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S_g^*-Compact and S_g^*-Connected Spaces

S. Pious Missier[1], J. Arul Jesti[2]

[1]Associate Professor, PG and Research Department of Mathematics, V.O. Chidambaram College,Thoothukudi, India

[2]Research Scholar, PG and Research Department of Mathematics,V.O. Chidambaram College, Thoothukudi, India

ABSTRACT: *The determination of this paper is to introduce two new spaces , namely S_g^*-compact and S_g^*-connected spaces. Additionally some properties of these spaces are investigated.*

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I. Introduction

The notions of compactness and connectedness are useful and fundamental notions of not only general topology but also of other advanced branches of mathematics. Many researchers have investigated the basic properties of compactness and connectedness. The productivity and fruitfulness of these notions of compactness and connectedness motivated mathematicians to generalize these notions. In the course of these attempts many stronger and weaker forms of compactness and connectedness have been introduced and investigated. Recently, S.Pious Missier and J.Arul Jesti have introduced the concept of S_g^*-open sets[3], and introduced some more functions in S_g^*-open sets. The aim of this paper is to introduce the concept of S_g^*-compactness and S_g^*-connectedness and to investigate some of its characterizations.

II. Preliminaries

Throughout this paper (X, τ), (Y, σ) and (Z, η) (or X,Y and Z) represent non-empty topological spaces on which no separation axioms are assumed unless explicitly stated. For a subset A of a space (X, τ), S_g^*Cl(A) and S_g^*Int(A) denote the S_g^*-closure and the S_g^*-interior of A respectively.

Definition 2.1: A subset A of a topological space (X,τ) is called a ***S_g^*-open set*** [3] if there is an open set U in X such that U⊆A⊆ sCl^*(U). The collection of all S_g^*-open sets in (X, τ) is denoted by S_g^*O(X,τ).

Definition 2.2: A subset A of a topological space (X,τ) is called a ***S_g^*-closed set***[3] if X\A is S_g^*-open. The collection of all S_g^*-closed sets in (X, τ) is denoted by S_g^*C(X,τ).

Theorem 2.3 [3]:(i)Every open set is S_g^*-open

(ii)Every closed set is S_g^*-closed set

(iii)Every S_g^*-open set is semi-open

Definition 2.4: A topological space (X,τ) is said to be ***S_g^*-$T_{1/2}$space*** [4] if every S_g^*-open set of X is open in X.

Definition 2.5: A topological space (X,τ) is said to be ***S_g^*-locally indiscrete space*** [5] if every S_g^*-open set of X is closed in X.

Definition 2.6: A mapping $f: X \to Y$ is said to be ***S_g^*-continuous*** [4] if the inverse image of every open set in Y is S_g^*-open in X.

Defintion 2.7: A mapping $f: X \to Y$ is said to be ***S_g^*-irresolute***[4] if the inverse image of every S_g^*-open set in Y is S_g^*-open in X.

Definition 2.8: A function $f: X \to Y$ is said to be ***contra- S_g^*-continuous*** [5] if the inverse image of every open set in Y is S_g^*-closed in X.

Definition 2.9: A mapping $f: X \to Y$ is said to be ***strongly S_g^*-continuous*** [4]if the inverse image of every S_g^*-open set in Y is open in X.

Definition 2.10: A mapping $f: X \to Y$ is said to be ***perfectly S_g^*-continuous*** [4]if the inverse image of every S_g^*-open set in Y is open and closed in X.

Definition 2.11: A function $f: (X,\tau) \to (Y,\sigma)$ is said to be ***slightly S_g^*-continuous***[7] if the inverse image of every clopen set in Y is S_g^*-open in X.

Definition 2.12: A mapping $f:(X,\tau)\to(Y,\sigma)$ is said to be ***totally S_g^*-continuous***[7] if the inverse image of every open set in (Y,σ) is S_g^*-clopen in (X,τ).
Definition 2.13: A topological space (X,τ) is said to be **compact**[8](resp. semi-compact[2]) if every open(resp. semi-open) cover of (X,τ) has a finite subcover.
Definition 2.14: A topological space (X,τ) is said to be ***connected***[8](resp. semi-connected[1]) if X cannot be expressed as the union of two non-empty open (resp. semi-open) sets in X.

