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CONNECTEDNESS IN SOFT m-STRUCTURE *

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Abstract. In the present paper, we introduce the concept of soft connectedness in a soft m-structure and study some of its properties and characterizations.

Keywords: Soft m-structure, Soft m-connectedness and Soft m-connectedness between soft sets.

1. Introduction

The concept of soft set is fundamentally important in almost every scientific field. Soft set theory is a new mathematical tool dealing with uncertainty and has been applied in several directions since its introduction by Molodtsov [19] in 1999. The operations on soft sets and soft structures have been studied in [1, 16, 23]. Maji et. al [15] gave the first practical application of soft sets in decision theory. In 2011 Shabir and Naz [22] initiated a study of soft topological spaces. In recent years, many soft topological concepts such as soft connectedness and their strong forms [8, 11, 17, 20, 24],soft separation axioms [14, 20, 22], weak and strong forms of soft open sets and soft continuity [17, 2, 3, 4, 5, 6, 9, 10, 12, 13, 25] have been introduced and studied. Recently, the authors of this paper [21] initiated a study of soft m-structures. In the present paper we introduce the concept of soft connectedness in soft m-structures and we study some of its properties and characterizations.

2. Preliminaries

Let U be an initial universe set, E be a set of parameters, P(U) denote the power set of U and A $\subseteq$ E.

Definition 2.1. [19] A pair (F, A) is called a soft set over U, where F is a mapping given by F: A $\rightarrow$ P(U). In other words, a soft set over U is a parameterized family of subsets of the universe U. For all e $\in$ A, F(e) may be considered a set of e-approximate elements of the soft set (F, A).

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Definition 2.2. [16] For two soft sets (F, A) and (G, B) over a common universe U, we say that (F, A) is a soft subset of (G, B), denoted by (F, A) $\subseteq$ (G, B), if

(a) A $\subseteq$ B and

(b) F (e) $\subseteq$ G (e) for all e $\in$ E.

Definition 2.3. [16] Two soft sets (F, A) and (G, B) over a common universe U are said to be soft equal denoted by (F, A) = (G, B) if (F, A) $\subseteq$ (G, B) and (G, B) $\subseteq$ (F, A).

Definition 2.4. [7] The complement of a soft set (F, A), denoted by $(F, A)^c$, is defined by $(F, A)^c$ = (F^c, A), where F^c : A $\rightarrow$ P(U) is a mapping given by F^c(e) = U $-$ F(e), for all e $\in$ E.

Definition 2.5. [16] Let a soft set (F, A) over U.

(a) A null soft set denoted by ϕ if for all e $\in$ A, F (e) = ϕ.

(b) An absolute soft set denoted by $\widetilde{U}$, if for each e $\in$ A, F(e) = U.

Clearly, $\widetilde{U}^c = \phi$ and $\phi^c = \widetilde{U}$.

Definition 2.6. [7] The union of two sets (F, A) and (G, B) over a common universe U is a soft set (H, C), where C = A $\cup$ B and for all e $\in$ C,

$$H(e) = \begin{cases} F(e), & if e \in A - B \\ G(e), & if e \in B - A \\ F(e) \cup G(e), & \text{if } e \in A \cap B \end{cases}$$

Definition 2.7. [7] The intersection of two soft sets (F, A) and (G, B) over a common universe U is a soft set (H, C) where C = A $\cap$ B and H(e) = F(e) $\cap$ G(e) for each e $\in$ E.

Let X and Y be initial universe sets and E and K be non-empty sets of the parameters, S(X, E) denotes the family of all soft sets over X, and S(Y, K) denotes the family of all soft sets over Y.

Definition 2.8. [12] Let S(X,E) and S(Y,K) be families of soft sets. Let u: X $\rightarrow$ Y and p: E $\rightarrow$ K be mappings. Then a mapping f_{pu}: S(X, E) $\rightarrow$ S(Y, K) is defined as:

(i)Let (F, A) be a soft set in S(X, E). The image of (F, A) under f_{pu}, written as f_{pu} (F, A) = (f_{pu}(F), p(A)), is a soft set in S(Y,K) such that

$$f_{pu}(F)(k) = \begin{cases} \bigcup_{e \in p^{-1}(k) \bigcap A} u(F(e)), & p^-1(k) \bigcap A \neq \phi \\ \phi, & p^{-1}(k) \bigcap A = \phi \end{cases}$$

For all k ∈ K.
(ii) Let (G , B) be a soft set in S(Y , K). The inverse image of (G, B) under f_{pu}, written as f_{pu}^{-1}(G,B) = (f_{pu}^{-1}(G),p^{-1}(B))), is a soft set in S(X,E) such that

$$f_{pu}^{-1}(G)(e) = \begin{cases} u^{-1}G(p(e)), & p(e)\in B \\ \phi, & p(e)\notin B \end{cases}$$

For all e ∈ E.

Definition 2.9. [25]Let f_{pu} : S(X, E) → S(Y, K) be a mapping and u : X → Y and p : E → K be mappings. Then f_{pu} is soft onto, if u : X → Y and p : E → K are onto and f_{pu} is soft one-one, if u : X → Y and p : E → K are one-one.

Definition 2.10. [22] A subfamily τ of S(X , E) is called a soft topology over X if:

1. $\widetilde{\phi}$, $\widetilde{X}$ belong to τ .
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. The members of τ are called soft open sets in X and their complements are called soft closed sets in X.

Definition 2.11. If (X ,τ , E) is a soft topological space and a soft set (F, E) over X.

(a) The soft closure of (F, E) is denoted by Cl(F,E), and defined as the intersection of all soft closed super sets of (F,E) [22].

(b) The soft interior of (F, E) is denoted by Int(F,E), and defined as the soft union of all soft open subsets of (F, E) [25].

