Time Effective Fuzzy Soft Set and Its Some Applications with and Without a Neutrosophic

Ayman Hazaymeh
Department of Mathematics, Faculty of Science and Information Technology, Jadara University, Irbid, Jordan
Emails: aymanha@jadara.edu.jo

Abstract

As a generalization of fuzzy soft sets, we present the idea of time-effective fuzzy soft sets (T-EFSS) in this study. Additionally, i will describe its fundamental operations complement, union intersection, AND, and OR—and examine their characteristics. I will finally provide two applications of this idea to decision-making situations. The second application that neurosophic Membership offers In addition, to demonstrate influence over variables that might impact membership values following application.

Keywords: soft set; fuzzy soft set;time-fuzzy soft set; effective fuzzy soft set; Neutrosophic set

1 Introduction

Most of the problems in engineering, medical science, economics, the environment, etc. have various uncertainties. Molodtsov[1]] initiated the concept of the soft set theory as a mathematical tool for dealing with such uncertainties. After Molodtsov's work, some operations and applications of soft sets were studied by Chen et al.,[2] Maji et al.[3] and Maji et al.[4] Also, Maji et al.[5]] have introduced the concept of fuzzy soft set as a more general concept and as a combination of fuzzy set and soft set, where they studied its properties. Also, Roy and Maji[6] used this theory to solve some decision-making problems. Further, in 2010, Çağman et al.[12] introduced the concept of fuzzy parameterized fuzzy soft set (*fpfs*) and their operations. as well as the fpfs-aggregation operator to form the fpfs-decision making method, which allows the construction of more efficient decision-processes. Alkhazaleh and Salleh[10] introduced the concept of soft expert sets and fuzzy soft expert sets, where the user can know the opinions of all experts in one model without any operations. In 2011, Salleh[13] gave a brief survey from soft set to intuitionistic fuzzy soft set. For making decisions, immediate sensory information is frequently insufficient in real-world scenarios. It is feasible to distinguish between circumstances that would otherwise seem to be identical by enriching the state with knowledge about past actions and circumstances. This allows one to not only make the right decision but also discover the right decision. Furthermore, historical knowledge can take the place of implausible sensors, like being able to pinpoint a maze's precise location. In situations where time value is ignored and decision-making is imprecise, using historical data as part of the state representation provides us with important information to aid in better decision-making. We must perform certain operations, such as union and intersection, if we wish to gather the opinions of multiple time periods. To solve this problem, in 2013, Ayman A. Hazaymeh,[20] in his PhD thesis, considered a collection of time (periods) and generalized it into a time-fuzzy soft set (TFSS), and studied some of its properties, and explained this concept in a decision making problem. Since there is uncertainty in everything in the world, the neutrosophic has emerged and found a home in science. Previous research has demonstrated the relationship between the neutrosophic set and other sets. Researchers concentrated on a few key concepts, including the neutrosophic set, neutrosophic logic, neutrosophic measure, neutrosophic integral, and neutrosophic set with a single value. Numerous neutrosophic applications may be found in many fields, including information technology, information systems, and decision support systems. Some examples of these fields include

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relational database systems, semantic web services, financial data set identification, decline analysis, and the rise of the new economy.[18] Presented novel developments in the theory and applications of neutrosophic sets, such as bipolar neutrosophic sets, interval-valued neutrosophic sets, and single-valued neutrosophic sets.[17] defined the neutrosophic parameterized soft set and explained how it works [15]. Next, they define the neutrosophic parameterized aggregation operator to construct a neutrosophic parameterized soft decision-making approach that facilitates the development of more efficient decision processes.[19] presented the idea of a time-neuromorphic soft set, examined some of its characteristics, and provided an example of how it may be used in decision-making scenarios. In order to address decision-making issues,[20] presented the idea of "n"-valued refined neutrosophic soft sets and their characteristics; they also suggested a similarity metric between two "n"-valued refined neutrosophic soft sets. Additional influence on parameters could affect membership values after application in a positive way or not at all. If this influence comes from various sources, such as the impact of time history and a set of effective parameters, neutronosophic sets are therefore more advantageous and successful in promoting logical decision-making. The time-effective fuzzy soft set concept will be introduced in this work. As we shall see, it is more effective and beneficial, and the decisions made will be more exact. This implies that when making decisions, we will take the component time value of the information into mind. Additionally, we will define and examine the features of its fundamental operations: complement, union, and intersection. Lastly, we will provide an application of this idea to situations involving decision-making.

2 Preliminaries

In this section, we introduce some basic notions in soft set theory. Molodtsov[1] defined soft set over U in the following way: Let U be a universe set and E be a set of parameters; $P(U)$ denotes the power set of U and $A \subseteq E$.

Definition 2.1. [1] Consider the mapping

$$F : A \to P(U).$$

Then any A pair (F, A) is called a *soft set* over U. In other words, a soft set over U is a parameterized family of subsets of the universe set U. So that, for $\varepsilon \in A, F(\varepsilon)$ may be considered as the set of ε-approximate elements of the soft set (F, A).

Definition 2.2. [5] Let U be an initial universal set, and let E be a set of parameters. Let I^U denote the power set of all fuzzy subsets of U. Let $A \subseteq E$ and F be a mapping

$$F : A \to I^U.$$

A pair (F, E) is called a *fuzzy soft set* over U.

