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Soft g*-Closed Sets in Soft Biminimal Spaces

*R. Gowri[1] S. Vembu[2]
[1] *Department of Mathematics, Government College for Women (Autonomous), Kumbakonam, India*
[2] *Research Scholar, Department of Mathematics, Government College for Women (Autonomous), Kumbakonam, India*
Corresponding Author: R. Gowri

Abstract:
In this paper, we introduce $sg^*\tilde{m}_{(i,j)}$-closed sets and $sg^*\tilde{m}_{(i,j)}$-open sets in soft biminimal spaces which are defined over an initial universe set with a fixed set of parameters and its basic properties are investigated. Also, we introduce $\tilde{m}_{(i,j)} - T^*_{\frac{1}{2}}$-spaces and $\tilde{m}_{(i,j)} - T^{**}_{\frac{1}{2}}$-spaces in soft biminimal spaces.

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I. Introduction

Levine [7] introduced generalized closed and open sets in topological spaces. Let X be a nonempty set and m^1_X, m^2_X be biminimal structures on X. A triple (X, m^1_X, m^2_X) is called a biminimal structure space (briefly bim-space) defined by C. Boonpok [1]. Also, he studied $m^1_X m^2_X$-closed sets and $m^1_X m^2_X$-open sets in biminimal structure spaces. C. Viriyapong [16] et.al introduced generalized m-closed sets in biminimal structure spaces. He defined a subset A of a biminimal structure space (X, m^1_X, m^2_X) is said to be (i,j)-generalized m-closed (briefly $gm^{(i,j)}_X$-closed) if $m^j_X - Cl(A) \subseteq U$ whenever $A \subseteq U$ and $U \in m^i_X$. Also, introduced separation axioms $m^{(i,j)} - T_{\frac{1}{2}}$, $m^{(i,j)} - T^{\xi}_{\frac{1}{2}}$ and $m^{(i,j)} - {}^{\xi}T_{\frac{1}{2}}$ in biminimal structure spaces. D. Molodtsov [9] introduced the concept of soft set theory and started to develop the basics of the corresponding theory as a new approach for modeling uncertainties. In this paper, we introduce soft g^*-closed sets in soft biminimal spaces which are defined over an initial universe with a fixed set of parameters and its basic properties are investigate and we introduce $\tilde{m}_{(i,j)} - T^*_{\frac{1}{2}}$ and $\tilde{m}_{(i,j)} - T^{**}_{\frac{1}{2}}$-spaces in soft biminimal spaces.

II. Preliminaries

Definition 2.1 [9] *Let U be an initial universe and E be a set of parameters. Let $P(U)$ denote the power set of U and A be a nonempty subset of E. A soft set F_A on the universe U is defined by the set of ordered pairs $F_A = \{(x, f_A(x)) : x \in E\}$, where $f_A : E \to P(U)$ such that $f_A(x) = \emptyset$ if $x \notin A$. Here, f_A is called approximate function of the soft set F_A. The value of $f_A(x)$ may be arbitrary, some of them may* *be empty, some may have non empty intersection.*

Note that the set of all soft sets over U will be denoted by S(U).

Definition 2.2 [3] *Let X be an initial universe set, E be the set of parameters and $A \subseteq E$. Let F_A be a non empty soft set over X and $\tilde{P}(F_A)$ is the soft power set of F_A. A subfamily $\tilde{m}$ of $\tilde{P}(F_A)$ is called a soft minimal set over X if $F_\emptyset \in \tilde{m}$ and $F_A \in \tilde{m}$.*

$(F_A, \tilde{m})$ or $(X, \tilde{m}, E)$ is called a soft minimal space over X. Each member of $\tilde{m}$ is said to be $\tilde{m}$ -soft open set and the complement of an $\tilde{m}$-soft open set is said to be $\tilde{m}$-soft closed set over X.

Definition 2.3 [3] *Let X be an initial universe set, E be the set of parameters and $A \subseteq E$. Let F_A be a non empty soft set over X. Let $(F_A, \tilde{m_1})$ and $(F_A, \tilde{m_2})$ be the two different soft minimals over X. Then $(X, \tilde{m_1}, \tilde{m_2}, E)$ or $(F_A, \tilde{m_1}, \tilde{m_2})$ is called a soft biminimal spaces.*

Definition 2.4 [3] *Let $(F_A, \tilde{m})$ be a soft minimal space over X. For a soft subset F_B of F_A, the $\tilde{m}$-soft closure of F_B and $\tilde{m}$-soft interior of F_B are defined as follows:*

(1) $\tilde{m}Cl(F_B) = \cap \left\{ F_\alpha : F_B \tilde{\subseteq} F_\alpha, F_A - F_\alpha \in \tilde{m} \right\}$,

(2) $\tilde{m}Int(F_B) = \cup \left\{ F_\beta : F_\beta \tilde{\subseteq} F_B, F_\beta \in \tilde{m} \right\}$.

Lemma 2.5 [3] *Let $(F_A, \tilde{m})$ be a soft minimal space over X. For a soft subset F_B and F_C of F_A, the following properties hold:*

(1) $\tilde{m}Cl(F_A - F_B) = F_A - \tilde{m}Int(F_B)$ *and* $\tilde{m}Int(F_A - F_B) = F_A - \tilde{m}Cl(F_B)$,

(2) If $(F_A - F_B) \in \tilde{m}$, *then* $\tilde{m}Cl(F_B) = F_B$ *and if* $F_B \in \tilde{m}$, *then* $\tilde{m}Int(F_B) = F_B$,

(3) $\tilde{m}Cl(F_\emptyset) = F_\emptyset$, $\tilde{m}Cl(F_A) = F_A$, $\tilde{m}Int(F_\emptyset) = F_\emptyset$ *and* $\tilde{m}Int(F_A) = F_A$,

(4) If $F_B \tilde{\subseteq} F_C$, *then* $\tilde{m}Cl(F_B) \tilde{\subseteq} \tilde{m}Cl(F_C)$ *and* $\tilde{m}Int(F_B) \tilde{\subseteq} \tilde{m}Int(F_C)$,

(5) $F_B \tilde{\subseteq} \tilde{m}Cl(F_B)$ *and* $\tilde{m}Int(F_B) \tilde{\subseteq} F_B$,

(6) $\tilde{m}Cl(\tilde{m}Cl(F_B)) = \tilde{m}Cl(F_B)$ *and* $\tilde{m}Int(\tilde{m}Int(F_B)) = \tilde{m}Int(F_B)$.

