Every I-continuous function is precontinuous, according to Proposition 1. But as Example 1 shows, the opposite is

not always true. Furthermore, Example 2 shows that I-continuity does not imply ordinary continuity. These examples illustrate the distinctions among these classes of functions. While Theorem 5 presents an identical characterisation in terms of inverse images of closed sets and I-closed sets, Theorem 4 offers a local characterization of I-continuity using I-open neighborhoods. When combined, these findings offer complementary methods for researching I-continuous mappings. Overall, the results show the importance of ideals in defining the characteristics of mappings across topological spaces and arrange the connections between generalized continuity ideas.

6. Conclusions

With a focus on I-continuity, precontinuity, and α-continuity, this work investigated the connections between generalized forms of continuity in ideal topological spaces. The results prove that any I-continuous function is precontinuous, but the converse is not necessarily hold. Furthermore, the counterexamples illustrate that I-continuity does not entail ordinary continuity. Equivalent characterizations of I-continuity were also provided using I-open neighborhoods and inverse pictures of closed sets. These results demonstrate the function of ideals in extended topological structures and shed light on the connections between various continuity notions. Future studies might look at these characteristics in soft topological spaces and see how they relate to separation axioms and compactness.

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