Definition 2.3. [5] For two fuzzy soft sets, (F, A) and (G, B) over U, (F, A), is called a fuzzy soft subset of (G, B) if

1. $A \subset B$ and
2. $\forall \varepsilon \in A, F(\varepsilon)$ is a fuzzy subset of $G(\varepsilon)$.

This relationship is denoted by $(F,\ A) \tilde{\subset} (G, B)$. In this case, (G, B) is called a fuzzy soft superset of (F, A).

Definition 2.4. [5]The complement of a fuzzy soft set (F, A) is denoted by $(F, A)^c$ and is defined by $(F, A)^c$ = $(F^c, \rceil A)$ where $F^c : \rceil A \to P(U)$ is a mapping given by

$$F^c(\alpha) = c(F(\rceil\alpha)), \forall \alpha \in \rceil A.$$

Where c is any fuzzy complement.

Definition 2.5. [5] If (F, A) and (G, B) are two fuzzy soft sets then "(F, A) AND (G, B)" denoted by $(F,\ A) \wedge (G, B)$ is defined by

$$(F, A) \wedge (G, B) = (H, A \times B)$$

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such that $H(\alpha,\beta) = t(F(\alpha), G(\beta)), \forall (\alpha,\beta) \in A \times B$, where t is any t-norm.

Definition 2.6. [5] If (F, A) and (G, B) are two fuzzy soft sets then "(F, A) OR (G, B)" denoted by $(F, A) \vee (G, B)$ is defined by

$$(F, A) \vee (G, B) = (O, A \times B)$$

such that $O(\alpha,\beta) = s(F(\alpha), G(\beta)), \forall (\alpha,\beta) \in A \times B$, where s is any s-norm.

Definition 2.7. [5] The union of two fuzzy soft sets (F, A) and (G, B) over a common universe U is the fuzzy soft set (H, C) where $C = A \cup B$, and $\forall \varepsilon \in C$,

$$H(\varepsilon) = \begin{cases} F(\varepsilon), & if \quad \varepsilon \in A - B, \\ G(\varepsilon), & if \quad \varepsilon \in B - A, \\ s(F(\varepsilon), G(\varepsilon)), & if \quad \varepsilon \in A \cap B. \end{cases}$$

Where s is any s-norm.

Definition 2.8. [5] The intersection of two fuzzy soft sets (F, A) and (G, B) over a common universe U is the fuzzy soft set (H, C) where $C = A \cup B$, and $\forall \varepsilon \in C$,

$$H(\varepsilon) = \begin{cases} F(\varepsilon), & if \quad \varepsilon \in A - B, \\ G(\varepsilon), & if \quad \varepsilon \in B - A, \\ s(F(\varepsilon), G(\varepsilon)), & if \quad \varepsilon \in A \cap B. \end{cases}$$

Definition 2.9. An effective set is a fuzzy set Λ in a universe of discourse A where Λ is a function $\Lambda : A \to [0, 1]$. A Here is the set of effective parameters that may change the membership values by having a positive effect (or no effect) on the values of the memberships after applying them, defined as follows:

$$\Lambda = \{\langle a, \delta_\Lambda(a)\rangle : a \in A\}.$$

Definition 2.10. Let U be an initial universal set, E be a set of parameters, A a set of effective parameters, and Λ be the effective set over A. Let I^U denote all fuzzy subsets of U. A pair $(F, E)_\Lambda$ is called an effective fuzzy soft set (EFSS in short) over U, where F is a mapping given by

$$F : E \to I^U.$$

define as follows: $F(e_i)_\Lambda = \left\{ \dfrac{x_j}{\mu_U(x_j)_\Lambda} : x_j \in U \,,\, e_i \in E \right\}$. Where $\forall a_k \in A$

$$\mu_U(x_j)_\Lambda = \begin{cases} \mu_U(x_j) + \left[\dfrac{(1-\mu_U(x_j)) \sum\limits_k \delta_{\Lambda_{x_j}}(a_k)}{|A|} \right], & if \quad \mu_U(x_j) \in (0,1), \\ \mu_U(x_j), & O.W. \end{cases}$$

Definition 2.11. [15] A neutrosophic set A on the universe of discourse X is defined as $A = \{< x; T_A(x); I_A(x); F_A(x) > ; x \in X\}$ where $T; I; F : X \to]^-0; 1^+[$ and $^-0 \leqslant T_A(x) + I_A(x) + F_A(x) \leq 3^+$.

Definition 2.12. [20] Let U be an initial universal set, and let E be a set of parameters. Let I^U denote the power set of all fuzzy subsets of U; let $A \subseteq E$ and let T be a set of times where $T = \{t_1, t_2, ..., t_n\}$. A collection of pairs $(F, E)_t \, \forall\, t \in T$ is called a *time-fuzzy soft set* $\{T - FSS\}$ over U where F is a mapping given by

$$F_t : A \to I^U.$$

Definition 2.13. [19] Let U be an initial universal set, and let E be a set of parameters. Let N^U denote the power set of all neutrosophic subsets of U; let $A \subseteq E$; and let T be a set of times where $T = \{t_1, t_2, ..., t_n\}$ .A collection of pairs $(F, E)_t \, \forall\, t \in T$ is called a *time-neutrosophic soft set* $\{T - NSS\}$ over U where F is a mapping given by