Lemma 2.6 [3] *Let F_A be a non empty soft set and $\tilde{m}$ be soft minimal over X satisfying property $\mathcal{B}$. For a soft subset F_B of F_A, the following properties hold:*

(1) $F_B \in \tilde{m}$ *if and only if* $\tilde{m}Int(F_B) = F_B$,

(2) F_B *is* $\tilde{m}$*-closed if and only if* $\tilde{m}Cl(F_B) = F_B$,

(3) $\tilde{m}Int(F_B) \in \tilde{m}$ *and* $\tilde{m}Cl(F_B) \in \tilde{m}$*-closed.*

Definition 2.7 [3] *Let F_A be a non-empty soft set and $\tilde{m}$ be soft minimal over X satisfying property $\mathcal{B}$ if the union of any family of subsets belonging to $\tilde{m}$ belongs to $\tilde{m}$.*

Definition 2.8 [4] *A soft subset F_B of a soft biminimal space $(F_A, \tilde{m_1}, \tilde{m_2})$ is called a soft generalized $\tilde{m}_i\tilde{m}_j$-closed sets (briefly $sg\tilde{m}_{(i,j)}$-closed) if $\tilde{m}_jCl(F_B) \tilde{\subseteq} U_B$ whenever $F_B \tilde{\subseteq} U_B$ and U_B is soft $\tilde{m}_i$-open, where $i, j = 1, 2$ and $i \neq j$. The complement of a $sg\tilde{m}_{(i,j)}$-closed set is called a $sg\tilde{m}_{(i,j)}$-open.*

Definition 2.9 [4] *A soft minimal space $(F_A, \tilde{m})$ is said to be $T_{\frac{1}{2}}$-space if every $sg\tilde{m}$-closed set is soft $\tilde{m}$-closed.*

III. $sg^*\tilde{m}_{(i,j)}$- Closed Sets In Soft Biminimal Spaces

Definition 3.1 *A soft subset F_B of a soft biminimal space $(F_A, \tilde{m_1}, \tilde{m_2})$ is said to be $sg^*\tilde{m}_{(i,j)}$-closed set if $\tilde{m}_jCl(F_B) \tilde{\subseteq} U_B$ whenever $F_B \tilde{\subseteq} U_B$ and U_B is $sg\tilde{m}_i$-open, where $i, j = 1, 2$ and $i \neq j$. The complement of a $sg^*\tilde{m}_{(i,j)}$-closed set is said to be $sg^*\tilde{m}_{(i,j)}$-open.*

The family of all $sg^*\tilde{m}_{(i,j)}$-closed (resp. $sg^*\tilde{m}_{(i,j)}$-open)sets of $(F_A, \tilde{m_1}, \tilde{m_2})$ is denoted by $sg^*\tilde{m}_{(i,j)}C(F_A)$ (resp. $sg^*\tilde{m}_{(i,j)}O(F_A)$), where $i, j = 1, 2$ and $i \neq j$.

Example 3.2 *Let $X = \{u_1, u_2\}$, $E = \{x_1, x_2, x_3\}$, $A = \{x_1, x_2\} \subseteq E$ and*
$F_A = \{(x_1, \{u_1, u_2\}), (x_2, \{u_1, u_2\})\}$. Then
$F_{A_1} = \{(x_1, \{u_1\})\}$, $F_{A_2} = \{(x_1, \{u_2\})\}$, $F_{A_3} = \{(x_1, \{u_1, u_2\})\}$,
$F_{A_4} = \{(x_2, \{u_1\})\}$, $F_{A_5} = \{(x_2, \{u_2\})\}$, $F_{A_6} = \{(x_2, \{u_1, u_2\})\}$,
$F_{A_7} = \{(x_1, \{u_1\}), (x_2, \{u_1\})\}$, $F_{A_8} = \{(x_1, \{u_1\}), (x_2, \{u_2\})\}$,
$F_{A_9} = \{(x_1, \{u_1\}), (x_2, \{u_1, u_2\})\}$, $F_{A_{10}} = \{(x_1, \{u_2\}), (x_2, \{u_1\})\}$,
$F_{A_{11}} = \{(x_1, \{u_2\}), (x_2, \{u_2\})\}$, $F_{A_{12}} = \{(x_1, \{u_2\}), (x_2, \{u_1, u_2\})\}$
$F_{A_{13}} = \{(x_1, \{u_1, u_2\}), (x_2, \{u_1\})\}$, $F_{A_{14}} = \{(x_1, \{u_1, u_2\}), (x_2, \{u_2\})\}$,
$F_{A_{15}} = F_A$, $F_{A_{16}} = F_\emptyset$ *are all soft subsets of* F_A

Take, $\tilde{m_1} = \{F_\emptyset, F_{A_2}, F_{A_8}, F_{A_{11}}, F_A\}$ *and* $\tilde{m_2} = \{F_\emptyset, F_{A_8}, F_{A_{13}}, F_A\}$.
Here, $F_\emptyset$, F_{A_5}, F_{A_7}, F_{A_9}, $F_{A_{10}}$, $F_{A_{12}}$, $F_{A_{13}}$, F_A *are* $sg^*\tilde{m}_{(1,2)}$*-closed sets*

Definition 3.3 *A soft subset F_B of a soft biminimal spaces $(F_A, \tilde{m_1}, \tilde{m_2})$ is said to be pairwise $sg^*\tilde{m}$-closed if F_B is $sg^*\tilde{m}_{(1,2)}$-closed and $sg^*\tilde{m}_{(2,1)}$-closed. The complement of a pairwise $sg^*\tilde{m}$-closed set is said to be pairwise $sg^*\tilde{m}$-open.*

Remark 3.4 *By setting $\tilde{m_1} = \tilde{m_2}$ in Definition 3.1, a $sg^*\tilde{m}_{(i,j)}$-closed becomes $sg^*\tilde{m}$-closed set.*

Proposition 3.5 *If F_B is soft $\tilde{m}_j$-closed subset of $(F_A, \tilde{m_1}, \tilde{m_2})$, then F_B is $sg^*\tilde{m}_{(i,j)}$-closed.*

The converse of the above proposition 3.5 is not true as seen from the following example.