Definition 2.12. [25] The soft set (F,E) ∈ S(X,E) is called a soft point if there exist x ∈ X and e ∈ E such that F(e) = {x} and F(e') = ϕ for each e' ∈ E − {e}, and the soft point (F,E) is denoted by x_e.

Definition 2.13. A soft set (A, E) of a soft topological space(X,τ,E) is called :

(a) Soft regular open (A, E) = Int(Cl(A, E)) [6];

(b) Soft α-open if (A, E) ⊂ Int(Cl(Int(A, E))) [3] ;

(c) Soft semi-open if (A, E) ⊂ Cl(Int(A, E)) [17] ;

(d) Soft preopen if (A, E) ⊂ Int(Cl(A, E)) [2] ;

(e) Soft b-open if (A, E) ⊂ Int(Cl(A, E)) ∪ Cl(Int (A, E)) [5].

(f) Soft β-open if (A, E) $\subset$ Cl(Int(Cl(A, E))) [4]

The family of all soft regular open (resp. soft α-open, soft semi-open, soft preopen, soft β-open, soft b-open) sets of X will be denoted by SRO(X,E) (resp. SαO(X,E), SSO(X,E), SPO(X,E), SβO(X, E), SbO(X, E)).

Definition 2.14. Let (A,E) be a soft subset of a soft topological space (X,τ,E). Then:

(a) The intersection of all soft semi-open sets containing (A, E) is called semi-closure of (A,E). It is denoted by sCl(A,E) [17].

(b) The intersection of all soft preopen sets containing (A, E) is called preclosure of (A,E). It is denoted by pCl(A,E)[2].

(c) The intersection of all soft α open sets containing (A,E) is called α-closure of (A,E). It is denoted by αCl(A,E)[3].

(d) The intersection of all soft b-open sets containing (A,E) is called b-closure of (A,E). It is denoted by bCl(A,E)[5].

(e) The intersection of all soft β-open sets containing (A,E) is called β-closure of (A,E). It is denoted by βCl(A,E)[4].

Definition 2.15. A soft mapping f_{pu} : (X,τ,E)$\rightarrow$ (X,σ,K) is said to be :

(a) Soft continuous if f_{pu}^{-1} (U, K) $\in \tau$ for every soft set (U, K) $\in \sigma$ [25] .

(b) Soft α-continuous if f_{pu}^{-1} (U, K) $\in$ SαO(X, E) for every soft set (U, K) $\in \sigma$ [3].

(c) Soft semi-continuous if f_{pu}^{-1} (U, K) $\in$ SSO(X, E) for every soft set (U, K) $\in \sigma$ [17].

(d) Soft precontinuous if f_{pu}^{-1} (U, K) $\in$ SPO(X, E) for every soft set (U, K) $\in \sigma$ [2].

(e) Soft b-continuous if f_{pu}^{-1} (U, K) $\in$ SbO(X, E) for every soft set (U, K) $\in \sigma$ [5].

(f) Soft β-continuous if f_{pu}^{-1} (U, K) $\in$ SβO(X, E) for every soft set (U, K) $\in \sigma$ [4].

Definition 2.16. A soft mapping f_{pu} : (X,τ,E)$\rightarrow$ (X,σ,K) is said to be :

(a) Soft open if f_{pu}(U, E) $\in \sigma$ for every soft set (U, E) $\in \tau$ [26].

(b) Soft α-open if f_{pu} (U, E) $\in$ SαO(Y, K) for every soft set (U, E) $\in \tau$ [3].

(c) Soft semi-open if f_{pu}(U, E) $\in$ SSO(Y, K) for every soft set (U, E) $\in \tau$ [17].

(d) Soft preopen if f_{pu}(U, E) $\in$ SPO(Y, K) for every soft set (U, E) $\in \tau$ [2].

(e) Soft b-open if f_{pu}(U, E) $\in$ SbO(Y, K) for every soft set (U, E) $\in \tau$ [5].

(f) Soft β-open if f_{pu}(U, E) $\in$ SβO(Y, K) for every soft set (U, E) $\in \tau$ [4].

Definition 2.17. [14] Let (X,τ,E) be a soft topological space, and (A,E),(B,E) be two soft sets over X. The soft sets (A,E) and (B,E) are said to be soft-separated, if (A,E) $\cap$ Cl(B,E) = ϕ and Cl(A,E) $\cap$ (B,E) = ϕ.

Definition 2.18. [14] Let (X,τ,E) be a soft topological space and if there exist two non-empty soft separated sets (A,E),(B,E) such that (A,E) $\cup$ (B,E) = $\tilde{X}$, then (A,E) and (B,E) are said to be a soft disconnection for a soft topological space (X,τ,E).(X,τ,E) is said to be soft-disconnected if (X,τ,E) has a soft disconnection. Otherwise, (X,τ,E) is said to be soft-connected.

Definition 2.19. [17] Let (X,τ ,E) be a soft topological space. The nonempty soft sets (F,A) and (F,B) in S(X,E) are called soft semi-separated iff sCl(F,A) $\cap$ (F,B) = (F,A) $\cap$ sCl(F,B) = ϕ.

Definition 2.20. [17] Let (X,τ ,E)be a soft topological space. If there does not exist a soft semi-separation of X, then it is said to be soft s-connected.

Definition 2.21. [24] Let (X,τ ,E) be a soft topological space. The nonempty soft sets (F,A) and (F,B) in S(X,E) are called soft preseparated iff pCl(F,A) $\cap$ (F,B) = (F,A) $\cap$ pCl(F,B) = ϕ.

Definition 2.22. [24] Let (X,τ ,E)be a soft topological space. If there does not exist a soft preseparation of X, then it is said to be soft P-connected.

Definition 2.23. [21] A subfamily $m_{(X,E)}$ of S(X,E) is called a soft minimal structure (briefly soft m-structure) over X if $\phi \in m_{(X,E)}$ and $\tilde{X} \in m_{(X,E)}$.