$$F_t : A \to N^U.$$

Definition 2.14. [16] Comparison Matrix. It is a matrix whose rows are labeled by the object names $h_1; h_2; ..., h_n$ and the columns are labeled by the parameters $e_1; e_2; ..., e_m$: The entries c_{ij} are calculated by $c_{ij} = a + b - c$, where 'a' is the integer calculated as 'how many times $T_{h_i}(e_j)$ exceeds or equals $T_{h_k}(e_j)$', for $h_i \neq h_k$, $\forall h_k \in U$, 'b is the integer calculated as 'how many times $I_{h_i}(e_j)$ exceeds or equals $I_{h_k}(e_j)$', for $h_i \neq h_k$, $\forall h_k \in U$, and 'c' is the integer 'how many times $F_{h_i}(e_j)$ exceeds or equals $F_{h_k}(e_j)$', for $h_i \neq h_k$, $\forall h_k \in U$.

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3 Time Effective Fuzzy Soft Set

In this section, we introduce the definition of a time-effective fuzzy soft set and give the basic properties of this concept. Some or all of the parameters have a time value for previous information, which means we must take the component time value of the information into consideration when we are making decisions because the decisions made will be more precise.

Definition 3.1. Let U be a universe, E be a set of parameters, I^U denote the power set of all fuzzy subsets of U, $\widetilde{E} = \{a_1, a_2, \ldots, a_k\}$ a set of effective parameters, and Λ be the effective set over $\widetilde{E}$. Let T be a set of times where $T = \{t_1, t_2, \ldots, t_n\}$. Then the pairs (F_{t_i}, Z) for all $t \in T$ are called a *time-effective fuzzy soft set* where: [left=]align* $\mathrm{F}_{t_i}(\sigma) = \left\{ \frac{u_j}{\mu_F(u_j^{t_i})} \right\}, \quad u_j^{t_i} \in U, \ \mu_{F_{t_i}} \in [0,1], \quad \forall\, t \in T$ and $\sigma \in Z = E \times T$,

$F_{t_i}^{(a_k)} : Z \to \{\mu_F(u_j^{t_i})\}, \quad \forall\, t \in T$ and $\sigma \in E \times T, \quad i = 1, 2, \ldots, m, \ j = 1, 2, \ldots, n, \ k = 1, 2, \ldots, k$. Where

[left=]align* $\mu_F(u_j^{t_i})_\Lambda = \begin{cases} \mu_U(u_j) + \left[\frac{(1-\mu_U(u_j)) \sum_k \delta_{\Lambda_{u_j}}(a_k)}{|\widetilde{E}|} \right], & \text{if } \mu_U(u_j) \in (0,1), \\ \mu_U(u_j), & \text{otherwise.} \end{cases}$

Example 3.2. Let $U = \{u_1, u_2, u_3, u_4\}$ be a set of universe, $E = \{e_1, e_2, e_3\}$ a set of parameters and $T = \{t_1, t_2, t_3,\}$ be a set of time and let $\widetilde{E} = \{a_1, a_2, a_3, a_4\}$ be a set of effective parameters. Suppose that the effective set over $\widetilde{E}$ for all $\{u_1, u_2, u_3\}$ given by experts as follows:

$$\Lambda_{t_1}(u_1) = \left\{ \frac{a_1^{t_1}}{1}, \frac{a_2^{t_1}}{0.2}, \frac{a_3^{t_1}}{0.8}, \frac{a_4^{t_1}}{0} \right\}, \ \Lambda_{t_1}(u_2) = \left\{ \frac{a_1^{t_1}}{0.8}, \frac{a_2^{t_1}}{0}, \frac{a_3^{t_1}}{0.5}, \frac{a_4^{t_1}}{0.4} \right\}, \ \Lambda_{t_1}(u_3) = \left\{ \frac{a_1^{t_1}}{0.6}, \frac{a_2^{t_1}}{0.7}, \frac{a_3^{t_1}}{0.3}, \frac{a_4^{t_1}}{1} \right\}$$

$$\Lambda_{t_2}(u_1) = \left\{ \frac{a_1^{t_2}}{0.2}, \frac{a_2^{t_2}}{1}, \frac{a_3^{t_2}}{0}, \frac{a_4^{t_2}}{0.5} \right\}, \ \Lambda_{t_2}(u_2) = \left\{ \frac{a_1^{t_2}}{0.6}, \frac{a_2^{t_2}}{0.5}, \frac{a_3^{t_2}}{0}, \frac{a_4^{t_2}}{0.9} \right\}, \ \Lambda_{t_2}(u_3) = \left\{ \frac{a_1^{t_2}}{1}, \frac{a_2^{t_2}}{0}, \frac{a_3^{t_2}}{0.4}, \frac{a_4^{t_2}}{0.6} \right\},$$

$$\Lambda_{t_3}(u_1) = \left\{ \frac{a_1^{t_3}}{0.6}, \frac{a_2^{t_3}}{1}, \frac{a_3^{t_3}}{1}, \frac{a_4^{t_3}}{0.5} \right\},, \ \Lambda_{t_3}(u_2) = \left\{ \frac{a_1^{t_3}}{0.9}, \frac{a_2^{t_3}}{0.5}, \frac{a_3^{t_3}}{0}, \frac{a_4^{t_3}}{0.7} \right\}, \ \Lambda_{t_3}(u_3) = \left\{ \frac{a_1^{t_3}}{0.7}, \frac{a_3^{t_2}}{1}, \frac{a_3^{t_3}}{0.7}, \frac{a_4^{t_3}}{0.4} \right\},$$

