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Supra semi*generalized closed soft sets

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Abstract. In 1999, Molodtsov [36] introduced the concept of soft sets as a general mathematical tool for dealing with uncertain objects. The concept of generalized closed soft sets in soft topological spaces was introduced by Kannan [28] in 2012. The notions of supra soft topological space were first introduced by by El-sheikh and Abd El-latif [13]. In this paper, we introduce the notion of supra semi star generalized closed soft sets (supra semi*g-closed soft for short) in a supra topological space (X, μ, E) and study their properties in detail. We further investigate some relationship among various types of supra generalized closed soft sets.

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1. Introduction

The concept of soft sets was first introduced by Molodtsov [36] in 1999 as a general mathematical tool for dealing with uncertain objects. In [35, 36], Molodtsov successfully applied the soft theory in several directions, such as smoothness of functions,game theory, operations research,Riemann integration, Perron integration, probability, theory of measurement, and so on.
After presentation of the operations of soft sets [33], the properties and applications of soft set theory have been studied increasingly [8, 29, 35, 39]. In recent years, many interesting applications of soft set theory have been expanded by embedding the ideas of fuzzy sets [6, 7, 9, 10, 17, 26, 31, 32, 33, 34, 35, 37, 38, 41, 42]. To develop soft set theory, the operations of the soft sets are redefined and a uni-int decision making method was constructed by using these new operations [11].
Recently, in 2011, Shabir and Naz [40] initiated the study of soft topological spaces. They defined soft topology on the collection τ of soft sets over X. Consequently, they defined basic notions of soft topological spaces such as open and closed soft sets,

soft subspace, soft closure, soft nbd of a point and soft separation axioms, which is extended in [43]. In [12, 18], The researchers introduced some soft operations such as semi open soft, pre open soft, α-open soft, β-open soft, b-open soft and investigated their properties in detail. Kandil et al. [25] introduced the notion of soft semi separation axioms. In particular, they study the properties of the soft semi regular spaces and soft semi normal spaces. Maji et al. [31] initiated the study involving both fuzzy sets and soft sets. In [5], Karal and Ahmed defined the notion of a mapping on classes of fuzzy soft sets, which is a fundamental important in fuzzy soft set theory, to improve this work and they studied properties of fuzzy soft images and fuzzy soft inverse images of fuzzy soft sets. Some fuzzy soft topological properties were introduced in [1, 2, 3, 16, 17, 26].

The notion of soft ideal was initiated for the first time by Kandil et al.[21]. They also introduced the concept of soft local function. These concepts are discussed with a view to find new soft topologies from the original one, called soft topological spaces with soft ideal $(X, \tau, E, \tilde{I})$. Applications to various fields were further investigated by Kandil et al. [15, 19, 20, 22, 23, 24, 27].

In 1970, Levine [30] introduced the notion of g-closed sets in topological spaces as a generalization of closed sets. Recently, K. Kannan [28] introduced the concept of g-closed soft sets in a soft topological spaces. The notion of supra soft topological spaces was initiated for the first time by El-sheikh and Abd El-latif [13], which is extended in [4, 14]. El-sheikh and Abd El-latif [13] have extended the notions of g-closed soft sets to such spaces.

The main purpose of this paper is to introduce the notion of supra semi star generalized closed soft sets (supra semi*g-closed soft for short) in a supra topological space (X, μ, E).We further investigate some relationship among various types of supra generalized closed soft sets.

2. Preliminaries

In this section, we recall some definitions and results on soft set theory and soft topology.

Definition 2.1 ([36])**.** Let X be an initial universe and E be a set of parameters. Let $P(X)$ denote the power set of X and A be a non-empty subset of E. A pair (F, A) denoted by F_A is called a soft set over X , where F is a mapping given by $F : A \to P(X)$. In other words, a soft set over X is a parameterized family of subsets of the universe X. For a particular $e \in A$, $F(e)$ may be considered the set of e-approximate elements of the soft set (F, A) and if $e \notin A$, then $F(e) = \phi$ i.e
$F_A = \{F(e) : e \in A \subseteq E,\ F : A \to P(X)\}$. The family of all these soft sets over X denoted by $SS(X)_A$.