III. S_g^*-Compactness

Definition 3.1: A collection $\{A_i: i\in\Lambda\}$ of S_g^*-open sets in a topological space (X,τ) is called a **S_g^*-open cover** of a subset A in (X,τ) if $A\subset\bigcup_{i\in\Lambda}A_{i.}$
Definition 3.2: A topological space (X,τ) is called **S_g^*-compact** if every S_g^*-open cover of (X,τ) has a finite subcover.
Definition 3.3: A subset A of a topological space (X,τ) is called **S_g^*-compact relative to X** if for every collection $\{U_i: i\in\Lambda\}$ of a S_g^*-open subsets of X such that $A\subset\cup\{U_i: i\in\Lambda\}$, there exists a finite subset Λ_0 of Λ such that $A\subset\cup\{U_i: i\in\Lambda_0\}$.
Definition 3.4: A subset B of a topological space X is said to be **S_g^*-compact** if B is S_g^*-compact as a subspace of X.
Theorem 3.5: (i) Every S_g^*-compact space is compact.
(ii) Every semi-compact space is S_g^*-compact.
Proof: (i) and (ii) follows from definition 2.13 and from definition 3.2.
Theorem 3.6: Every S_g^*-closed subset of a S_g^*- compact space (X,τ) is S_g^*-compact relative to (X,τ).
Proof: Let A be a S_g^*-closed subset of a S_g^*- compact space (X,τ). Then A^c is S_g^*-open in (X,τ). Let $\{U_i: i\in\Lambda\}$ be a cover of A by S_g^*-open subsets of X such that $A\subset\cup\{U_i: i\in\Lambda\}$. So $A^c\cup\{U_i: i\in\Lambda\}=X$. Since (X,τ) is S_g^*-there exists a finite subset Λ_0 of Λ such that $A\subset A^c\cup\{U_i: i\in\Lambda\}$=X. Then $A\subset\cup\{U_i: i\in\Lambda\}$ and hence A is S_g^*-compact relative to X.
Theorem 3.7: Let $f:(X,\tau)\to(Y,\sigma)$ be a surjective S_g^*-continuous map. If (X,τ) is S_g^*-compact, then (Y,σ) is compact.
Proof: Let $\{A_i: i\in\Lambda\}$ be an open cover of Y. Since f is S_g^*-continuous, $\{f^{-1}(A_i): i\epsilon\Lambda\}$ is a S_g^*-open cover of X. Also, since X is S_g^*-compact, it has a finite subcover, say $\{f^{-1}(A_1), f^{-1}(A_2), \dots f^{-1}(A_n)\}$. The surjectiveness of f implies $\{A_1, A_2, \dots, A_n\}$ is a finite subcover of Y and hence Y is compact.
Theorem 3.8: Let $f:(X,\tau)\to(Y,\sigma)$ be a S_g^*-irresolute surjective map. If (X,τ) is S_g^*-compact, then (Y,σ) is S_g^*-compact.
Proof: Let $\{A_i: i\in\Lambda\}$ be a S_g^*-open cover of Y. Since f is S_g^*-irresolute, $\{f^{-1}(A_i): i\epsilon\Lambda\}$ is a S_g^*-open cover of X. Also, since X is S_g^*-compact, it has a finite subcover, say $\{f^{-1}(A_1), f^{-1}(A_2), \dots f^{-1}(A_n)\}$. Now f is onto implies $\{A_1, A_2, \dots, A_n\}$ is a finite subcover of Y and hence Y is S_g^*-compact.
Theorem 3.9: If a map $f:(X,\tau)\to(Y,\sigma)$ is S_g^*-irresolute and a subset B of (X,τ) is S_g^*-compact relative to X, then the image $f(B)$ is S_g^*-compact relative to Y.
Proof: Let $\{A_i: i\in\Lambda\}$ be any collection of S_g^*-open subsets of Y such that $f(B)\subset\cup\{A_i: i\in\Lambda\}$. Then $B\subset\cup\{f^{-1}(A_i): i\in\Lambda\}$ holds. Since by hypothesis B is S_g^*-compact relative to X, there exists a finite subset Λ_0 of Λ such that $B\subset\cup\{f^{-1}(A_i): i\in\Lambda_0\}$. Therefore we have $f(B)\subset\cup\{A_i: i\in\Lambda_0\}$ which shows that $f(B)$ is S_g^*-compact relative to Y.
Theorem 3.10: If a surjective map $f:(X,\tau)\to(Y,\sigma)$ is strongly S_g^*-continuous and (X,τ) is a compact space, then (Y,σ) is S_g^*-compact.
Proof: Let $\{A_i: i\in\Lambda\}$ be a S_g^*-open cover of Y. Since f is strongly S_g^*-continuous, $\{f^{-1}(A_i): i\epsilon\Lambda\}$ is a open cover of X. Thus the open cover has a finite subcover, say $\{f^{-1}(A_1), f^{-1}(A_2), \dots f^{-1}(A_n)\}$ as X is compact. The surjectiveness of f implies $\{A_1, A_2, \dots, A_n\}$ is a finite subcover of Y and hence Y is S_g^*-compact.
Corollary 3.11: If a surjective map $f:(X,\tau)\to(Y,\sigma)$ is perfectly S_g^*-continuous and (X,τ) is a compact space, then (Y,σ) is S_g^*-compact.
Proof: Since every perfectly S_g^*-continuous function is strongly S_g^*-continuous, the result follows from theorem 3.10.