(X,$m_{(X,E)}$) is called a soft space with a soft minimal structure $m_{(X,E)}$ or simply a soft m-space. Each member of $m_{(X,E)}$ is called a soft m-open set and the complement of a soft m-open set is called a soft m-closed set.

Remark 2.1. [21] Let (X,τ,E) be a soft topological space. Then the families τ, SSO(X,E), SPO(X,E), SαO(X,E), SβO(X,E), SbO(X,E), SRO(X,E) are all soft m-structures over X.

Definition 2.24. [21] Let X be a nonempty set, E be a set of parameters and $m_{(X,E)}$ be a soft m-structure over X. The soft $m_{(X,E)}$-closure and the soft $m_{(X,E)}$-interior of the soft set (A,E) over X are defined as follows:

(1) $m_{(X,E)}$-Cl(A,E) = $\cap$ {(F,E) : (A,E) $\subset$ (F,E) ,$(F,E)^c \in m_{(X,E)}$ }.

(2) $m_{(X,E)}$-Int(A,E) = $\cup$ {(F,E) : (F,E) $\subset$ (A,E) ,(F,E) $\in m_{(X,E)}$ }.

Remark 2.2. [21] Let (X,τ,E) be a soft topological space and (A,E) be a soft set over X. If $m_{(X,E)} = \tau$ (respectively SO(X,E), SPO(X,E), SαO(X,E), SβO(X,E), SbO(X,E)), then we have:

(1) $m_{(X,E)}$-Cl(A,E) = Cl(A,E) (resp. sCl(A,E) ,pCl(A,E),αCl(A,E),β Cl(A,E), bCl(A,E)).

(2) $m_{(X,E)}$-Int(A,E)= Int(A,E) (resp. sInt(A,E) ,pInt(A,E),αInt(A,E),βInt(A,E), bInt(A,E)).

Theorem 2.1. *[21] Let S(X,E) be a family of soft sets and $m_{(X,E)}$ a soft minimal structure over X.*

For soft sets (A,E) and (B,E) of X, the following holds:

(a) *(i): $m_{(X,E)}$-Int$(A,E)^c = (m_{(X,E)} - Cl(A,E))^c$ and (ii) : $m_{(X,E)}$-Cl$(A,E)^c = (m_{(X,E)} - Int(A,E))^c$.*

(b) *If $(A,E)^c \in m_{(X,E)}$, then $m_{(X,E)}$-Cl(A,E) = (A,E) and if (A,E) $\in m_{(X,E)}$,then $m_{(X,E)}$-Int(A,E) = (A,E).*

(c) *$m_{(X,E)}$-Cl(ϕ) = ϕ ,$m_{(X,E)}$-Cl($\tilde{X}$) = $\tilde{X}$, $m_{(X,E)}$-Int(ϕ) = ϕ ,$m_{(X,E)}$-Int($\tilde{X}$) = $\tilde{X}$.*

(d) *If (A,E) $\subset$ (B,E), then $m_{(X,E)}$-Cl(A,E) $\subset$ $m_{(X,E)}$-Cl(B,E), $m_{(X,E)}$-Int(A,E) $\subset$ $m_{(X,E)}$-Int(B,E).*

(e) *(A,E) $\subset$ $m_{(X,E)}$-Cl(A,E) and $m_{(X,E)}$-Int(A,E) $\subset$ (A,E).*

(f) *$m_{(X,E)}$-Cl($m_{(X,E)}$-Cl(A,E)) = $m_{(X,E)}$-Cl(A,E) and $m_{(X,E)}$-Int($m_{(X,E)}$-Int(A,E)) = $m_{(X,E)}$-Int(A,E).*

Definition 2.25. [21] A soft mapping f_{pu} : (X,$m_{(X,E)}$) $\rightarrow$ (Y,$m_{(Y,K)}$), where the minimal soft structure $m_{(X,E)}$ and $m_{(Y,K)}$ over X and Y, respectively, is said to be soft M-continuous if for each $x_e \in$ S(X,E) and each (V,K) $\in m_{(Y,K)}$ containing f_{pu} (x_e), there exists (U,E) $\in m_{(X,E)}$ containing x_e such that f_{pu}(U,E) $\subset$ (V,K).

Throughout this paper soft clopen means soft closed and open.

3. Connectedness in soft m-structure

Definition 3.1. [21] A soft minimal structure $m_{(X,E)}$ over X is said to have the property **B** if the union of any family of subsets belongs to $m_{(X,E)}$ belongs to $m_{(X,E)}$.

Definition 3.2. Let X be a nonempty set, E be a set of parameters and $m_{(X,E)}$ be a soft m-structure over X with property **B**. In (X,$m_{(X,E)}$) two nonempty soft sets (A,E) and (B,E) over X are called soft m-separated iff $m_{(X,E)}$-Cl(A,E) $\cap$ (B,E) = (A,E) $\cap$ $m_{(X,E)}$-Cl(B,E) = ϕ.

Remark 3.1. Let (X,τ,E) be a soft topological space over X. If $m_{(X,E)} = \tau$ (resp. SSO(X,E),SPO(X,E),SbO(X,E)) and $m_{(X,E)}$-Cl(A,E) = Cl(A,E) (resp. sCl(A,E), pCl(A,E), bCl(A,E)) we get definitions of soft separated(resp. soft semi-separated, soft preseparated, soft b-separated) sets.

Definition 3.3. Let $m_{(X,E)}$ be a soft m-structure over X with the property **B**. Then (X,$m_{(X,E)}$) is said to be soft m-connected if there does not exist two nonempty soft m-separated sets (A,E) and (B,E) over X, such that (A,E) $\cup$ (B,E) = $\tilde{X}$. Otherwise it is soft m-disconnected. In this case, the pair (A,E) and (B,E) is called soft m-disconnection over X.