Definition 2.2 ([40])**.** Let τ be a collection of soft sets over a universe X with a fixed set of parameters E, then $\tau \subseteq SS(X)_E$ is called a soft topology on X if

- **(1):** $\tilde{X}, \tilde{\phi} \in \tau$, where $\tilde{\phi}(e) = \phi$ and $\tilde{X}(e) = X,\ \forall e \in E$,
- **(2):** the union of any number of soft sets in τ belongs to τ,
- **(3):** the intersection of any two soft sets in τ belongs to τ.

The triplet (X, τ, E) is called a soft topological space over X.

Definition 2.3 ([43])**.** The soft set $(F,E) \in SS(X)_E$ is called a soft point in X_E if there exist $x \in X$ and $e \in E$ such that $F(e) = \{x\}$ and $F(e^c) = \phi$ for each $e^c \in E - \{e\}$, and the soft point (F,E) is denoted by x_e.

Definition 2.4 ([18])**.** Let (X,τ,E) be a soft topological space and $(F,E) \in SS(X)_E$. Then, (F,E) is said to be semi open soft set if $(F,E)\tilde{\subseteq} cl(int(F,E))$. The set of all semi open soft sets is denoted by $SOS(X)$ and the set of all semi closed soft sets is denoted by $SCS(X)$.

Definition 2.5 ([13])**.** Let τ be a collection of soft sets over a universe X with a fixed set of parameters E, then $\mu \subseteq SS(X)_E$ is called supra soft topology on X with a fixed set E if

(1): $\tilde{X}, \tilde{\phi} \in \mu$,

(2): the union of any number of soft sets in μ belongs to μ.

The triplet (X,μ,E) is called supra soft topological space (or supra soft spaces) over X.

Definition 2.6 ([13])**.** Let (X,τ,E) be a soft topological space and (X,μ,E) be a supra soft topological space. We say that, μ is a supra soft topology associated with τ if $\tau \subset \mu$.

Definition 2.7 ([13])**.** Let (X,μ,E) be a supra soft topological space over X, then the members of μ are said to be supra open soft sets in X. We denote the set of all supra open soft sets over X by $supra - OS(X,\mu,E)$, or when there can be no confusion by $supra - OS(X)$ and the set of all supra closed soft sets by $supra - CS(X,\mu,E)$, or $supra - CS(X)$.

Definition 2.8 ([13])**.** Let (X,μ,E) be a supra soft topological space over and $(F,E) \in SS(X)_E$. Then, the supra soft interior of (G,E), denoted by $int^s(G,E)$ is the soft union of all supra open soft subsets of (G,E). Clearly, $int^s(G,E)$ is the largest supra open soft set over X which contained in (G,E) i.e
$int^s(G,E) = \tilde{\cup}\{(H,E) : (H,E)\ is\ supra\ open\ soft\ set\ and\ (H,E)\tilde{\subseteq}(G,E)\}$.

Definition 2.9 ([13])**.** Let (X,μ,E) be a supra soft topological space over and $(F,E) \in SS(X)_E$. Then, the supra soft closure of (F,E), denoted by $cl^s(F,E)$ is the soft intersection of all supra closed super soft sets of (F,E). Clearly, $cl^s(F,E)$ is the smallest supra closed soft set over X which contains (F,E) i.e
$cl^s(F,E) = \tilde{\cap}\{(H,E) : (H,E)\ is\ supra\ closed\ soft\ set\ and\ (F,E)\tilde{\subseteq}(H,E)\}$.

Definition 2.10 ([13])**.** Let (X,μ,E) be a supra soft topological space and $(F,E) \in SS(X)_E$. Then, (F,E) is said to be supra semi open β-open soft set if $(F,E)\tilde{\subseteq} cl^s(int^s(F,E))$. The set of all supra β-open soft sets is denoted by $supra - SOS(X)$ and the set of all supra semi closed soft sets is denoted by $supra - SCS(X)$.

3. Supra semi*g-closed soft sets

The notion of supra soft topological spaces was initiated for the first time by El-sheikh and Abd El-latif [13]. Kannan [28] introduced generalized closed soft sets in soft topological spaces. In this section we generalize the notions of generalized closed soft sets to supra soft topological spaces based on the notion of semi open soft sets.