IV. S_g^*-Connectedness

Definition 4.1: A topological space (X,τ) is called a S_g^*-connected space if X cannot be written as a disjoint union of two nonempty S_g^*-open sets.

Example 4.2: Let $X=\{a,b,c\}$ with $\tau=\{\emptyset,X,\{a\}\}$. Then $S_g^*O(X,\tau)=\{\emptyset,X,\{a\},\{a,b\},\{a,c\}\}$ and it is S_g^*-connected.

Theorem 4.3: Every S_g^*-connected space is connected.

Proof: Let (X,τ) be a S_g^*-connected space. Suppose that (X,τ) is not connected, then $X=A\cup B$ where A and B are disjoint nonempty open sets in (X,τ). Since every open set is a S_g^*-open set, (X,τ) is not a S_g^*-connected space and so (X,τ) is connected.

Remark 4.4: The converse of theorem 4.3 is not true as can be seen from the following example.

Example 4.5: Let $X=\{a,b,c,d\}$ and $\tau=\{X,\phi,\{a\},\{b,c\},\{a,b,c\}\}$. Clearly (X,τ) is connected. The S_g^*-open sets of X are $\{X,\phi,\{a\},\{b,c\},\{a,b,c\},\{b,c,d\}\}$. Here (X,τ) is not S_g^*-connected because $X=\{a\}\cup\{b,c,d\}$ where $\{a\}$ and $\{b,c,d\}$ are non-empty S_g^*-open sets.

Theorem 4.6: A contra S_g^*-continuous image of a S_g^*-connected space is connected.

Proof: Let $f:(X,\tau)\to(Y,\sigma)$ be a contra S_g^*-continuous map of a S_g^*-connected space (X,τ) onto a topological space (Y,σ). Suppose (Y,σ) is not connected. Let A and B form a disconnection of Y. Then A and B are clopen and $Y=A\cup B$ where $A\cap B=\emptyset$. Since f is contra S_g^*-continuous, $X=f^{-1}(Y)=f^{-1}(A\cup B)=f^{-1}(A)\cup f^{-1}(B)$. Thus X is the union of disjoint nonempty S_g^*-open sets in (X,τ). Also $f^{-1}(A)\cap f^{-1}(B)=\emptyset$. Hence X is not S_g^*-connected which is a contradiction. Therefore Y is connected.

Theorem 4.7: For a subset A of a topological space (X,τ), the following are equivalent.

(i) (X,τ) is S_g^*-connected.

(ii) The only subsets of (X,τ) which are both S_g^*-open and S_g^*-closed are the empty set $\emptyset$ and X.

(iii) Each S_g^*-continuous map of (X,τ) into a discrete space (Y,σ) with atleast two points is a constant map.