Remark 3.2. Let (X,τ,E) be a soft topological space over X. If we replace soft m-separated by soft separated (resp. soft semi-separated, soft preseparated, soft b-separated) sets we get a definition for soft connectedness (resp. soft semi-connectedness, soft preconnectedness, soft b-connectedness).

Theorem 3.1. *Let (X,$m_{(X,E)}$) be a soft m-space with the property* **B**. *Then the following conditions are equivalent:*

(1) (X,$m_{(X,E)}$) has a soft m-disconnection.

(2) There exist two disjoint soft m-closed sets (A,E) ,(B,E) $\in m_{(X,E)}$ such that (A,E) $\cup$ (B,E) = $\tilde{X}$.

(3) There exist two disjoint soft m-open sets (A,E) ,(B,E) $\in m_{(X,E)}$ such that (A,E) $\cup$ (B,E) = $\tilde{X}$.

(4) (X,$m_{(X,E)}$) has a proper soft m-open and soft m-closed set over X.

Proof: (1) $\rightarrow$ (2) : Let (X,$m_{(X,E)}$) have a soft m-disconnection (A,E) and (B,E). Then (A,E) $\cap$ (B,E) = ϕ and

$m_{(X,E)}$-Cl(A,E) = $m_{(X,E)}$-Cl(A,E) $\cap$ ((A,E) $\cup$ (B,E)) = ($m_{(X,E)}$-Cl(A,E) $\cap$ (A,E)) $\cup$ ($m_{(X,E)}$-Cl(A,E) $\cap$ (B,E)) = (A,E).

Therefore, (A,E) is a soft m-closed set over X. Similarly, we can see that (B,E) is also a soft m-closed set over X.

(2) $\rightarrow$ (3) : Let (X,$m_{(X,E)}$) has a soft m-disconnection (A,E) and (B,E) such that (A,E) and (B,E) are soft m-closed. Then $(A,E)^c$ and $(B,E)^c$ are soft m-open sets in $m_{(X,E)}$. Then it is easy to see $(A,E)^c \cap (B,E)^c = \phi$ and $(A,E)^c \cup (B,E)^c = \tilde{X}$.

(3) $\rightarrow$ (4) : Let (X,$m_{(X,E)}$) have a soft m-disconnection (A,E) and (B,E) such that (A,E) and (B,E) are soft m-open over X. Then (A,E) and (B,E are also soft closed in (X,$m_{(X,E)}$).

(4) $\rightarrow$ (1) : Let (X,$m_{(X,E)}$) has a proper soft m-open and soft m-closed set (F,E) over X. Put (H,E) = $(F,E)^c$. Then (H,E) and (F,E) are non-empty soft m-closed sets in (X,$m_{(X,E)}$). (H,E) $\cap$ (F,E) = ϕ and (H,E) $\cup$ (F,E) = $\tilde{X}$. Therefore, (H,E) and (F,E) is a soft m-disconnection of (X,$m_{(X,E)}$).

Remark 3.3. Let (X,τ,E) be a soft topological space over X ,if $m_{(X,E)} = \tau$ (resp. SSO(X,E),SPO(X,E),SbO(X,E)) Then the following conditions are equivalent:

(1) (X,τ,E) has a soft disconnection (resp. soft semi-disconnection, soft pre disconnection, soft b-disconnection).

(2) There exist two disjoint soft closed (resp. soft semi-closed, soft pre-closed, soft b-closed) sets (A,E) ,(B,E) such that (A,E) $\cup$ (B,E) = $\tilde{X}$.

(3) There exist two disjoint soft open (resp. soft semi-open, soft pre-open, soft b-open) sets (A,E) ,(B,E) such that (A,E) $\cup$ (B,E) = $\tilde{X}$.

(4) (X,τ,E) has a proper soft open(resp. soft semi-open, soft pre-open, soft b-open) and soft closed (resp. soft semi-closed, soft pre-closed, soft b-closed) set over X.

Corollary 3.1. *Let (X,$m_{(X,E)}$) be a soft m-space with the property* **B**. *Then the following conditions are equivalent: (1) (X,$m_{(X,E)}$) is a soft m-connected.*

(2) There does not exist two disjoint soft m-closed sets (A,E), (B,E) $\in m_{(X,E)}$ such that (A,E) $\cup$ (B,E) = $\tilde{X}$.

(3) There does not exist two disjoint soft m-open sets (A,E), (B,E) $\in m_{(X,E)}$ such that (A,E) $\cup$ (B,E) = $\tilde{X}$.

(4) (X,$m_{(X,E)}$) at most has two soft m-closed and soft m-open sets over X, that is, ϕ and $\tilde{X}$.

Remark 3.4. Let (X,τ,E) be a soft topological space over X ,if $m_{(X,E)} = \tau$ (resp. SSO(X,E),SPO(X,E),SbO(X,E)). Then the following conditions are equivalent:

(1) (X,τ,E) is a soft connected (resp. soft semi-connected, soft preconnected ,soft b-connected).

(2) There does not exist two disjoint soft closed (resp. soft semi-closed, soft preclosed, soft b-closed) sets (A,E) ,(B,E) such that (A,E) $\cup$ (B,E) = $\tilde{X}$.

(3) There does not exist two disjoint soft open (resp. soft semi-open, soft pre-open, soft b-open) sets (A,E), (B,E) such that (A,E) $\cup$ (B,E) = $\tilde{X}$.

(4) (X,τ,E) has a proper soft open(resp. soft semi-open, soft pre-open, soft b-open) and soft closed (resp. soft semi-closed, soft pre-closed, soft b-closed)set over X.

Definition 3.4. Let (X,$m_{(X,E)}$) be a soft m-space with the property **B**, Y $\subset$ X in (X,$m_{(X,E)}$). The soft space (Y,$m_{(Y,E)}$) is called a soft m-subspace of (X,$m_{(X,E)}$) if $m_{(Y,E)} = \{$(A,E) $\cap \tilde{Y}$: (A,E) $\in m_{(X,E)}\}$.