Definition 3.1. A soft set (F,E) is called a supra semi* generalized closed soft set (supra semi*g-closed soft) in a supra soft topological space (X,μ,E) if $cl^s(F,E)\tilde{\subseteq}(G,E)$ whenever $(F,E)\tilde{\subseteq}(G,E)$ and (G,E) is supra semi open soft in X.

Example 3.1. Suppose that there are three cars in the universe X given by $X = \{h_1,h_2,h_3\}$. Let $E=\{e_1,e_2\}$ be the set of decision parameters which are stands for "expensive" and "beautiful" respectively.
Let $(G_1,E),(G_2,E)$ be two soft sets over the common universe X, which describe the composition of the cars, where
$G_1(e_1)=\{h_2,h_3\}, \quad G_1(e_2)=\{h_1,h_2\}$,
$G_2(e_1)=\{h_1,h_2\}, \quad G_2(e_2)=\{h_1,h_3\}$.
Then, $\mu=\{\tilde{X},\tilde{\phi},(G_1,E),(G_2,E)\}$ is a supra soft topology over X. Hence, the soft sets $(F_1,E),(F_2,E)$, where
$F_1(e_1)=\{h_2,h_3\}, \quad F_1(e_2)=\{h_1,h_3\}$,
$F_2(e_1)=\{h_1,h_2\}, \quad F_2(e_2)=\{h_1,h_2\}$.
are supra semi*g-closed soft sets in (X,μ,E), but the soft sets $(G_1,E),(G_2,E)$ are not supra semi*g-closed soft in (X,μ,E).

Remark 3.1. The soft intersection (resp. soft union) of any two supra semi*g-closed soft sets is not supra semi*g-closed soft in general as shown in the following examples.

Examples 3.1. **(1):** In Example 3.1, $(F_1,E),(F_2,E)$ are supra semi*g-closed soft in (X,μ,E), but their soft intersection $(F_1,E)\tilde{\cap}(F_2,E)=(M,E)$ where $M(e_1)=\{h_2\}, \quad M(e_2)=\{h_1\}$ is not supra semi*g-closed soft.

(2): Suppose that there are four alternatives in the universe of houses $X = \{h_1,h_2,h_3,h_4\}$ and consider $E=\{e_1,e_2\}$ be the set of decision parameters which are stands for "quality of houses" and "green surroundings" respectively.
Let $(F_1,E),(F_2,E),(F_3,E),(F_4,E),(F_5,E),(F_6,E),(F_7,E),(F_8,E)$, $(F_9,E),(F_{10},E),(F_{11},E),(F_{12},E)$ be twelve soft sets over the common universe X which describe the goodness of the houses, where
$F_1(e_1)=\{h_1\}$, $F_1(e_2)=\{h_4\}$,
$F_2(e_1)=\{h_1,h_4\}$, $F_2(e_2)=\{h_1,h_4\}$,
$F_3(e_1)=\{h_4\}$, $F_3(e_2)=\{h_1\}$,
$F_4(e_1)=\{h_1,h_2\}$, $F_4(e_2)=\{h_2,h_4\}$,
$F_5(e_1)=\{h_2,h_4\}$, $F_5(e_2)=\{h_1,h_2\}$,
$F_6(e_1)=\{h_1,h_2,h_3\}$, $F_6(e_2)=\{h_1,h_2,h_3\}$,
$F_7(e_1)=\{h_2,h_3,h_4\}$, $F_7(e_2)=\{h_2,h_3,h_4\}$,
$F_8(e_1)=\{h_1,h_2,h_4\}$, $F_8(e_2)=\{h_1,h_2,h_4\}$,
$F_9(e_1)=X$, $F_9(e_2)=\{h_1,h_2,h_3\}$,
$F_{10}(e_1)=\{h_2,h_3,h_4\}$, $F_{10}(e_2)=X$,
$F_{11}(e_1)=\{h_1,h_2,h_3\}$, $F_{11}(e_2)=X$,
$F_{12}(e_1)=X$, $F_{12}(e_2)=\{h_2,h_3,h_4\}$.
Hence, $\mu=\{\tilde{X},\tilde{\phi},(F_1,E),(F_2,E),(F_3,E),(F_4,E),(F_5,E),(F_6,E)$, $(F_7,E),(F_8,E),(F_9,E),(F_{10},E),(F_{11},E),(F_{12},E)\}$ is a supra soft topology over X. Therefore, the soft sets $(G,E),(H,E)$, where
$G(e_1)=\{h_4\}$, $G(e_2)=\{h_4\}$,

$H(e_1) = \{h_1\}$, $H(e_2) = \{h_1\}$,
are supra semi*g-closed soft sets in (X, μ, E), but their soft union $(G, E)\tilde{\cup}(H, E) = (A, E)$ where
$A(e_1) = \{h_1, h_4\}$, $A(e_2) = \{h_1, h_4\}$ is not supra semi*g-closed soft.