Example 3.6 *In example 3.2, the soft subset F_{A_7} is $sg^*\tilde{m}_{(1,2)}$-closed but not soft $\tilde{m_2}$-closed.*

Proposition 3.7 *If F_B is both $sg\tilde{m}_i$-open and $sg^*\tilde{m}_{(i,j)}$-closed, then F_B is soft $\tilde{m}_j$-closed.*

Proposition 3.8 *Every $sg^*\tilde{m}_{(i,j)}$-closed set is $sg\tilde{m}_{(i,j)}$-closed.*

The converse of the above proposition 3.8 is not true as can be seen from the following example

Example 3.9 *Let us consider the soft subsets of F_A that are given in Example 3.2. Let $(F_A, \tilde{m}_1, \tilde{m}_2)$ be a soft biminimal space where $X = \{u_1, u_2\}$, $E = \{x_1, x_2, x_3\}$, $A = \{x_1, x_2\} \subseteq E$, $F_A = \{(x_1, \{u_1, u_2\}), (x_2, \{u_1, u_2\})\}$ and $\tilde{m}_1 = \{F_\emptyset, F_{A_2}, F_{A_7}, F_{A_{12}}, F_A\}$, $\tilde{m}_2 = \{F_\emptyset, F_{A_3}, F_{A_8}, F_{A_9}, F_A\}$. Then the soft subset F_{A_3} is $sg\tilde{m}_{(1,2)}$-closed but not $sg^*\tilde{m}_{(1,2)}$-closed set.*

Remark 3.10 *$sg^*\tilde{m}_{(i,j)}$-closed sets and $sg\tilde{m}_j$-closed sets are independent. The following example supports our claim*

Example 3.11 *Let us consider the soft subsets of F_A that are given in Example 3.2. Let $(F_A, \tilde{m}_1, \tilde{m}_2)$ be a soft biminimal space where $X = \{u_1, u_2\}$, $A = \{x_1, x_2\}$, $F_A = \{(x_1, \{u_1, u_2\}), (x_2, \{u_1, u_2\})\}$ and $\tilde{m}_1 = \{F_\emptyset, F_{A_4}, F_{A_7}, F_{A_{10}}, F_A\}$, $\tilde{m}_2 = \{F_\emptyset, F_{A_5}, F_{A_8}, F_{A_{12}}, F_A\}$. Then the soft subset F_{A_2} is $sg\tilde{m}_2$-closed but not $sg^*\tilde{m}_{(1,2)}$-closed set. Also, the soft subset F_{A_8} is $sg^*\tilde{m}_{(1,2)}$-closed set but not $sg\tilde{m}_2$-closed.*

Proposition 3.12 *If F_B and G_B are $sg^*\tilde{m}_{(i,j)}$-closed, then $F_B \cup G_B$ is also $sg^*\tilde{m}_{(i,j)}$-closed set.*

Remark 3.13 *The intersection of two $sg^*\tilde{m}_{(i,j)}$-closed sets need not be $sg^*\tilde{m}_{(i,j)}$-closed as seen from the following example.*

Example 3.14 *In Example 3.9, F_{A_6} and $F_{A_{14}}$ are $sg^*\tilde{m}_{(1,2)}$-closed but $F_{A_6} \cap F_{A_{14}} = F_{A_5}$ is not $sg^*\tilde{m}_{(1,2)}$-closed.*

Remark 3.15 *$sg^*\tilde{m}_{(1,2)}C(F_A)$ is generally not equal to $sg^*\tilde{m}_{(2,1)}C(F_A)$.*

Example 3.16 *Let us consider the soft subsets of F_A that are given in Example 3.2. Let $(F_A, \tilde{m}_1, \tilde{m}_2)$ be a soft biminimal space where $X = \{u_1, u_2\}$, $E = \{x_1, x_2, x_3\}$, $A = \{x_1, x_2\} \subseteq E$, $F_A = \{(x_1, \{u_1, u_2\}), (x_2, \{u_1, u_2\})\}$ and $\tilde{m}_1 = \{F_\emptyset, F_{A_2}, F_{A_7}, F_A\}$, $\tilde{m}_2 = \{F_\emptyset, F_{A_1}, F_{A_7}, F_{A_8}, F_{A_{13}}, F_A\}$. Then, $sg^*\tilde{m}_{(1,2)}C(F_A) = \{F_\emptyset, F_{A_2}, F_{A_5}, F_{A_9}, F_{A_{10}}, F_{A_{11}}, F_{A_{12}}, F_{A_{14}}, F_A\}$ and $sg^*\tilde{m}_{(2,1)}C(F_A) = \{F_\emptyset, F_{A_3}, F_{A_5}, F_{A_{10}}, F_{A_{11}}, F_{A_{12}}, F_{A_{13}}, F_{A_{14}}, F_A\}$. Thus, $sg\tilde{m}_{(1,2)}C(F_A) \neq sg\tilde{m}_{(2,1)}C(F_A)$.*

Proposition 3.17 *Let $\tilde{m}_1$ and $\tilde{m}_2$ be soft minimals on F_A. If $\tilde{m}_1 \tilde{\subseteq} \tilde{m}_2$, then $sg^*\tilde{m}_{(2,1)}C(F_A) \tilde{\subseteq} sg^*\tilde{m}_{(1,2)}C(F_A)$.*

The converse of the above proposition 3.17 is not true as seen from the following example.