Proof: (i)⟹(ii): Suppose that $S\subset X$ is a proper subset, which is both S_g^*-open and S_g^*-closed. Then S^c is also S_g^*-open and S_g^*-closed. Therefore $X=S\cup S^c$ is a disjoint union of two nonempty S_g^*-open sets which contradicts the fact that X is S_g^*-connected. Hence $S=\emptyset$ or $S=X$.

(ii)⟹(i): Suppose that $X=A\cup B$ where A and B are disjoint nonempty S_g^*-open sets in (X,τ). Since $A=B^c$, A is S_g^*-closed. But by assumption $A=\emptyset$, which is a contradiction. Hence (i) holds.

(ii)⟹ (iii): Let $f:(X,\tau)\to(Y,\sigma)$ be a S_g^*-continuous map where (Y,σ) is a discrete space with atleast two points. Then $f^{-1}(\{y\})$ is S_g^*-closed and S_g^*-open for each $y\in Y$ and $X=\cup\{f^{-1}(\{y\}):y\in Y\}$. By assumption, $f^{-1}(\{y\})=\emptyset$ or $f^{-1}(\{y\})=X$. If $f^{-1}(\{y\})=\emptyset$ for all $y\in Y$, then f will not be a map. Hence, there exists only one point say $y_1\in Y$ such that $f^{-1}(\{y\})\neq\emptyset$ and $f^{-1}(\{y_1\})=X$ which shows that f is a constant map.

(iii)⟹(ii):Let U be both S_g^*-open and S_g^*-closed in (X,τ). Suppose that $U\neq\emptyset$. Define $f:(X,\tau)\to(Y,\sigma)$ by $f(U)=\{y_1\}$ and $f(U^c)=\{y_2\}$ for some distinct points y_1 and y_2 in (Y,σ), then f is S_g^*-continuous. By assumption, f is a constant map. Therefore $y_1=y_2$ and so $U=X$.

Theorem 4.8: Let (X,τ) be S_g^*-connected. Then each contra S_g^*-continuous map of (X,τ) into a discrete space (Y,σ) with atleast two points is a constant map.

Proof: Let $f:(X,\tau)\to(Y,\sigma)$ be a contra S_g^*-continuous map where (Y,σ) is a discrete space with atleast two points. Then X is covered by S_g^*-open and S_g^*-closed covering $\{f^{-1}(\{y\}):y\in Y\}$. Since (X,τ) is S_g^*-connected, the only subsets of (X,τ) which are both S_g^*-open and S_g^*-closed are the empty set $\emptyset$ and X. Therefore $f^{-1}(\{y\})=\emptyset$ or $f^{-1}(\{y\})=X$. If $f^{-1}(\{y\})=\emptyset$ for all $y\in Y$, then f fails to be a map. Then, there exists only one point say $y\in Y$ such that $f^{-1}(\{y\})\neq\emptyset$ and $f^{-1}(\{y\})=X$ which shows that f is a constant map.

Theorem 4.9: If $f:(X,\tau)\to(Y,\sigma)$ is a S_g^*-continuous surjection and (X,τ) is S_g^*-connected, then (Y,σ) is connected.

Proof: Suppose (Y,σ) is not connected. Then $Y=A\cup B$ where A and B are disjoint nonempty open subsets of (Y,σ). Since f is S_g^*-continuous and onto, $X=f^{-1}(A)\cup f^{-1}(B)$ where $f^{-1}(A)$ and $f^{-1}(B)$ are disjoint nonempty S_g^*-open sets in (X,τ). This contradicts the fact that (X,τ) is S_g^*-connected and hence (Y,σ) is connected.

Theorem 4.10: If a surjective map $f:(X,\tau)\to(Y,\sigma)$ is S_g^*-irresolute and (X,τ) is S_g^*-connected, then (Y,σ) is S_g^*-connected.

Proof: If possible assume that Y is not S_g^*-connected. Then $Y=A\cup B$ where A and B are nonempty disjoint S_g^*-open sets of (Y,σ). Since f is S_g^*-irresolute, $f^{-1}(A)$ and $f^{-1}(B)$ are S_g^*-open sets in (X,τ). Since f is onto, $f^{-1}(A)$ and $f^{-1}(B)$ are nonempty. Now $X=f^{-1}(Y)=f^{-1}(A\cup B)=f^{-1}(A)\cup f^{-1}(B)$. Thus X is the union of disjoint nonempty S_g^*-open sets in (X,τ). This contradicts the fact that (X,τ) is S_g^*-connected and hence (Y,σ) is S_g^*-connected.