Let the time fuzzy soft set F defined as follows:

$$F_{\widetilde{E}_1}(e_1) = \left\{ \frac{u_1{}^{t_1}}{0.6}, \frac{u_2{}^{t_1}}{0.3}, \frac{u_3{}^{t_1}}{0.4} \right\}, F_{\widetilde{E}_1}(e_2) = \left\{ \frac{u_1{}^{t_1}}{0.5}, \frac{u_2{}^{t_1}}{0.3}, \frac{u_3{}^{t_1}}{0.7} \right\},$$
$$F_{\widetilde{E}_1}(e_3) = \left\{ \frac{u_1{}^{t_1}}{0.3}, \frac{u_2{}^{t_1}}{0.6}, \frac{u_3{}^{t_1}}{0.9} \right\}, F_{\widetilde{E}_2}(e_1) = \left\{ \frac{u_1{}^{t_2}}{0.7}, \frac{u_2{}^{t_2}}{0.4}, \frac{u_3{}^{t_2}}{0.3} \right\},$$

$$F_{\widetilde{E}_2}(e_2) = \left\{ \frac{u_1{}^{t_2}}{0.5}, \frac{u_2{}^{t_2}}{0.3}, \frac{u_3{}^{t_2}}{0.7} \right\}, F_{\widetilde{E}_2}(e_3) = \left\{ \frac{u_1{}^{t_2}}{0.7}, \frac{u_2{}^{t_2}}{0.8}, \frac{u_3{}^{t_2}}{0.4} \right\},$$

$$F_{\widetilde{E}_3}(e_1) = \left\{ \frac{u_1{}^{t_3}}{0.7}, \frac{u_2{}^{t_3}}{0.8}, \frac{u_3{}^{t_3}}{0.4} \right\}, F_{\widetilde{E}_3}(e_2) = \left\{ \frac{u_1{}^{t_3}}{0.7}, \frac{u_2{}^{t_3}}{0.5}, \frac{u_3{}^{t_3}}{0.7} \right\},$$

$$F_{\widetilde{E}_3}(e_3) = \left\{ \frac{u_1{}^{t_3}}{0.3}, \frac{u_2{}^{t_3}}{0.6}, \frac{u_3{}^{t_3}}{0.9} \right\}.$$

$$F_{\Lambda_{t_1}}(e_1) = \left\{ \frac{u_1^{t_1}}{0.6 + 0.4\left[\frac{1+0.2+0.8+0}{4}\right]}, \frac{u_2^{t_1}}{0.3 + 0.7\left[\frac{0.8+0+0.5+0.4}{4}\right]}, \frac{u_3^{t_1}}{0.4 + 0.6\left[\frac{0.6+0.7+0.3+1}{4}\right]} \right\}$$

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Then we can find the time-effective fuzzy soft sets $(F_\Lambda, Z)^t$ as consisting of the following collection of approximations:

$$(F_\Lambda, Z)^t = \left\{ \left(e_1, \left\{\frac{u_1{}^{t_1}}{0.8}, \frac{u_2{}^{t_1}}{0.59}, \frac{u_3{}^{t_1}}{0.79}\right\}\right), \left(e_2, \left\{\frac{u_1{}^{t_1}}{0.75}, \frac{u_2{}^{t_1}}{0.59}, \frac{u_3{}^{t_1}}{0.89}\right\}\right), \right.$$
$$\left(e_3, \left\{\frac{u_1{}^{t_1}}{0.65}, \frac{u_2{}^{t_1}}{0.77}, \frac{u_3{}^{t_1}}{0.96}\right\}\right), \left(e_1, \left\{\frac{u_1{}^{t_2}}{0.82}, \frac{u_2{}^{t_2}}{0.7}, \frac{u_3{}^{t_2}}{0.65}\right\}\right),$$
$$\left(e_2, \left\{\frac{u_1{}^{t_2}}{0.71}, \frac{u_2{}^{t_2}}{0.65}, \frac{u_3{}^{t_2}}{0.85}\right\}\right), \left(e_3, \left\{\frac{u_1{}^{t_2}}{0.82}, \frac{u_2{}^{t_2}}{0.9}, \frac{u_3{}^{t_2}}{0.7}\right\}\right),$$
$$\left(e_1, \left\{\frac{u_1{}^{t_3}}{0.93}, \frac{u_2{}^{t_3}}{0.90}, \frac{u_3{}^{t_3}}{0.82}\right\}\right), \left(e_2, \left\{\frac{u_1{}^{t_3}}{0.93}, \frac{u_2{}^{t_3}}{0.76}, \frac{u_3{}^{t_3}}{0.91}\right\}\right),$$
$$\left.\left(e_3, \left\{\frac{u_1{}^{t_3}}{0.83}, \frac{u_2{}^{t_3}}{0.81}, \frac{u_3{}^{t_3}}{0.97}\right\}\right) \right\}.$$

Definition 3.3. For two T-EFSSs $(F_\Lambda, A)^t$ and $(G_\Lambda, B)^t$ over U, $(F_\Lambda, A)^t$ is called a T-EFSS subset of $(G_\Lambda, B)^t$ if

1. $A \subseteq B$,
2. $\forall t \in T, \epsilon \in A$, $(F_\Lambda, A)^t$ is time effective fuzzy soft subset of $(G_\Lambda, B)^t$.