Example 3.18 *Let us consider the soft subsets of F_A that are given in Example 3.2. Let $(F_A, \tilde{m}_1, \tilde{m}_2)$ be a soft biminimal space where $X = \{u_1, u_2\}$, $E = \{x_1, x_2, x_3\}$, $A = \{x_1, x_2\} \subseteq E$, $F_A = \{(x_1, \{u_1, u_2\}), (x_2, \{u_1, u_2\})\}$ and $\tilde{m}_1 = \{F_\emptyset, F_{A_8}, F_{A_{14}}, F_A\}$, $\tilde{m}_2 = \{F_\emptyset, F_{A_8}, F_A\}$. Then $sg^*\tilde{m}_{(2,1)}C(F_A) \tilde{\subsetneq} sg^*\tilde{m}_{(1,2)}C(F_A)$ but $\tilde{m}_1$ is not contained in $\tilde{m}_2$.*

Proposition 3.19 *For each element $(x, u) \in (F_A, \tilde{m}_1, \tilde{m}_2)$, the singleton $\{(x, u)\}$ is $sg\tilde{m}_i$-closed or $\{(x, u)\}^c$ is $sg^*\tilde{m}_{(i,j)}$-closed set.*

Proof: Suppose that $\{(x, u)\}$ is not sg$\tilde{m}_i$-closed. Then $\{(x, u)\}^c$ is not sg$\tilde{m}_i$-open and F_A is the only sg$\tilde{m}_i$-open set which contains $\{(x, u)\}^c$ and $\{(x, u)\}^c$ is $sg^*\tilde{m}_{(i,j)}$-closed. □

Proposition 3.20 *Let F_B be a soft subset of soft biminimal space $(F_A, \tilde{m}_1, \tilde{m}_2)$. If F_B be $sg^*\tilde{m}_{(i,j)}$-closed, then $\tilde{m}_jCl(F_B) - F_B$ contains no nonempty $sg\tilde{m}_i$-closed set, where $i, j = 1, 2$ and $i \neq j$*

Proof: Let F_B be $sg^*\tilde{m}_{(i,j)}$-closed set and H_B be a $sg\tilde{m}_i$-closed set such that $H_B \tilde{\subseteq} \tilde{m}_jCl(F_B) - F_B$. Since $F_B \in sg^*\tilde{m}_{(i,j)}(F_A)$, we have $\tilde{m}_jCl(F_B) \tilde{\subsetneq} (H_B)^c$. Thus $H_B \tilde{\subsetneq} [\tilde{m}_jCl(F_B)] \cap [\tilde{m}_jCl(F_B)]^c = F_\emptyset$. Therefore, $H_B = F_\emptyset$. Hence, $\tilde{m}_jCl(F_B) - F_B$ contains no nonempty sg$\tilde{m}_i$-closed set. □

Remark 3.21 *The converse of the above proposition 3.20 is not true as seen from the following example*

Example 3.22 *Let us consider the soft subsets of F_A that are given in Example 3.2. Let $(F_A, \tilde{m}_1, \tilde{m}_2)$ be a soft biminimal space where $X = \{u_1, u_2\}$, $E = \{x_1, x_2, x_3\}$, $A = \{x_1, x_2\} \subseteq E$ and $F_A = \{(x_1, \{u_1, u_2\}), (x_2, \{u_1, u_2\})\}$, and $\tilde{m}_1 = \{F_\emptyset, F_{A_2}, F_{A_5}, F_{A_7}, F_A\}$ and $\tilde{m}_2 = \{F_\emptyset, F_{A_5}, F_{A_7}, F_A\}$. Take $F_B = F_{A_5}$. Then $\tilde{m}_2Cl(F_B) - F_B = \tilde{m}_2Cl(F_{A_5}) - F_{A_5} = F_{A_2}$ does not contain any non empty $sg\tilde{m}_1$-closed set. But $F_B = F_{A_5}$ is not $sg^*\tilde{m}_{(1,2)}$-closed.*

Corollary 3.23 *Let $\tilde{m}_1$ and $\tilde{m}_2$ be soft minimals on F_A satisfying property $\mathcal{B}$. If F_B is $sg^*\tilde{m}_{(i,j)}$-closed set in $(F_A, \tilde{m}_1, \tilde{m}_2)$ then F_B is soft $\tilde{m}_j$-closed if and only if $\tilde{m}_jCl(F_B) - F_B$ is $sg\tilde{m}_i$-closed.*

Proof: If F_B is soft $\tilde{m}_j$-closed, then $\tilde{m}_jCl(F_B) = F_B$. That is $\tilde{m}_jCl(F_B) - F_B = F_\emptyset$ and hence $\tilde{m}_jCl(F_B) - F_B$ is sg$\tilde{m}_i$-closed.
Conversely, If $\tilde{m}_jCl(F_B) - F_B$ is sg$\tilde{m}_i$-closed, then by proposition 3.20, $\tilde{m}_jCl(F_B) - F_B = F_\emptyset$, since F_B is $sg^*\tilde{m}_{(i,j)}$-closed. Therefore, F_B is soft $\tilde{m}_j$-closed. □

Proposition 3.24 *If F_B be $sg^*\tilde{m}_{(i,j)}$-closed set of $(F_A, \tilde{m}_1, \tilde{m}_2)$ such that $F_B \tilde{\subsetneq} G_B \tilde{\subsetneq} \tilde{m}_jCl(F_B)$, then G_B is also $sg^*\tilde{m}_{(i,j)}$-closed set of $(F_A, \tilde{m}_1, \tilde{m}_2)$, where $i, j = 1, 2$ and $i \neq j$.*

Proof: Suppose that F_B is $sg^*\tilde{m}_{(i,j)}$-closed set and $F_B \tilde{\subseteq} G_B \tilde{\subseteq} \tilde{m}_jCl(F_B)$. Let $G_B \tilde{\subseteq} U_B$ and U_B is sg$\tilde{m}_i$-open. Then $F_B\tilde{\subseteq}U_B$. Since F_B is $sg^*\tilde{m}_{(i,j)}$-closed, we have $\tilde{m}_jCl(F_B) \tilde{\subseteq} U_B$. Since $G_B \tilde{\subseteq} \tilde{m}_jCl(F_B)$, $\tilde{m}_jCl(G_B) \tilde{\subseteq} \tilde{m}_jCl(F_B) \tilde{\subseteq} U_B$. Hence, G_B is $sg^*\tilde{m}_{(i,j)}$-closed set. □