Theorem 4.11: If a surjective map $f:(X,\tau)\to(Y,\sigma)$ is strongly S_g^*-continuous and (X,τ) is a connected space, then (Y,σ) is S_g^*-connected.

Proof: Similar to the proof of the above theorem.

Theorem 4.12: Let $f:(X,\tau)\to(Y,\sigma)$ be a perfectly S_g^*-continuous map, (X,τ) a connected space, then (Y,σ) has an indiscrete topology.

Proof: Suppose that there exists a proper open set U of (Y,σ), then U is S_g^*-open in (Y,σ). Since f is perfectly S_g^*-continuous, $f^{-1}(U)$ is a proper open and closed subset of (X,τ). This implies (X,τ) is not connected which is a contradiction. Therefore (Y,σ) has an indiscrete topology.

Theorem 4.13: Let $f:(X,\tau)\to(Y,\sigma)$ be a totally S_g^*-continuous map, from a S_g^*-connected space (X,τ) onto any space (Y,σ), then (Y,σ) is an indiscrete space.

Proof: Suppose (Y,σ) is not indiscrete. Let A be a proper nonempty open subset of (Y,σ). Then $f^{-1}(A)$ is a proper nonempty S_g^*-open and S_g^*-closed subset of (X,τ), which is a contradiction to the fact that (X,τ) is S_g^*-connected. Then (Y,σ) must be indiscrete.

Theorem 4.14: If f is a contra S_g^*-continuous map from a S_g^*-connected space (X,τ) onto any space (Y,σ), then (Y,σ) is not a discrete space.

Proof: Suppose (Y,σ) is discrete. Let A be any proper nonempty open and closed subset of (Y,σ). Then $f^{-1}(A)$ is a proper nonempty S_g^*-open and S_g^*-closed subset of (X,τ), which is a contradiction to the fact that (X,τ) is S_g^*-connected. Hence (Y,σ) is not a discrete space.

Theorem 4.15: Suppose that X is a S_g^*-$T_{1/2}$ space then X is connected if and only if it is S_g^*-connected.

Proof: Suppose that X is connected. Then X cannot be written as a union of two non-empty disjoint proper subsets of X. Suppose X is not S_g^*-connected. Let A and B be any two S_g^*-open sets subsets of X such that $X=A\cup B$, where $A\cap B=\emptyset$. Since X is a S_g^*-$T_{1/2}$ space, every S_g^*-open sets are open. Hence A and B are open sets which contradicts the fact that X is not connected. Then X is S_g^*-connected. The converse part follows from the theorem that every S_g^*-connected space is connected.

Theorem 4.16: If $f:(X,\tau)\to(Y,\sigma)$ is slightly S_g^*-continuous surjective function and X is S_g^*-connected then Y is connected.

Proof: Suppose Y is not connected. Then there exists non-empty disjoint open set A and B such that Y=$A\cup B$. Therefore A and B are clopen sets in Y. Since f is slightly S_g^*-continuous and surjective, $f^{-1}(A)$ and $f^{-1}(B)$are non-empty disjoint S_g^*-opensets in X. Also $f^{-1}(Y)=X=f^{-1}(B)$. This shows that X is not S_g^*-connected, a contradiction. Hence Y is connected.

Theorem 4.17: If f is slightly S_g^*-continuous function from a connected space (X,τ) onto a space (Y,σ) then Y is not a discrete space.

Proof: Suppose that Y is a discrete space. Let A be a proper nonempty open subset of Y. Then $f^{-1}(A)$ is nonempty S_g^*-clopen subset of X, which is a contradiction to the fact that X is S_g^*-connected. Hence Y is not a discrete space.

Theorem 4.18: A space X is S_g^*-connected if every slightly S_g^*-continuous from X into any T_o space Y is constant.