Definition 3.4. Two T-EFSSs, $(F_\Lambda, A)^t$ and $(G_\Lambda, B)^t$ over U, are said to be *equal* if $(F_\Lambda, A)^t$ is a T-EFSS subset of $(G_\Lambda, B)^t$ and $(G_\Lambda, B)^t$ is a T-EFSS subset of $(F_\Lambda, A)^t$.

Example 3.5. Consider Example 3.2 and suppose that the

$$(F_\Lambda, A)^t = \left\{ \left(e_1, \left\{\frac{u_1{}^{t_1}}{0.8}, \frac{u_2{}^{t_1}}{0.5}, \frac{u_3{}^{t_1}}{0.7}\right\}\right), \left(e_2, \left\{\frac{u_1{}^{t_1}}{0.6}, \frac{u_2{}^{t_1}}{0.5}, \frac{u_3{}^{t_1}}{0.9}\right\}\right), \right.$$
$$\left(e_2, \left\{\frac{u_1{}^{t_2}}{0.8}, \frac{u_2{}^{t_2}}{0.4}, \frac{u_3{}^{t_2}}{0.7}\right\}\right), \left(e_3, \left\{\frac{u_1{}^{t_2}}{0.8}, \frac{u_2{}^{t_2}}{0.7}, \frac{u_3{}^{t_2}}{0.8}\right\}\right),$$
$$\left.\left(e_1, \left\{\frac{u_1{}^{t_3}}{0.5}, \frac{u_2{}^{t_3}}{0.8}, \frac{u_3{}^{t_3}}{0.7}\right\}\right), \left(e_3, \left\{\frac{u_1{}^{t_3}}{0.4}, \frac{u_2{}^{t_3}}{0.6}, \frac{u_3{}^{t_3}}{0.7}\right\}\right) \right\}.$$

$$(G_\Lambda, B)^t = \left\{ \left(e_2, \left\{\frac{u_1{}^{t_1}}{0.4}, \frac{u_2{}^{t_1}}{0.3}, \frac{u_3{}^{t_1}}{0.5}\right\}\right), \left(e_3, \left\{\frac{u_1{}^{t_2}}{0.7}, \frac{u_2{}^{2}}{0.6}, \frac{u_3{}^{t_2}}{0.7}\right\}\right), \right.$$
$$\left.\left(e_1, \left\{\frac{u_1{}^{t_3}}{0.5}, \frac{u_2{}^{t_3}}{0.8}, \frac{u_3{}^{t_3}}{0.3}\right\}\right) \right\}.$$

Therefore, $(G, E)_{T_{\widetilde{E}}} \subseteq (F, E)_{T_{\widetilde{E}}}$.

Definition 3.6. The union and intersection of two time effective sets Λ'_t and Λ''_t over the set of effective parameters $\widetilde{E}$ are the effective sets Λ_s and Λ_m, respectively, where s is any s-norm and m is any m-norm.

Definition 3.7. The complement of the time effective fuzzy set Λ_t over the set of effective parameters $\widetilde{E}$ is the effective set $\Lambda^c{}_t$ where c is any fuzzy complement.

Definition 3.8. The $\Lambda_{\text{complement}}$ of the T-EFSS $(F_\Lambda, E)_t$ is the EFSS $(F_{\Lambda^c}, E)_t$, where $\Lambda^c{}_t$ is any fuzzy complement of Λ_t.

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Here we keep the fuzzy soft set F as is and find the fuzzy complement of the effective set Λ_t, then we apply Eq. 2.10 to get a new T-EFSS.

Definition 3.9. The $Soft_{complement}$ of the T-EFSS $(F_\Lambda, E)_t$ is the EFSS $(F^c_\Lambda, E)_t$, where F^c is fuzzy soft complement of F.

Here we find the time effective fuzzy set complement of F, which is F^c and keep the effective set Λ as is, then we apply Eq. 2.10 to get a new EFSS.

Definition 3.10. The $Total_{complement}$ of the T-EFSS $(F_\Lambda, E)_t$ is the T-EFSS $(F^c_{\Lambda^c}, E)_t$, where F^c is the fuzzy soft complement of F and ${\Lambda^c}_t$ is any fuzzy complement of Λ_t.

Here we find the fuzzy soft complement of F, which is F^c, and the fuzzy complement of the effective set Λ_t, which is ${\Lambda^c}_t$. Then we apply Definition. 2.10 to get a new T-EFSS.