Theorem 3.25 *A soft subset F_B of soft biminimal space in $(F_A, \tilde{m}_1, \tilde{m}_2)$ is $sg^*\tilde{m}_{(i,j)}$-open set if and only if $H_B \tilde{\subseteq} \tilde{m}_jInt(F_B)$ whenever H_B is sg$\tilde{m}_i$-closed and $H_B \tilde{\subseteq} F_B$, where $i, j = 1, 2$ and $i \neq j$.*

Proof: Let F_B be $sg^*\tilde{m}_{(i,j)}$-open set. Let H_B be a sg$\tilde{m}_i$-closed set such that $H_B \tilde{\subseteq} F_B$. Let $F_B \tilde{\subseteq} H_B$ and H_B is sg$\tilde{m}_i$-closed. Then $(F_B)^c \tilde{\subseteq} (H_B)^c$ and $(H_B)^c$ is sg$\tilde{m}_i$-open, we have $(F_B)^c$ is $sg^*\tilde{m}_{(i,j)}$-closed. Hence, $[\tilde{m}_jCl(F_B)^c] \tilde{\subseteq} (H_B)^c$. Consequently, $[\tilde{m}_jInt(F_B)]^c \tilde{\subseteq} (H_B)^c$. Therefore, $H_B \tilde{\subseteq} \tilde{m}_jInt(F_B)$.
Conversely, suppose $H_B \tilde{\subseteq} \tilde{m}_jInt(F_B)$ whenever $H_B \tilde{\subseteq} F_B$ and H_B is sg$\tilde{m}_i$-closed. Let $(F_B)^c \tilde{\subseteq} U_B$ and U_B is sg$\tilde{m}_i$-open. Then $(U_B)^c \tilde{\subseteq} F_B$ and $(U_B)^c$ is sg$\tilde{m}_i$-closed. By hypothesis $(U_B)^c \tilde{\subseteq} \tilde{m}_jInt(F_B)$. Hence, $[\tilde{m}_jInt(F_B)]^c \tilde{\subseteq} U_B$. (i.e) $[\tilde{m}_jCl(F_B)^c] \tilde{\subseteq} U_B$. Consequently, $(F_B)^c$ is $sg^*\tilde{m}_{(i,j)}$-closed set. Hence, F_B is $sg^*\tilde{m}_{(i,j)}$-open. □

Remark 3.26 *Every soft $\tilde{m}_1$-open set is $sg^*\tilde{m}_{(1,2)}$-open but the converse is not true in general as can be seen from the following example.*

Example 3.27 *Let us consider the soft subsets of F_A that are given in Example 3.2. Let $(F_A, \tilde{m}_1, \tilde{m}_2)$ be a soft biminimal space where $X = \{u_1, u_2\}$,
$E = \{x_1, x_2, x_3\}$, $A = \{x_1, x_2\} \subseteq E$ and $F_A = \{(x_1, \{u_1, u_2\}), (x_2, \{u_1, u_2\})\}$,
$\tilde{m}_1 = \{F_\emptyset, F_{A_1}, F_{A_6}, F_{A_9}, F_A\}$ and $\tilde{m}_2 = \{F_\emptyset, F_{A_7}, F_{A_{13}}, F_A\}$. Then the soft subset F_{A_8} is $sg^*\tilde{m}_{(1,2)}$-open but not soft $\tilde{m}_1$-open.*

Remark 3.28 *The union of any two $sg^*\tilde{m}_{(i,j)}$-open set is not necessary $sg^*\tilde{m}_{(i,j)}$-open set as in the following example.*

Example 3.29 *Let us consider the soft subsets of F_A that are given in Example 3.2. Let $(F_A, \tilde{m}_1, \tilde{m}_2)$ be a soft biminimal space where $X = \{u_1, u_2\}$,
$E = \{x_1, x_2, x_3\}$, $A = \{x_1, x_2\} \subseteq E$, $F_A = \{(x_1, \{u_1, u_2\}), (x_2, \{u_1, u_2\})\}$ and
$\tilde{m}_1 = \{F_\emptyset, F_{A_1}, F_{A_4}, F_{A_8}, F_A\}$, $\tilde{m}_2 = \{F_\emptyset, F_{A_2}, F_{A_5}, F_{A_{10}}, F_A\}$. Then $F_B = F_{A_2}$ and $G_B = F_{A_8}$ are $sg^*\tilde{m}_{(1,2)}$-open sets but $F_B \cup G_B = F_{A_{14}}$ is not $sg^*\tilde{m}_{(1,2)}$-open.*

Proposition 3.30 *If F_B and G_B are two $sg^*\tilde{m}_{(i,j)}$-open subsets of soft biminimal space $(F_A, \tilde{m}_1, \tilde{m}_2)$, then $F_B \cap G_B$ is also $sg^*\tilde{m}_{(i,j)}$-open.*

Proof: Suppose H_B is sg$\tilde{m}_j$-closed set contained in $F_B \cap G_B$. Since F_B and G_B are $sg^*\tilde{m}_{(i,j)}$-open sets. Since, $H_B \tilde{\subseteq} F_B \cap G_B$, we have $H_B\tilde{\subseteq}F_B$ and $H_B\tilde{\subseteq}G_B$. Since F_B and G_B are two $sg^*\tilde{m}_{(i,j)}$-open sets, we have $H_B\tilde{\subseteq}\tilde{m}_jInt(F_B)$ and $H_B\tilde{\subseteq}\tilde{m}_jInt(G_B)$. Therefore, $H_B\tilde{\subseteq}\tilde{m}_jInt(F_B) \cap \tilde{m}_jInt(G_B)\tilde{\subseteq}\tilde{m}_jInt(F_B \cap G_B)$. Hence, $F_B \cap G_B$ is $sg^*\tilde{m}_{(i,j)}$-open. □