Lemma 3.1. *Let (X,$m_{(X,E)}$) be a soft m-space with the property* **B**, *(Y,$m_{(Y,E)}$) be a soft m-subspace of (X,$m_{(X,E)}$). If (A,E) $\subset \tilde{Y} \subset \tilde{X}$. Then $m_{(Y,E)}$-Cl(A,E) = $m_{(X,E)}$-Cl(A,E) $\cap \tilde{Y}$.*

Proof: We have $m_{(Y,E)}$-Cl(A,E) = $\cap$ {(F,E): (A,E) $\subset$ (F,E), $\tilde{Y}$ -(F,E) $\in m_{(Y,E)}$)}= $\cap$ {(F,E) $\cap \tilde{Y}$: (A,E) $\subset$ (F,E)$\cap \tilde{Y}$, $\tilde{X}$ - (F,E) $\in m_{(X,E)}$)}= $\cap$ {(F,E) $\cap \tilde{Y}$: (A,E) $\subset$ (F,E), $\tilde{X}$ - (F,E) $\in m_{(X,E)}$)} = $\cap$ { (F,E) : (A,E) $\subset$ (F,E) ,$\tilde{X}$ - (F,E) $\in m_{(X,E)}$} $\cap$ $\tilde{Y}$ = $m_{(X,E)}$-Cl(A,E) $\cap \tilde{Y}$.

Therefore, the lemma holds.

Lemma 3.2. *Let (X,$m_{(X,E)}$) be a soft m-space with the property* **B***, (Y,$m_{(Y,E)}$) be a soft m-subspace of (X,$m_{(X,E)}$). If (A,E) and (B,E) are soft sets in (Y,$m_{(Y,E)}$), then (A,E) and (B,E) are soft m-separated in (Y,$m_{(Y,E)}$) if and only if (A,E) and (B,E) are soft m-separated in (X,$m_{(X,E)}$).*

Proof: We have $m_{(Y,E)}$-Cl(A,E) $\cap$ (B,E) = ($m_{(X,E)}$-Cl(A,E) $\cap$ $\tilde{Y}$) $\cap$ (B,E) = $m_{(X,E)}$-Cl(A,E) $\cap$ (B,E) by lemma 3.1.

Similarly, we have

$m_{(Y,E)}$-Cl(B,E) $\cap$ (A,E) = $m_{(X,E)}$-Cl(B,E) $\cap$ (A,E).

Therefore, the lemma holds.

Lemma 3.3. *Let (X,$m_{(X,E)}$) be a soft m-space with the property* **B***, $\tilde{Y} \subset \tilde{X}$. (Y,$m_{(Y,E)}$) be a soft m-subspace of (X,$m_{(X,E)}$). (Y,$m_{(Y,E)}$) is soft m-connected. If (A,E) and (B,E) are soft m-separated in (X,$m_{(X,E)}$), such that $\tilde{Y} \subset$ (A,E) $\cup$ (B,E), then $\tilde{Y} \subset$ (A,E) or $\tilde{Y} \subset$ (B,E).*

Proof: We have $\tilde{Y} \subset$ (A,E) $\cup$ (B,E),we have $\tilde{Y}$ =($\tilde{Y} \cap$ (A,E))$\cup$ ($\tilde{Y} \cap$ (B,E)). By lemma 3.2 ,$\tilde{Y} \cap$ (A,E) and $\tilde{Y} \cap$ (B,E) are soft m-separated in (Y,$m_{(Y,E)}$). Since (Y,$m_{(Y,E)}$) is soft m-connected, we have $\tilde{Y} \cap$ (A,E) = ϕ or $\tilde{Y} \cap$ (B,E) = ϕ. Therefore, $\tilde{Y} \subset$ (A,E) or $\tilde{Y} \subset$ (B,E).

Lemma 3.4. *Let $\{(X_\alpha, m_{(X_\alpha,E)}$: $\alpha \in J$ } be a soft family non-empty soft m-connected subspaces of (X,$m_{(X,E)}$). If $\bigcap_{\alpha\in J} X_\alpha \neq \phi$, then $(\cup_{\alpha\in J}X_\alpha, \cup_{\alpha\in J}m_{(X_\alpha,E)}$ is a soft m-connected subspace of (X,$m_{(X,E)}$).*

Proof: Let $Y = (\bigcup_{\alpha\in J} X_\alpha)$. Choose a soft point $x_e \in \tilde{Y}$. Let (C,E) and (D,E) be a soft m-disconnection of $(\cup_{\alpha\in J}X_\alpha, \cup_{\alpha\in J}m_{(X_\alpha,E)}$. Then, $x_e \in$ (C,E) and $x_e \in$ (D,E), we assume that $x_e \in$ (C,E).For each $\alpha \in$ J. Since $\{(X_\alpha, m_{(X_\alpha,E)}$ is soft m-connected, it follows from lemma 3.3 that $\tilde{(}X_\alpha) \subset$ (C,E) or $\tilde{(}X_\alpha) \subset$ (D,E). Therefore, we have $\tilde{Y} \subset$ (C,E) since $x_e \in$ (C,E) and then (D,E) = ϕ, which is a contradiction. Thus $(\cup_{\alpha\in J}X_\alpha, \cup_{\alpha\in J}m_{(X_\alpha,E)})$ is a soft m-connected subspace of (X,$m_{(X,E)}$).