Example 3.11. Consider Example 3.2. Let

$$\Lambda(x_1) = \left\{\frac{a_1}{0.8}, \frac{a_2}{1}, \frac{a_3}{0}, \frac{a_4}{0.2}\right\},\ \Lambda(x_2) = \left\{\frac{a_1}{0.4}, \frac{a_2}{0.5}, \frac{a_3}{0}, \frac{a_4}{0.8}\right\},\ \Lambda(x_3) = \left\{\frac{a_1}{1}, \frac{a_2}{1}, \frac{a_3}{0.7}, \frac{a_4}{0.6}\right\}.$$

By using the basic fuzzy complement of the effective set Λ, we get the following effective set Λ^c:

$$\Lambda^c(x_1) = \left\{\frac{a_1}{0.2}, \frac{a_2}{0}, \frac{a_3}{1}, \frac{a_4}{0.8}\right\},\ \Lambda^c(x_2) = \left\{\frac{a_1}{0.6}, \frac{a_2}{0.5}, \frac{a_3}{1}, \frac{a_4}{0.2}\right\},\ \Lambda^c(x_3) = \left\{\frac{a_1}{0}, \frac{a_2}{0}, \frac{a_3}{0.3}, \frac{a_4}{0.4}\right\}.$$

Also let

$$F(e_1) = \left\{\frac{x_1}{0.3}, \frac{x_2}{0.7}, \frac{x_3}{0.5}\right\},\ F(e_2) = \left\{\frac{x_1}{0.5}, \frac{x_2}{0.6}, \frac{x_3}{0.6}\right\},\ F(e_3) = \left\{\frac{x_1}{0.7}, \frac{x_2}{0.6}, \frac{x_3}{0.5}\right\},$$

$$F(e_4) = \left\{\frac{x_1}{0.8}, \frac{x_2}{0.4}, \frac{x_3}{0.4}\right\},\ F(e_5) = \left\{\frac{x_1}{0.6}, \frac{x_2}{0.9}, \frac{x_3}{0.3}\right\},\ F(e_6) = \left\{\frac{x_1}{0.2}, \frac{x_2}{0.4}, \frac{x_3}{0.7}\right\},$$

be the fuzzy soft set, and by using the fuzzy soft complement over F we have the following fuzzy soft set:

$$F^c(e_1) = \left\{\frac{x_1}{0.7}, \frac{x_2}{0.3}, \frac{x_3}{0.5}\right\},\ F^c(e_2) = \left\{\frac{x_1}{0.5}, \frac{x_2}{0.4}, \frac{x_3}{0.4}\right\},\ F^c(e_3) = \left\{\frac{x_1}{0.3}, \frac{x_2}{0.6}, \frac{x_3}{0.5}\right\},$$

$$F^c(e_4) = \left\{\frac{x_1}{0.2}, \frac{x_2}{0.6}, \frac{x_3}{0.6}\right\},\ F^c(e_5) = \left\{\frac{x_1}{0.6}, \frac{x_2}{0.9}, \frac{x_3}{0.3}\right\},\ F^c(e_6) = \left\{\frac{x_1}{0.2}, \frac{x_2}{0.6}, \frac{x_3}{0.6}\right\}.$$

By using the definitions 3.8, 3.9 and, 3.10 and applying Definition 2.10, we obtain the following: $Total_{complement}$, $\Lambda_{complement}$, and $Soft_{complement}$, respectively:

$$\begin{aligned}(F^c_{\Lambda^c}, E) = \Bigg\{ &\left(e_1, \left\{\frac{x_1}{0.85}, \frac{x_2}{0.7}, \frac{x_3}{0.59}\right\}\right), \left(e_2, \left\{\frac{x_1}{0.75}, \frac{x_2}{0.75}, \frac{x_3}{0.5}\right\}\right), \\ &\left(e_3, \left\{\frac{x_1}{0.65}, \frac{x_2}{0.63}, \frac{x_3}{0.59}\right\}\right), \left(e_4, \left\{\frac{x_1}{0.6}, \frac{x_2}{0.83}, \frac{x_3}{0.67}\right\}\right), \\ &\left(e_5, \left\{\frac{x_1}{0.8}, \frac{x_2}{0.95}, \frac{x_3}{0.43}\right\}\right), \left(e_6, \left\{\frac{x_1}{0.6}, \frac{x_2}{0.83}, \frac{x_3}{0.47}\right\}\right) \Bigg\}.\end{aligned}$$

$$\begin{aligned}(F_{\Lambda^c}, E) = \Bigg\{ &\left(e_1, \left\{\frac{x_1}{0.65}, \frac{x_2}{0.87}, \frac{x_3}{0.59}\right\}\right), \left(e_2, \left\{\frac{x_1}{0.75}, \frac{x_2}{0.83}, \frac{x_3}{0.67}\right\}\right), \\ &\left(e_3, \left\{\frac{x_1}{0.85}, \frac{x_2}{0.83}, \frac{x_3}{0.59}\right\}\right), \left(e_4, \left\{\frac{x_1}{0.9}, \frac{x_2}{0.75}, \frac{x_3}{0.5}\right\}\right), \\ &\left(e_5, \left\{\frac{x_1}{0.8}, \frac{x_2}{0.96}, \frac{x_3}{0.43}\right\}\right), \left(e_6, \left\{\frac{x_1}{0.6}, \frac{x_2}{0.75}, \frac{x_3}{0.75}\right\}\right) \Bigg\}.\end{aligned}$$

$$\begin{aligned}(F^c_{\Lambda}, E) = \Bigg\{ &\left(e_1, \left\{\frac{x_1}{0.85}, \frac{x_2}{0.6}, \frac{x_3}{0.92}\right\}\right), \left(e_2, \left\{\frac{x_1}{0.75}, \frac{x_2}{0.66}, \frac{x_3}{0.9}\right\}\right), \\ &\left(e_3, \left\{\frac{x_1}{0.65}, \frac{x_2}{0.77}, \frac{x_3}{0.92}\right\}\right), \left(e_4, \left\{\frac{x_1}{0.6}, \frac{x_2}{0.77}, \frac{x_3}{0.93}\right\}\right), \\ &\left(e_5, \left\{\frac{x_1}{0.8}, \frac{x_2}{0.94}, \frac{x_3}{0.88}\right\}\right), \left(e_6, \left\{\frac{x_1}{0.6}, \frac{x_2}{0.77}, \frac{x_3}{0.93}\right\}\right) \Bigg\}.\end{aligned}$$

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Definition 3.12. A time effective fuzzy soft set $(F,E)_{T_{\widetilde{E}}}$ over U is said to be semi-null T-EFSS, denoted by $T_{\widetilde{E}} \sim \phi$, if for all $t \in T$, $F_{T_{\widetilde{E}}}(e) = \Phi$ for at least one e.