Proposition 3.31 *The intersection of $sg^*\tilde{m}_{(i,j)}$-open set and soft $\tilde{m}_j$-open set is always $sg^*\tilde{m}_{(i,j)}$-open.*

Proof: Suppose that F_B is $sg^*\tilde{m}_{(i,j)}$-open and G_B is soft $\tilde{m}_j$-open. Since G_B is soft $\tilde{m}_j$-open, we have $(G_B)^c$ is soft $\tilde{m}_j$-closed. Then $(G_B)^c$ is $sg^*\tilde{m}_{(i,j)}$-closed (by proposition 3.5). Hence, G_B is $sg^*\tilde{m}_{(i,j)}$-open. Hence $F_B \cap G_B$ is $sg^*\tilde{m}_{(i,j)}$-open (by theorem 3.30) □

Proposition 3.32 *Let F_B and G_B be a soft subset of soft biminimal space $(F_A, \tilde{m}_1, \tilde{m}_2)$ such that $\tilde{m}_j Int(F_B) \tilde{\subseteq} G_B \tilde{\subseteq} F_B$. If F_B is $sg^*\tilde{m}_{(i,j)}$-open, then G_B is $sg^*\tilde{m}_{(i,j)}$-open, where $i, j = 1, 2$ and $i \neq j$.*

Proof: Let F_B is $sg^*\tilde{m}_{(i,j)}$-open. Let H_B be a sg$\tilde{m}_i$-closed such that $H_B \tilde{\subseteq} G_B$. Since $H_B \tilde{\subseteq} G_B$ and $G_B \tilde{\subseteq} F_B$, we have $H_B \tilde{\subseteq} F_B$. Therefore, $H_B \tilde{\subseteq} \tilde{m}_j Int(F_B)$. Since $\tilde{m}_j Int(F_B) \tilde{\subseteq} G_B$, we have $\tilde{m}_j Int(\tilde{m}_j Int(F_B)) \tilde{\subseteq} \tilde{m}_j Int(G_B)$. Therefore, $\tilde{m}_j Int(F_B) \tilde{\subseteq} \tilde{m}_j Int(G_B)$. Consequently, $H_B \tilde{\subseteq} \tilde{m}_j Int(G_B)$. Hence, G_B is $sg^*\tilde{m}_{(i,j)}$-open. □

Proposition 3.33 *A soft subset F_B is $sg^*\tilde{m}_{(i,j)}$-closed set then $\tilde{m}_j Cl(F_B) - F_B$ is $sg^*\tilde{m}_{(i,j)}$-open set.*

Proof: Let F_B is $sg^*\tilde{m}_{(i,j)}$-closed set. Let $H_B \tilde{\subseteq} \tilde{m}_j Cl(F_B) - F_B$ where H_B is sg$\tilde{m}_i$-closed set. Since F_B is $sg^*\tilde{m}_{(i,j)}$-closed, we have $\tilde{m}_j Cl(F_B) - F_B$ does not contain nonempty sg$\tilde{m}_i$-closed by Proposition 3.20. Consequently, $H_B = F_\emptyset$. Therefore, $F_\emptyset \tilde{\subseteq} \tilde{m}_j Cl(F_B) - F_B$, $F_\emptyset \tilde{\subseteq} \tilde{m}_j Int(\tilde{m}_j Cl(F_B) - F_B)$, we obtain $H_B \tilde{\subseteq} \tilde{m}_j Int(\tilde{m}_j Cl(F_B) - F_B)$. Hence, $\tilde{m}_j Cl(F_B) - F_B$ is $sg^*\tilde{m}_{(i,j)}$-open. □

IV. $\tilde{m}_{(i,j)} - T^*_{\frac{1}{2}}$ and $\tilde{m}_{(i,j)} - T^{**}_{\frac{1}{2}}$-Soft biminimal spaces

In this section, we introduce $\tilde{m}_{(i,j)} - T^*_{\frac{1}{2}}$ and $\tilde{m}_{(i,j)} - T^{**}_{\frac{1}{2}}$-soft biminimal spaces with the help of $sg^*\tilde{m}_{(i,j)}$-closed set.

Definition 4.1 *A soft biminimal space $(F_A, \tilde{m}_1, \tilde{m}_2)$ is said to be an $\tilde{m}_{(i,j)} - T_{\frac{1}{2}}$-space if every sg$\tilde{m}_{(i,j)}$-closed set is soft $\tilde{m}_j$-closed.*

Definition 4.2 *A soft biminimal space $(F_A, \tilde{m}_1, \tilde{m}_2)$ is said to be an $\tilde{m}_{(i,j)} - T^*_{\frac{1}{2}}$-space if every $sg^*\tilde{m}_{(i,j)}$-closed set is soft $\tilde{m}_j$-closed.*

Proposition 4.3 *If $(F_A, \tilde{m}_1, \tilde{m}_2)$ is $\tilde{m}_{(i,j)} - T_{\frac{1}{2}}$-space, then it is a $\tilde{m}_{(i,j)} - T^*_{\frac{1}{2}}$-space.*

Remark 4.4 *The converse of the above Proposition 4.3 is not trure. The following example supports our claim.*

Example 4.5 *Let us consider the soft subsets of F_A that are given in Example 3.2. Let $(F_A, \tilde{m}_1, \tilde{m}_2)$ be a soft biminimal space where $U = \{u_1, u_2\}$, $A = \{x_1, x_2\}$ and $F_A = \{(x_1, \{u_1, u_2\}), (x_2, \{u_1, u_2\})\}$, $\tilde{m}_1 = \{F_\emptyset, F_{A_1}, F_A\}$ and $\tilde{m}_2 = \{F_\emptyset, F_{A_1}, F_{A_{12}}, F_A\}$. Then $(F_A, \tilde{m}_1, \tilde{m}_2)$ is $\tilde{m}_{(1,2)} - T^*_{\frac{1}{2}}$-space but not a $\tilde{m}_{(1,2)} - T_{\frac{1}{2}}$-space.*