Proof: Let every slightly S_g^*-continuous function from a space X into Y be constant. If X is not S_g^*-connected then there exists a proper nonempty S_g^*-clopen subset A of X . Let (Y,σ) be such that Y=$\{a,b\}\sigma=\{\emptyset,y,\{a\},\{b\}\}$ be a topology. Let $f:X\to Y$ be any function such that$f(A)=\{a\}$ and $f(X-A)=\{b\}$. Then f is a non-constant and slightly S_g^*-continuous function such that Y is T_o which is a contradiction. Hence Y is S_g^*-connected.

Theorem 4.19: A space (X,τ) is S_g^*-connected if and only if every totally S_g^*-continuous function from a space (X,τ) into any T_0 space (Y,σ) is a constant map.

Proof: Suppose $f:(X,\tau)\to(Y,\sigma)$ is a totally S_g^* -continuous function where (Y,σ) is a T_0-space. Suppose that f is not a constant map, then we can select two points x and y such that $f(x)\neq f(y)$. Since (Y,σ) is a T_0-spaceand $f(x)$ and $f(y)$ are distinct points of Y,there exists an open set G in (Y,σ) containing $f(x)$ but not $f(y)$. Since f is a totally S_g^*-continuous function, $f^{-1}(G)$ is a S_g^*-clopen subset of (x,τ). Clearly $x\in f^{-1}(G)$ and $y\notin f^{-1}(G)$. Now $X=f^{-1}(G)\cup\left(f^{-1}(G)\right)^c$ which is the union of non-empty S_g^*-open subsets of X. Thus X is not S_g^*-connected space,which contradicts the fact that X is S_g^*-connected. Hence f is a constant map.

Conversely, suppose (X,τ) is not a S_g^*-connected space there exists a proper non-empty S_g^*-clopen subset A of X. Let $Y=\{a,b\}$ and $\tau=\{Y,\emptyset,\{a\},\{b\}\}$ be a topology for Y. Let $f:(X,\tau)\to(Y,\sigma)$ be a function such that $f(A)=\{a\}$ and $f(Y\backslash A)=\{b\}$. Then f is non-constant and totally S_g^*-continuous such that Y is T_0, which is a contradiction. Hence X must be S_g^*-connected.

Theorem 4.20: Let $f:(X,\tau)\to(Y,\sigma)$ be a totally S_g^*-continuous function & Y is a T_1-space. If A is a non-empty S_g^*-connected subset of X. Then $f(A)$is singleton.

Proof: Suppose that $f(A)$is not a singleton . Let $f(x_1)=y_1\in A$ and $f(x_2)=y_2\in A$. Since $y_1,y_2\in Y$ and Y is a T_1-space, there exists an open set G in (Y,σ) containing y,but not y_2. Since f is totally S_g^*-continuous, $f^{-1}(G)$ is S_g^*-continuous, $f^{-1}(G)$ is S_g^*-clopen set containing x_1 but not x_2. Now $X=f^{-1}(G)\cup\left(f^{-1}(G)\right)^c$. Thus we have expressed X as a union of two non-empty S_g^*-open sets. This contradicts the fact that X is S_g^*-connected. Therefore $f(A)$ is singleton.

Theorem 4.21: Every semi-connected space is S_g^*-connected.

Proof: Let (X,τ) be a semi-connected space. Suppose that (X,τ) is not S_g^*-connected, then $X=A\cup B$ where A and B are disjoint nonempty S_g^*-open sets in (X,τ). Since every S_g^*-open set is semi-open, (X,τ) is not a semi-connected space which is a contradiction and hence (X,τ) is S_g^*-connected.

Remark 4.22: The converse of theorem 4.21 is not true as can be seen from the following example.

Example 4.23: Let $X=\{a,b,c,d\}$ and $\tau=\{X,\phi,\{a\},\{b\},\{c\},\{a,b\},\{b,c\},\{a,c\},\{a,b,c\}\}$. Then $SO(X,\tau)=$
$\{X,\phi,\{a\},\{b\},\{c\},\{a,b\},\{b,c\},\{a,c\},\{a,d\},\{b,d\},\{c,d\},\{a,b,c\},\{a,c,d\},\{a,b,d\},\{b,c,d\}\}$ and $S_g^*O(X,\tau)=\tau$ Here (X,τ) is S_g^*-connected but not semi-connected because $X=\{a\}\cup\{b,c,d\}$ where $\{a\}$ and $\{b,c,d\}$ are non-empty disjoint semi-open sets.

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