Remark 3.2. Every supra closed soft set is supra semi*g-closed soft. But, the converse is not true in general as shown in the following example.

Example 3.2. In Example 3.1, $(F_1, E), (F_2, E)$ are supra semi*g-closed soft in (X, μ, E), but are not supra closed soft over X.

Theorem 3.1. *If (F, E) is supra semi*g-closed soft and supra semi open soft, then it is supra closed soft.*

Proof. Let (F, E) be a supra semi*g-closed soft and supra semi open soft. Since $(F, E)\tilde{\subseteq}(F, E)$, then $cl^s(F, E)\tilde{\subseteq}(F, E)$. This implies that, $cl^s(F, E) = (F, E)$. Therefore, (F, E) is supra closed soft. □

Proposition 3.1. *Every supra semi*g-closed soft set is supra g-closed soft.*

Proof. It is clear from the fact that, every supra open soft set is supra semi open soft [13]. □

Remark 3.3. The converse of Proposition 3.1 is not true in general as shown in the following example.

Example 3.3. In Example 3.1, the soft set (G, E) where
$G(e_1) = \{h_2, h_3\}, \quad G(e_2) = \{h_1, h_3\}$,
is supra g-closed soft set, but it is not supra semi*g-closed soft. Because of, the soft set (H, E), which defined by:
$H(e_1) = \{h_2, h_3\}, \quad H(e_2) = X$,
is supra semi open soft set such that $(G, E)\tilde{\subseteq}(H, E)$, but we have $cl^s(G, E)\tilde{\nsubseteq}(H, E)$.

Theorem 3.2. *In a supra soft topological space (X, μ, E), $\mu = supra - SOS(X) = \mu^c$ if and only if every soft subset of X is supra semi*g-closed soft.*

Proof. **Necessity:**Let (A, E) be any soft subset of X such that $(A, E)\tilde{\subseteq}(G, E)$, where (G, E) is supra semi open soft set in X. By hypothesis, $(G, E) \in \mu^c$. Hence, $cl^s(A, E)\tilde{\subseteq}cl^s(G, E) = (G, E)$. Therefore, (A, E) is supra semi*g-closed soft.

Sufficient: We first prove that $\mu = \mu^c$. Let $(O, E) \in \mu$. By hypothesis, (O, E) is supra semi*g-closed soft. Therefore, $cl^s(O, E)\tilde{\subseteq}(O, E)$. This implies that, $(O, E) \in \mu^c$. Thus, $\mu \subseteq \mu^c$. Next, $(B, E) \in \mu^c$. By a similar argument, we can get $\mu^c \subseteq \mu$. This means that, $\mu = \mu^c$.

Now, we prove that $\mu = supra - SOS(X)$. Let $(Z, E) \in supra - SOS(X)$. Since $(Z, E)\tilde{\subseteq}(Z, E)$. Then, $cl^s(Z, E)\tilde{\subseteq}(Z, E)$. This implies that, $(Z, E) \in \mu^c$. Thus, $supra - SOS(X) \subseteq \mu^c = \mu$. But, we have $\mu^c = \mu\tilde{\subseteq}supra - SOS(X)$. This means that, $\mu = supra - SOS(X) = \mu^c$. □

Theorem 3.3. *Let (X, μ, E) be a supra soft topological space and (F, E) be a supra semi*g-closed soft in X. If $(F, E)\tilde{\subseteq}(H, E)\tilde{\subseteq}cl^s(F, E)$, then (H, E) is supra semi*g-closed soft.*