Definition 3.13. A time effective fuzzy soft set $(F_\Lambda, A)^t$ over U is said to be null T-EFSS denoted by T_ϕ, if $\forall t \in T$, $F_t\,(e) = \Phi\ \forall e$.

Definition 3.14. A time effective fuzzy soft set $(F_\Lambda, A)^t$ over U is said to be semi-absolute T-EFSS denoted by $T_\sim A$, if $\forall t \in T$, $F_t\,(e) = \bar{1}$ for at least one e.

Definition 3.15. A time effective fuzzy soft set $(F_\Lambda, A)^t$ over U is said to be absolute T-EFSS denoted by T_A, if $\forall t \in T$, $F_t\,(e) = \bar{1}\ \forall e$.

Example 3.16. Consider Example 3.2. Let

$$
\begin{aligned}
(F_\Lambda, A)^t = \Bigg\{ & \left(e_1, \{\Phi\}^{t_1}\right), \left(e_2, \left\{\frac{{u_1}^{t_1}}{0.4}, \frac{{u_2}^{t_1}}{0.5}, \frac{{u_3}^{t_1}}{0.3}, \frac{{u_4}^{t_1}}{0.6}\right\}\right), \\
& \left(e_3, \left\{\frac{{u_1}^{t_1}}{0.2}, \frac{{u_2}^{t_1}}{0.3}, \frac{{u_3}^{t_1}}{0.6}, \frac{{u_4}^{t_1}}{0.5}\right\}\right), \left(e_1, \{\Phi\}^{t_2}\right), \\
& \left(e_2, \left\{\frac{{u_1}^{t_2}}{0.5}, \frac{{u_2}^{t_2}}{0.7}, \frac{{u_3}^{t_2}}{0.8}, \frac{{u_4}^{t_2}}{0.3}\right\}\right), \left(e_3, \left\{\frac{{u_1}^{t_2}}{0.3}, \frac{{u_2}^{t_2}}{0.2}, \frac{{u_3}^{t_2}}{0.4}, \frac{{u_4}^{t_2}}{0.6}\right\}\right), \\
& \left(e_1, \{\Phi\}^{t_3}\right), \left(e_2, \left\{\frac{{u_1}^{t_3}}{0.3}, \frac{{u_2}^{t_3}}{0.5}, \frac{{u_3}^{t_3}}{0.4}, \frac{{u_4}^{t_3}}{0.3}\right\}\right), \\
& \left(e_3, \left\{\frac{{u_1}^{t_3}}{0.7}, \frac{{u_2}^{t_3}}{0.4}, \frac{{u_3}^{t_3}}{0.2}, \frac{{u_4}^{t_3}}{0.1}\right\}\right) \Bigg\}.
\end{aligned}
$$

Then $(F_\Lambda, A)^t = T_\sim \phi$.

Let

$$
\begin{aligned}
(F_\Lambda, A)^t = \Bigg\{ & \left(e_1, \{\Phi\}^{t_1}\right), \left(e_2, \{\Phi\}^{t_1}\right), \left(e_3, \{\Phi\}^{t_1}\right), \\
& \left(e_1, \{\Phi\}^{t_2}\right), \left(e_2, \{\Phi\}^{t_2}\right), \left(e_3, \{\Phi\}^{t_2}\right), \\
& \left(e_1, \{\Phi\}^{t_3}\right), \left(e_2, \{\Phi\}^{t_3}\right), \left(e_3, \{\Phi\}^{t_3}\right) \Bigg\}.
\end{aligned}
$$

Then $(F_\Lambda, A)^t = T_\phi$.