Theorem 3.2. *Let $\{(X_\alpha, m_{(X_\alpha,E)})$: $\alpha \in J$ } be a soft family non-empty soft m-connected subspaces of (X,$m_{(X,E)}$).If $X_\alpha \cap X_\beta \neq \phi$ for $\alpha, \beta \in J$,then $(\cup_{\alpha\in J}X_\alpha, m_{(\cup_{\alpha\in J}X_\alpha,E)})$ is a soft m-connected subspace of (X,$m_{(X,E)}$).*

Proof : Let $\alpha_o \in$ J. For $\beta \in$ J,Put $A_\beta = X_{\alpha_o} \cup X_\beta$ By lemma 3.4 , $\{(A_\beta, m_{(X_\beta,E)}$ is soft m-connected. Then, $\{\{(A_\beta, m_{(X_\beta,E)} : \beta \in J\}$ is a family soft m-connected subspace of (X,$m_{(X,E)}$) and $\bigcap_{\beta\in J} A_\beta = X_{\alpha_o} \neq \phi$. Obviously, $(\bigcup_{\alpha\in J} X_\alpha = (\bigcup_{\beta\in J} A_\beta$. It follows from lemma 3.4 that $(\cup_{\alpha\in J}X_\alpha, \cup_{\alpha\in J}m_{(X_\alpha,E)}$ is a soft m-connected subspace of (X,$m_{(X,E)}$).

Theorem 3.3. *Let (X,$m_{(X,E)}$) be a soft m-space with the property* **B***, $\tilde{Y} \subset \tilde{X}$. (Y,$m_{(Y,E)}$) be a soft m-subspace of (X,$m_{(X,E)}$). If $\tilde{Y} \subset \tilde{A} \subset m_{(X,E)}$-Cl(F,E), then*

(A,$m_{(A,E)}$) is a soft connected m-subspace of (X,$m_{(X,E)}$). In particular, $m_{(X,E)}$-Cl(F,E) is a soft connected m-subspace of (X,$m_{(X,E)}$).

Proof: Let (C,E) and (D,E) be a soft m-disconnection of (A,$m_{(A,E)}$). By lemma 3.3, we have $\tilde{A} \subset$ (C,E) or $\tilde{A} \subset$ (D,E). We assume that $\tilde{A} \subset$ (C,E). By lemma 3.2, we have $m_{(X,E)}$-Cl(C,E) $\cap$ (D,E) = ϕ and, hence, $\tilde{A} \cap$ (D,E) = ϕ, which is a contradiction.

Theorem 3.4. *Let f_{pu} : (X,$m_{(X,E)}$) $\to$ (Y,$m_{(Y,K)}$) be a soft M-continuous mapping, where $m_{(X,E)}$ and $m_{(Y,K)}$ are soft minimal structures over X and Y, respectively. If (X,$m_{(X,E)}$) is soft m-connected, then the soft image of (X,$m_{(X,E)}$) is also soft m-connected.*

Proof: Let f_{pu} : (X,$m_{(X,E)}$) $\to$ (Y,$m_{(Y,K)}$) be a soft continuous mapping. Conversely, suppose that (Y,$m_{(Y,K)}$) is soft m-disconnected and the pair (A,K) and (B,K) is a soft m-disconnection of (Y,$m_{(Y,K)}$). Since f_{pu} : (X,$m_{(X,E)}$) $\to$ (Y,$m_{(Y,K)}$) is soft continuous, then f_{pu}^{-1}(A,K) $\in m_{(X,E)}$, f_{pu}^{-1}(B,K) $\in m_{(X,E)}$. Clearly, the pair f_{pu}^{-1}(A,K) and f_{pu}^{-1}(B,K) is a soft m-disconnection of (X,$m_{(X,E)}$), which is a contradiction. Hence, (Y,$m_{(Y,K)}$) is soft m-connected. This completes the proof.

Remark 3.5. Let (X,τ,E) and (Y,ϑ,K) be two soft topological spaces over X and Y, respectively. If $m_{(X,E)} = \tau$,$m_{(Y,K)} = \vartheta$. f_{pu} : (X ,τ,E) $\to$ (Y,ϑ,K) is a soft continuous mapping. If (X ,τ,E) is soft connected (resp. soft semi-connected, soft pre connected, soft b-connected) then the soft image of (X ,τ,E) is also soft connected (resp. soft semi-connected, soft preconnected, soft b-connected).

Definition 3.5. Let $m_{(X,E)}$ be a soft m-structure over X. A soft set (F,E) in (X,$m_{(X,E)}$) is soft m-connected if it is soft m-connected as a soft m-subspace.

Remark 3.6. Let (X,τ,E) be a soft topological space over X. A soft set (F,E) in (X,τ,E) is soft connected (resp. soft semi-connected, soft preconnected and soft b-connected) if it is soft connected (resp. soft semi-connected, soft preconnected and soft b-connected) as a soft subspace.

Theorem 3.5. *Let $m_{(X,E)}$ be a soft m-structure over X ,(G,E) be a soft m-connected set in (X,$m_{(X,E)}$) and (F,E) be a soft set over X such that (G,E) $\subset$ (F,E) $\subset$ $m_{(X,E)}$-Cl(G,E). Then(F,E) is soft m-connected.*

Proof: It is sufficient that $m_{(X,E)}$-Cl(G,E) is soft m-connected. On the contrary, suppose that $m_{(X,E)}$-Cl(G,E) is soft m-disconnected. Then there exists a soft m-disconnection ((H,E),(K,E)) of $m_{(X,E)}$-Cl(G,E). That is, there are ((H,E)$\cap$ (G,E)),((K,E)$\cap$ (G,E)) soft sets in (G,E) such that ((H,E)$\cap$ (G,E))$\cap$ ((K,E)$\cap$ (G,E)) = ((H,E) $\cap$ (K,E))$\cap$ (G,E) = ϕ, and ((H,E)$\cap$ (G,E))$\cup$ ((K,E)$\cap$(G,E)) = ((H,E)$\cup$ (K,E))$\cap$ (G,E) = (G,E). This yields that the pair ((H,E) $\cap$ (G,E)) and ((K,E)$\cap$ (G,E)) is a soft m-disconnection of (G,E), which is a contradiction. This proves that $m_{(X,E)}$-Cl(G,E) is soft m-connected. Hence, the proof is complete.