Proof. Let $(H, E)\tilde{\subseteq}(G, E)$ and $(G, E) \in supra{-}SOS(X)$. Since $(F, E)\tilde{\subseteq}(H, E)\tilde{\subseteq}(G, E)$ and (F, E) is supra semi*g-closed soft in X, then $cl^s(F, E)\tilde{\subseteq}(G, E)$. Hence, $cl^s(H, E)\tilde{\subseteq}cl^s(F, E)$ $\tilde{\subseteq}(G, E)$. Thus, $cl^s(H, E)\tilde{\subseteq}(G, E)$. Therefore, (H, E) is supra semi*g-closed soft. □

Theorem 3.4. *Let (X, μ, E) be a supra soft topological space. Then, (H, E) is supra semi*g-closed soft in X if and only if $cl^s(H, E)\setminus(H, E)$ contains only null supra semi closed soft set.*

Proof. **Necessity:**Let (H, E) be a supra semi*g-closed soft set, (F, E) be a non null supra semi closed soft set in X and $(F, E)\tilde{\subseteq}cl^s(H, E) \setminus (H, E)$. Then, $(F, E)^c$ is supra semi open soft, $(F, E)\tilde{\subseteq}cl^s(H, E)$ and $(F, E)\tilde{\subseteq}(H, E)^c$. Hence, $(H, E)\tilde{\subseteq}$ $(F, E)^c$. Since (H, E) is supra semi*g-closed soft. Then, $cl^s(H, E)\tilde{\subseteq}(F, E)^c$. Hence, $(F, E)\tilde{\subseteq}[cl^s(H, E)]^c$. This means that, $(F, E)\tilde{\subseteq}cl^s(H, E)\tilde{\cap}[cl^s(H, E)]^c = \tilde{\phi}$. Thus, $(F, E) = \tilde{\phi}$, which is a contradiction. Therefore, $cl^s(H, E) \setminus (H, E)$ contains only null supra semi closed soft set.

Sufficient: Assume that $cl^s(H, E) \setminus (H, E)$ contains only null supra semi closed soft set, $(H, E)\tilde{\subseteq}(G, E)$, (G, E) is supra semi open soft and suppose that $cl^s(H, E)\tilde{\nsubseteq}(G, E)$. Then, $cl^s(H, E)\tilde{\cap}(G, E)^c$ is non null supra semi closed soft subset of $cl^s(H, E) \setminus$ (H, E), which is a contradiction. Thus, (H, E) is supra semi*g-closed soft in X. This completes the proof. □

Corollary 3.1. *Let (F, E) be supra semi*g-closed soft set. Then, (F, E) is supra closed soft if and only if $cl^s(F, E) \setminus (F, E)$ is supra semi closed soft.*

Proof. **Necessity:**Let (F, E) be a supra semi*g-closed soft which is also supra closed soft. Then, $cl^s(F, E) \setminus (F, E) = \tilde{\phi}$, which is supra semi closed soft.

Sufficient: Suppose that $cl^s(F, E) \setminus (F, E)$ is supra semi closed soft and (F, E) is supra semi*g-closed soft. Then, $cl^s(F, E) \setminus (F, E) = \tilde{\phi}$ from Theorem 3.4. Hence, $cl^s(F, E) = (F, E)$. Thus, (F, E) is supra closed soft. □

4. Supra semi*g-open soft sets

Definition 4.1. A soft set (F, E) is called supra generalized open soft set (supra semi*g-open soft) in a supra soft topological space (X, μ, E) if its relative complement $(F, E)^c$ is supra semi*g-closed soft in X.

Example 4.1. In Example 3.1, $(F_1, E)^c, (F_2, E)^c$ are supra semi*g-open soft in (X, μ, E).

Remark 4.1. Every supra open soft set is supra semi*g-open soft. But, the converse is not true in general as shown in the following example.

Example 4.2. In Example 3.1, $(F_1, E)^c, (F_2, E)^c$ are supra semi*g-open soft in (X, μ, E), but it is not supra open soft over X.

Theorem 4.1. *Let (X, μ, E) be supra soft topological space. Then, the supra soft set (F, E) is supra semi*g-open soft set if and only if $(F, E)\tilde{\subseteq} int^s(G, E)$ whenever $(F, E)\tilde{\subseteq}(G, E)$ and (G, E) is supra semi closed soft in X.*

Proof. **Necessity:**Let (F, E) be a supra semi*g-open soft in X, $(F, E)\tilde{\subseteq}(G, E)$ and (F, E) is supra semi closed soft in X. Then, $(F, E)^c$ is supra semi*g-closed soft from Definition 4.1 and $(G, E)^c\tilde{\subseteq}(F, E)^c$. Since (F, E) is supra semi*g-open soft in X. Then, $cl^s(G, E)^c\tilde{\subseteq}(F, E)^c$. Hence, $(F, E)\tilde{\subseteq}[cl^s(G, E)^c]^c = int^s(G, E)$.