Theorem 4.6 *A soft biminimal space $(F_A, \tilde{m}_1, \tilde{m}_2)$ is a $\tilde{m}_{(i,j)} - T^*_{\frac{1}{2}}$-space if and only if $\{(x,u)\}$ is either soft $\tilde{m}_j$-open or $sg\tilde{m}_i$-closed for each $(x,u) \in F_A$, where $i, j = 1, 2$ and $i \neq j$.*

Proof: Suppose that $\{(x,u)\}$ is not sg$\tilde{m}_i$-closed. Then $\{(x,u)\}^c$ is $sg^*\tilde{m}_{(i,j)}$-closed set by Proposition 3.19 .Since $(F_A, \tilde{m}_1, \tilde{m}_2)$ is an $\tilde{m}_{(i,j)} - T^*_{\frac{1}{2}}$-space, $\{(x,u)\}^c$ is soft $\tilde{m}_j$-closed and hence $\{(x,u)\}$ is soft $\tilde{m}_j$-open. Conversely, let H_B be a $sg^*\tilde{m}_{(i,j)}$-closed set. By assumption, $\{(x,u)\}$ is soft $\tilde{m}_j$-open or $sg\tilde{m}_i$-closed for any $(x,u) \in \tilde{m}Cl(H_B)$. We have the following two cases: case(i): Suppose $\{(x,u)\}$ is soft $\tilde{m}_j$-open. Since $\{(x,u)\} \cap H_B \neq F_\emptyset$, we have $(x,u) \in H_B$. case(ii): Suppose $\{(x,u)\}$ is $sg\tilde{m}_i$-closed. If $(x,u) \notin H_B$, then $\{(x,u)\} \tilde{\subseteq} \tilde{m}Cl(H_B) - H_B$, which is a contradiction to Proposition 3.20. Hence, $(x,u) \in H_B$. Thus in both cases, we conclude that H_B is soft $\tilde{m}_j$-closed. Hence $(F_A, \tilde{m}_1, \tilde{m}_2)$ is an $\tilde{m}_{(i,j)} - T^*_{\frac{1}{2}}$-space. □

Remark 4.7 *$(F_A, \tilde{m}_1)$-space is not generally $\tilde{m} - T^*_{\frac{1}{2}}$-space even if $(F_A, \tilde{m}_1, \tilde{m}_2)$ is $\tilde{m}_{(1,2)} - T^*_{\frac{1}{2}}$-space as shown in the following Example 4.8 . Also $(F_A, \tilde{m}_1, \tilde{m}_2)$ is not generally $\tilde{m}_{(1,2)} - T^*_{\frac{1}{2}}$-space even if both $(F_A, \tilde{m}_1)$ and $(F_A, \tilde{m}_2)$ are $\tilde{m} - T^*_{\frac{1}{2}}$-spaces. This is shown in Example 4.9.*

Example 4.8 *Let us consider the soft subsets of F_A that are given in Example 3.2. Let $(F_A, \tilde{m}_1, \tilde{m}_2)$ be a soft biminimal space where $U = \{u_1, u_2\}$, $A = \{x_1, x_2\}$, $F_A = \{(x_1, \{u_1, u_2\}), (x_2, \{u_1, u_2\})\}$, $\tilde{m}_1 = \{F_\emptyset, F_{A_4}, F_{A_6}, F_A\}$ and $\tilde{m}_2 = \{F_\emptyset, F_{A_4}, F_{A_5}, F_{A_6}, F_A\}$. Then $(F_A, \tilde{m}_1)$ is not $\tilde{m} - T^*_{\frac{1}{2}}$-space but $(F_A, \tilde{m}_1, \tilde{m}_2)$ is $\tilde{m}_{(1,2)} - T^*_{\frac{1}{2}}$-space.*

Example 4.9 *Let us consider the soft subsets of F_A that are given in Example 3.2. Let $(F_A, \tilde{m}_1, \tilde{m}_2)$ be a soft biminimal space where $U = \{u_1, u_2\}$, $A = \{x_1, x_2\}$, $F_A = \{(x_1, \{u_1, u_2\}), (x_2, \{u_1, u_2\})\}$, $\tilde{m}_1 = \{F_\emptyset, F_{A_4}, F_{A_5}, F_{A_6}, F_A\}$ and $\tilde{m}_2 = \{F_\emptyset, F_{A_1}, F_{A_2}, F_{A_3}, F_A\}$. Then both $(F_A, \tilde{m}_1)$ and $(F_A, \tilde{m}_2)$ are $\tilde{m} - T^*_{\frac{1}{2}}$-space but $(F_A, \tilde{m}_1, \tilde{m}_2)$ is not $\tilde{m}_{(1,2)} - T^*_{\frac{1}{2}}$-space.*

Definition 4.10 *A soft biminimal space $(F_A, \tilde{m}_1, \tilde{m}_2)$ is said to be pairwise $\tilde{m} - T_{\frac{1}{2}}$-space if it is both $\tilde{m}_{(1,2)} - T_{\frac{1}{2}}$ and $\tilde{m}_{(2,1)} - T_{\frac{1}{2}}$ -space.*

Definition 4.11 *A soft biminimal space $(F_A, \tilde{m}_1, \tilde{m}_2)$ is said to be pairwise $\tilde{m} - T^*_{\frac{1}{2}}$-space if it is both $\tilde{m}_{(1,2)} - T^*_{\frac{1}{2}}$ and $\tilde{m}_{(2,1)} - T^*_{\frac{1}{2}}$ -space.*

Proposition 4.12 *If $(F_A, \tilde{m}_1, \tilde{m}_2)$ is pairwise $\tilde{m} - T_{\frac{1}{2}}$-space, then it is pairwise $\tilde{m} - T^*_{\frac{1}{2}}$ -space but not conversely.*