Lemma 3.5. *Let $m_{(X,E)}$ be a soft m-structure over X with the property* **B***, and let (A,E) and (B,E) be two soft sets over X. In (X,$m_{(X,E)}$) the following statements are equivalent:*

(1) ϕ, $\tilde{X}$ are only soft m-open and soft m-closed set in $m_{(X,E)}$.

(2) (X,$m_{(X,E)}$) is not a soft union of two disjoint soft sets (A,E) and (B,E) $\in m_{(X,E)}$.

(3)(X,$m_{(X,E)}$) is not a soft union of two disjoint soft sets $(A,E)^c$ and $(B,E)^c$ $\in m_{(X,E)}$.

(4)(X,$m_{(X,E)}$) is not a soft union of two nonempty soft m-separated sets.

Remark 3.7. Let (X, τ ,E) be a soft topological space over X, so we put $m_{(X,E)} = \tau$ (resp. SSO(X,E),SPO(X,E),SbO(X,E)). Also, let (A,E) and (B,E) be two soft sets over X. In (X, τ ,E) the following statements are equivalent:

(1) ϕ and $\tilde{X}$ are only soft clopen (resp. soft semi-clopen, soft preclopen, soft b-clopen) sets in (X, τ ,E).

(2) (X, τ ,E) is not a soft union of two soft disjoint soft open(resp. soft semi-open ,soft pre open, soft b-open) sets .

(3) (X, τ ,E) is not a soft union of two soft disjoint soft closed (resp. soft semi-closed, soft preclosed, soft b-closed) sets.

(4) (X, τ ,E) is not a soft union of two nonempty soft separated(soft semi separated, soft preseparated, soft b-separated) sets.

Theorem 3.6. *Let $m_{(X,E)}$ be a soft m-structure over X with the property* **B***. In (X,$m_{(X,E)}$) the following statements are equivalent:*

(1) (X, $m_{(X,E)}$) is a soft m-connected space.

(2)(X, $m_{(X,E)}$) is not a soft union of any two soft m-separated sets.

Proof : (1) $\rightarrow$ (2) : Assume (1). Suppose (2) is false, then let (A,E) and (B,E) be two soft m-separated sets such that $\tilde{X}$ = (A,E) $\cup$ (B,E). Since (X, $m_{(X,E)}$) is soft m-connected $m_{(X,E)}$-Cl(A,E) $\cap$ (B,E)=(A,E) $\cap$ $m_{(X,E)}$-Cl(B,E) = ϕ. Since (A,E) $\subset$ $m_{(X,E)}$-Cl(A,E) and (B,E) $\subset$ $m_{(X,E)}$-Cl(B,E),then (A,E) $\cup$ (B,E) = ϕ. Now $m_{(X,E)}$-Cl(A,E) $\subset$ $(B,E)^c$ =(A,E). Hence, $m_{(X,E)}$-Cl(A,E) = (A,E). Therefore, $(A,E)^c \in m_{(X,E)}$.By the same way we show that $(B,E)^c \in m_{(X,E)}$ which is a contradiction with remark 3.5. This shows that (2) is true. Therefore (1) $\rightarrow$ (2).

(2) $\rightarrow$ (1) : Assume that (2) is not true. Let $(A,E)^c$ and $(B,E)^c$ be two soft m-disjoint nonempty and $(A,E)^c$ and $(B,E)^c \in m_{(X,E)}$ such that $\tilde{X} = (A,E)^c \cup (B,E)^c$. Then, $m_{(X,E)}$-Cl$(A,E)^c$ $\cap$ (B,E)=(A,E) $\cap$ $m_{(X,E)}$-Cl$(B,E)^c = (A,E)^c \cap (B,E)^c = \phi$. This contradicts the hypothesis in (2). This show that (1) is true. Therefore, (2) $\rightarrow$ (1).

Remark 3.8. Let (X, τ ,E) be a soft topological space over X, so we put $m_{(X,E)} = \tau$. Then, the following statements are equivalent:

(1) (X, τ ,E) is a soft connected (soft semi-connected, soft preconnected, soft b-connected) space.

(2) (X, τ ,E) is not the soft union of any two soft separated (soft semi separated, soft preseparated, soft b-separated) sets.

Remark 3.9. (1) Let $m_{(X,E)}$ be a soft m-structure over X with the property **B**, and let (A,E) be a soft set over X. If $\phi \neq$ (A,E) $\subset$ (X,$m_{(X,E)}$) then (A,E) is a soft m-connected set in $m_{(X,E)}$ whenever (X,$m_{(X,E)}$) is a soft m-connected space.

(2) Let (X, τ ,E) be a soft topological space over X, so we put $m_{(X,E)} = \tau$. If $\phi \neq$ (A,E) $\subset$ (X, τ ,E) then (A,E) is a soft connected (soft semi-connected, soft preconnected, soft b-connected) set over X whenever (X, τ ,E) is a soft connected (soft semi-connected, soft preconnected, soft b-connected) space.

Theorem 3.7. *Let $m_{(X,E)}$ be a soft m-structure over X with the property* **B**. *In (X,$m_{(X,E)}$), let the soft set (A,E) be a soft m-connected set. Let (B,E) and (C,E) be soft m-separated sets. If (A,E) $\subset$ (B,E) $\cup$ (C,E). Then, either (A,E) $\subset$ (B,E) or (A,E) $\subset$ (C,E).*