Sufficient: Let $(F, E)^c\tilde{\subseteq}(H, E)$ and (H, E) is supra semi open soft in X. Then, $(H, E)^c\tilde{\subseteq}(F, E)$ and $(H, E)^c$ is supra semi closed soft in X. Hence, $(H, E)^c\tilde{\subseteq} int^s(F, E)$ from the necessary condition. Thus, $[int^s(F, E)]^c = cl^s[(F, E)^c]\tilde{\subseteq}(H, E)$ and (H, E) is supra semi open soft in X. This means that, $(F, E)^c$ is supra semi*g-closed soft in X. Therefore, (F, E) is supra semi*g-open soft set from Definition 4.1. This completes the proof. □

Remark 4.2. The following example deduce that, each supra semi*g-open soft set and supra semi open soft set are independent concepts.

Example 4.3. In Example 3.1, the soft set (G_1, E) is supra semi open soft set in (X, μ, E), but it is not supra semi*g-open soft. Also, the soft set (F_1, E) is supra semi*g-open soft set in (X, μ, E), but it is not supra semi open soft.

Remark 4.3. The soft intersection (resp. soft union) of any two supra semi*g-open soft sets is not supra semi*g-open soft in general as shown in the following examples.

Examples 4.1. **(1):** In Example 3.1, the soft sets $(A, E), (B, E)$, where
$A(e_1) = \{h_1, h_2\}$, $A(e_2) = \{h_1, h_3\}$,
$B(e_1) = \{h_2, h_3\}$, $B(e_2) = \phi$,
are supra semi*g-open soft sets in (X, μ, E), but their soft union $(A, E)\tilde{\cup}(B, E) = (M, E)$ where
$M(e_1) = X$, $M(e_2) = \{h_1, h_3\}$ is not supra semi*g-open soft.
(2): In Example 3.1 (2), the soft sets $(P, E), (O, E)$, where
$P(e_1) = \{h_1, h_2, h_3\}$, $P(e_2) = \{h_1, h_2, h_3\}$,
$O(e_1) = \{h_2, h_3, h_4\}$, $O(e_2) = \{h_2, h_3, h_4\}$,
are supra semi*g-open soft sets in (X, μ, E), but their soft intersection $(P, E)\tilde{\cap}(O, E) = (N, E)$ where
$N(e_1) = \{h_2, h_3\}$, $N(e_2) = \{h_2, h_3\}$ is not supra semi*g-open soft.

Theorem 4.2. *Let (X, μ, E) be a supra soft topological space and (F, E) be a supra semi*g-open soft in X. If $int^s(F, E)\tilde{\subseteq}(H, E)\tilde{\subseteq}(F, E)$, then (H, E) is supra semi*g-open soft.*

Proof. Let $(G, E)\tilde{\subseteq}(H, E)$ and $(G, E) \in supra{-}SCS(X)$. Since $(G, E)\tilde{\subseteq}(H, E)\tilde{\subseteq}(F, E)$ and (F, E) is supra semi*g-open soft in X, then $(G, E)\tilde{\subseteq} int^s(F, E)$. Hence, $(G, E)\tilde{\subseteq} int^s(F, E)$ $\tilde{\subseteq} int^s(H, E)$. Thus, $(G, E)\tilde{\subseteq} int^s(H, E)$. Therefore, (H, E) is supra semi*g-open soft. □

5. Conclusion

In the present work, we have continued to study the properties of supra soft topological spaces. We introduce the notions of supra semi*g-closed soft and supra semi*g-open sets. We have established several interesting properties. We hope that, this paper is going to help researcher enhance and promote the further study on soft topology to carry out a general framework for their applications in practical life.
In future, the study on supra soft separation axioms, supra locally closed soft sets and supra soft continuous mappings with the help of supra semi*g-closed soft sets may be carried out.

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