Example 4.13 *In Example 4.5. Then $(F_A, \tilde{m}_1, \tilde{m}_2)$ is also $\tilde{m}_{(2,1)} - T^*_{\frac{1}{2}}$ and therefore it is pairwise $\tilde{m} - T^*_{\frac{1}{2}}$ -space. But $(F_A, \tilde{m}_1, \tilde{m}_2)$ is not a pairwise $\tilde{m} - T_{\frac{1}{2}}$ -space, since it is not a $\tilde{m}_{(1,2)} - T_{\frac{1}{2}}$ -space.*

Definition 4.14 *A soft biminimal space $(F_A, \tilde{m}_1, \tilde{m}_2)$ is said to be an $\tilde{m}_{(i,j)} - T^{**}_{\frac{1}{2}}$-space if every $sg\tilde{m}_{(i,j)}$-closed set is $sg^*\tilde{m}_{(i,j)}$-closed.*

Proposition 4.15 *If $(F_A, \tilde{m}_1, \tilde{m}_2)$ is $\tilde{m}_{(i,j)} - T_{\frac{1}{2}}$-space, then it is a $\tilde{m}_{(i,j)} - T^{**}_{\frac{1}{2}}$-space.*

Remark 4.16 *The converse of the above Proposition 4.15 is not trure. The following example supports our claim.*

Example 4.17 *Let us consider the soft subsets of F_A that are given in Example 3.2. Let $(F_A, \tilde{m}_1, \tilde{m}_2)$ be a soft biminimal space where $U = \{u_1, u_2\}$, $A = \{x_1, x_2\}$, $F_A = \{(x_1, \{u_1, u_2\}), (x_2, \{u_1, u_2\})\}$, $\tilde{m}_1 = \{F_\emptyset, F_{A_9}, F_{A_{12}}, F_A\}$ and $\tilde{m}_2 = \{F_\emptyset, F_{A_6}, F_{A_9}, F_{A_{12}}, F_A\}$. Then $(F_A, \tilde{m}_1, \tilde{m}_2)$ is $\tilde{m}_{(1,2)} - T^{**}_{\frac{1}{2}}$-space but not $\tilde{m}_{(1,2)} - T_{\frac{1}{2}}$-space.*

Remark 4.18 *$\tilde{m}_{(i,j)} - T^{*}_{\frac{1}{2}}$ and $\tilde{m}_{(i,j)} - T^{**}_{\frac{1}{2}}$-spaces are independent as seen from the following examples.*

Example 4.19 *Let us consider the soft subsets of F_A that are given in Example 3.2. Let $(F_A, \tilde{m}_1, \tilde{m}_2)$ be a soft biminimal space where $U = \{u_1, u_2\}$, $A = \{x_1, x_2\}$, $F_A = \{(x_1, \{u_1, u_2\}), (x_2, \{u_1, u_2\})\}$, $\tilde{m}_1 = \{F_\emptyset, F_{A_2}, F_A\}$ and $\tilde{m}_2 = \{F_\emptyset, F_{A_2}, F_{A_9}, F_A\}$. Then $(F_A, \tilde{m}_1, \tilde{m}_2)$ is $\tilde{m}_{(1,2)} - T^{*}_{\frac{1}{2}}$-space but not $\tilde{m}_{(1,2)} - T^{**}_{\frac{1}{2}}$-space.*

Example 4.20 *Let us consider the soft subsets of F_A that are given in Example 3.2. Let $(F_A, \tilde{m}_1 \tilde{m}_2)$ be a soft biminimal space where $U = \{u_1, u_2\}$, $A = \{x_1, x_2\}$, $F_A = \{(x_1, \{u_1, u_2\}), (x_2, \{u_1, u_2\})\}$, $\tilde{m}_1 = \{F_\emptyset, F_{A_{13}}, F_{A_{14}}, F_A\}$ and $\tilde{m}_2 = \{F_\emptyset, F_{A_3}, F_A\}$. Then $(F_A, \tilde{m}_1, \tilde{m}_2)$ is $\tilde{m}_{(1,2)} - T^{**}_{\frac{1}{2}}$-space but not $\tilde{m}_{(1,2)} - T^{*}_{\frac{1}{2}}$-space.*

Theorem 4.21 *A soft biminimal space $(F_A, \tilde{m}_1, \tilde{m}_2)$ is $\tilde{m}_{(i,j)} - T_{\frac{1}{2}}$-space if and only if it is both $\tilde{m}_{(i,j)} - T^{*}_{\frac{1}{2}}$ and $\tilde{m}_{(i,j)} - T^{**}_{\frac{1}{2}}$-space*

Proof: Suppose that $(F_A, \tilde{m}_1, \tilde{m}_2)$ is an $\tilde{m}_{(i,j)} - T_{\frac{1}{2}}$-space. Then by Proposition 4.3 and Proposition 4.15, $(F_A, \tilde{m}_1, \tilde{m}_2)$ is $\tilde{m}_{(i,j)} - T^{*}_{\frac{1}{2}}$ and $\tilde{m}_{(i,j)} - T^{**}_{\frac{1}{2}}$-space.
Conversely, suppose that $(F_A, \tilde{m}_1, \tilde{m}_2)$ is both $\tilde{m}_{(i,j)} - T^{*}_{\frac{1}{2}}$ and $\tilde{m}_{(i,j)} - T^{**}_{\frac{1}{2}}$. Let F_B be a sg$\tilde{m}_{(i,j)}$-closed set of $(F_A, \tilde{m}_1, \tilde{m}_2)$. Since $(F_A, \tilde{m}_1, \tilde{m}_2)$ is a $\tilde{m}_{(i,j)} - T^{*}_{\frac{1}{2}}$-space, F_B is a $sg^*\tilde{m}_{(i,j)}$-closed set. Since $(F_A, \tilde{m}_1, \tilde{m}_2)$ is an $\tilde{m}_{(i,j)} - T^{**}_{\frac{1}{2}}$-space, F_B is soft m_j-closed set of $(F_A, \tilde{m}_1, \tilde{m}_2)$. Therefore, $(F_A, \tilde{m}_1, \tilde{m}_2)$ is an $\tilde{m}_{(i,j)} - T_{\frac{1}{2}}$-space. □

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