Proof: Suppose (A,E) is a soft m-connected set and (B,E),(C,E) are soft m-separated sets such that (A,E) $\subset$ (B,E) $\cup$ (C,E). Let (A,E) notsubset (B,E) and (A,E) is not a subset of (C,E). Suppose (A_1,E) = (B,E) $\cap$ (A,E) $\neq \phi$ and (A_2,E) = (C,E) $\cap$ (A,E) $\neq \phi$. Then, (A,E) = (A_1,E) $\cup$ (A_2,E). Since (A_1,E) $\subset$ (B,E). Hence, $m_{(X,E)}$-Cl(A_1,E) $\subset$ $m_{(X,E)}$-Cl(B,E). Since $m_{(X,E)}$-Cl(B,E)$\cap$ (C,E) = ϕ then $m_{(X,E)}$-Cl (A_1,E) $\cap$ (A_2,E) = ϕ. Since (A_2,E) $\subset$ (C,E). Hence, $m_{(X,E)}$-Cl(A_2,E) $\subset$ $m_{(X,E)}$-Cl(C,E). Since $m_{(X,E)}$-Cl(C,E)$\cap$ (B,E) = ϕ. Then $m_{(X,E)}$-Cl (A_2,E) $\cap$ (A_1,E) = ϕ. But (A,E) = (A_1,E)$\cup$ (A_2,E). Therefore, (A,E) is not a soft m-connected space. This is a contradiction. Then either (A,E) $\subset$ (B,E) or (A,E) $\subset$ (C,E).

Remark 3.10. Let (X, τ ,E) be a soft topological space over X, so we put $m_{(X,E)}$ = τ. Also, let (A,E) be a soft connected (resp. soft semi-connected, soft preconnected, soft b-connected) set. Let (B,E) and (C,E) be soft separated (resp. soft semi-separated, soft preseparated, soft b-separated) sets. If (A,E) $\subset$ (B,E) $\cup$ (C,E) then either (A,E) $\subset$ (B,E) or (A,E) $\subset$ (C,E).

Let $m_{(X,E)}$ be a soft m-structure over X with the property **B**. In (X,$m_{(X,E)}$), let the soft set (A,E) be a soft m-connected set, then $m_{(X,E)}$-Cl(A,E) is soft m-connected.

Proof: Suppose the soft set (A,E) is a soft m-connected set and $m_{(X,E)}$-Cl(A,E) is not. Then there exist two soft m-separated sets (B,E) and (C,E) such that $m_{(X,E)}$-Cl(A,E) = (B,E) $\cup$ (C,E). But (A,E) $\subset$ $m_{(X,E)}$-Cl(A,E),then (A,E) = (B,E) $\cup$ (C,E) and since (A,E) is a soft m-connected set, then by Theorem 3.7 either (A,E) $\subset$ (B,E) or (A,E) $\subset$ (C,E).

(i) If (A,E) $\subset$ (B,E) then $m_{(X,E)}$-Cl(A,E) $\subset$ $m_{(X,E)}$-Cl(B,E). But $m_{(X,E)}$-Cl(B,E) $\cap$ (C,E) = ϕ. Hence, $m_{(X,E)}$-Cl(A,E)$\cap$ (C,E) = ϕ. Since (C,E) $\subset$ $m_{(X,E)}$-Cl(A,E), then (C,E) = ϕ this is a contradiction.

(ii) If (A,E) $\subset$ (C,E) then in the same way we can prove that (B,E) = ϕ, which is a contradiction. Therefore, $m_{(X,E)}$-Cl(A,E) is soft m-connected.

Remark 3.11. Let (X, τ, E) be soft topological space over X, we put $m_{(X,E)} = \tau$ let soft set (A,E) be a soft connected (resp. soft semi connected,soft pre connected, soft b-connected)set then $m_{(X,E)}$-Cl(A,E) is soft connected(resp. soft semi connected,soft pre connected, soft b-connected).

Theorem 3.8. *Let $m_{(X,E)}$ be a soft m-structure over X with the property* **B**. *In (X,$m_{(X,E)}$), let the soft set (A,E) be a soft m-connected set and (A,E) $\subset$ (B,E) $\subset$ $m_{(X,E)}$-Cl(A,E) then (B,E) is soft m-connected.*

Proof: If (B,E) is not soft m-connected, then there exist two soft sets (C,E) and (D,E) such that $m_{(X,E)}$-Cl(C,E) $\cap$ (D,E) = (C,E) $\cap$ $m_{(X,E)}$-Cl(D,E)= ϕ and (B,E) = (C,E) $\cup$ (D,E). Since (A,E) $\subset$ (B,E), thus either (A,E) $\subset$ (C,E) or (A,E) $\subset$ (D,E). Suppose (A,E) $\subset$ (C,E) then $m_{(X,E)}$-Cl(A,E) $\subset$ $m_{(X,E)}$-Cl(C,E), thus $m_{(X,E)}$-Cl(A,E) $\subset$ (D,E) = $m_{(X,E)}$-Cl(C,E) $\subset$ (D,E) = ϕ. But (D,E) $\subset$ (B,E) $\subset$ $m_{(X,E)}$-Cl(A,E), thus $m_{(X,E)}$-Cl(A,E) $\cap$ (D,E) =(D,E). Therefore, (D,E) =ϕ which is a contradiction. Thus, (B,E) is a soft m-connected set.

If (A,E) $\subset$ (B,E), then we can prove that (C,E) = ϕ. This is a contradiction. Then (B,E) is soft m-connected.

Remark 3.12. Let (X, τ ,E) be a soft topological space over X, so we put $m_{(X,E)}$ = τ. Also, let the soft set (A,E) be a soft connected (resp. soft semi-connected, soft preconnected, soft b-connected) set and (A,E) $\subset$ (B,E) $\subset$ $m_{(X,E)}$-Cl(A,E), then (B,E) is soft connected (resp. soft semi-connected, soft preconnected, soft b-connected).

Remark 3.13. Let (X,τ,E) be a soft topological space over X, and (F,E) be a soft set over X. (X,τ,E) is soft connected (soft semi-connected, soft preconnected, soft b-connected) if and only if there does not exist nonempty soft set (F,E) over X which is both soft open (resp. soft semi-open, soft preopen, soft b-open) and soft closed (resp. soft semi-closed, soft pre-closed, soft b-closed) set over X.

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