$$
\begin{aligned}
(F_\Lambda, A)^t = \Bigg\{ & \left(e_1, \left\{\frac{{u_1}^{t_1}}{1}, \frac{{u_2}^{t_1}}{1}, \frac{{u_3}^{t_1}}{1}, \frac{{u_4}^{t_1}}{1}\right\}\right), \left(e_2, \left\{\frac{{u_1}^{t_1}}{1}, \frac{{u_2}^{t_1}}{1}, \frac{{u_3}^{t_1}}{1}, \frac{{u_4}^{t_1}}{1}\right\}\right), \\
& \left(e_3, \left\{\frac{{u_1}^{t_1}}{1}, \frac{{u_2}^{t_1}}{1}, \frac{{u_3}^{t_1}}{1}, \frac{{u_4}^{t_1}}{1}\right\}\right), \left(e_1, \left\{\frac{{u_1}^{t_2}}{1}, \frac{{u_2}^{t_2}}{1}, \frac{{u_3}^{t_2}}{1}, \frac{{u_4}^{t_2}}{1}\right\}\right), \\
& \left(e_2, \left\{\frac{{u_1}^{t_2}}{1}, \frac{{u_2}^{t_2}}{1}, \frac{{u_3}^{t_2}}{1}, \frac{{u_4}^{t_2}}{1}\right\}\right), \left(e_3, \left\{\frac{{u_1}^{t_2}}{1}, \frac{{u_2}^{t_2}}{1}, \frac{{u_3}^{t_2}}{1}, \frac{{u_4}^{t_2}}{1}\right\}\right), \\
& \left(e_1, \left\{\frac{{u_1}^{t_3}}{0.5}, \frac{{u_2}^{t_3}}{0.8}, \frac{{u_3}^{t_3}}{0.1}, \frac{{u_4}^{t_3}}{0.6}\right\}\right), \left(e_2, \left\{\frac{{u_1}^{t_3}}{0.3}, \frac{{u_2}^{t_3}}{0.5}, \frac{{u_3}^{t_3}}{0.4}, \frac{{u_4}^{t_3}}{0.3}\right\}\right),
\end{aligned}
$$

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$$\left(e_3, \left\{\frac{u_1{}^{t_3}}{0.7}, \frac{u_2{}^{t_3}}{0.4}, \frac{u_3{}^{t_3}}{0.2}, \frac{u_4{}^{t_3}}{0.1}\right\}\right)\Bigg\}.$$

Then $(F_\Lambda, A)^t = T_\sim A$.

Let

$$(F_\Lambda, A)^t = \Bigg\{ \left(e_1, \left\{\frac{u_1{}^{t_1}}{1}, \frac{u_2{}^{t_1}}{1}, \frac{u_3{}^{t_1}}{1}, \frac{u_4{}^{t_1}}{1}\right\}\right), \left(e_2, \left\{\frac{u_1{}^{t_1}}{1}, \frac{u_2{}^{t_1}}{1}, \frac{u_3{}^{t_1}}{1}, \frac{u_4{}^{t_1}}{1}\right\}\right),$$
$$\left(e_2, \left\{\frac{u_1{}^{t_2}}{1}, \frac{u_2{}^{t_2}}{1}, \frac{u_3{}^{t_2}}{1}, \frac{u_4{}^{t_2}}{1}\right\}\right), \left(e_3, \left\{\frac{u_1{}^{t_2}}{1}, \frac{u_2{}^{t_2}}{1}, \frac{u_3{}^{t_2}}{1}, \frac{u_4{}^{t_2}}{1}\right\}\right),$$
$$\left(e_1, \left\{\frac{u_1{}^{t_3}}{1}, \frac{u_2{}^{t_3}}{1}, \frac{u_3{}^{t_3}}{1}, \frac{u_4{}^{t_3}}{1}\right\}\right), \left(e_3, \left\{\frac{u_1{}^{t_3}}{1}, \frac{u_2{}^{t_3}}{1}, \frac{u_3{}^{t_3}}{1}, \frac{u_4{}^{t_3}}{1}\right\}\right)\Bigg\}.$$

Then $(F_\Lambda, A)^t = T_A$.

Definition 3.17. The *complement* of T-EFSS (F_Λ, E) is denoted by $(F^c_\Lambda, E)\,, \forall t \in T$ where c is a fuzzy soft complement.

Example 3.18. Consider Example 3.2. By using the basic fuzzy complement, we have

$$(F^c_\Lambda, E) = \Bigg\{ \left(e_1, \left\{\frac{u_1{}^{t_1}}{0.4}, \frac{u_2{}^{t_1}}{0.7}, \frac{u_3{}^{t_1}}{0.8}, \frac{u_4{}^{t_1}}{0.6}\right\}\right), \left(e_2, \left\{\frac{u_1{}^{t_1}}{0.5}, \frac{u_2{}^{t_1}}{0.7}, \frac{u_3{}^{t_1}}{0.8}, \frac{u_4{}^{t_1}}{0.3}\right\}\right),$$
$$\left(e_3, \left\{\frac{u_1{}^{t_1}}{0.7}, \frac{u_2{}^{t_1}}{0.4}, \frac{u_3{}^{t_1}}{0.2}, \frac{u_4{}^{t_1}}{0.1}\right\}\right), \left(e_1, \left\{\frac{u_1{}^{t_2}}{0.3}, \frac{u_2{}^{t_2}}{0.6}, \frac{u_3{}^{t_2}}{0.9}, \frac{u_4{}^{t_2}}{0.7}\right\}\right),$$
$$\left(e_2, \left\{\frac{u_1{}^{t_2}}{0.5}, \frac{u_2{}^{t_2}}{0.7}, \frac{u_3{}^{t_2}}{0.8}, \frac{u_4{}^{t_2}}{0.3}\right\}\right), \left(e_3, \left\{\frac{u_1{}^{t_2}}{0.3}, \frac{u_2{}^{t_2}}{0.2}, \frac{u_3{}^{t_2}}{0.4}, \frac{u_4{}^{t_2}}{0.6}\right\}\right),$$
$$\left(e_1, \left\{\frac{u_1{}^{t_3}}{0.3}, \frac{u_2{}^{t_3}}{0.2}, \frac{u_3{}^{t_3}}{0.4}, \frac{u_4{}^{t_3}}{0.6}\right\}\right), \left(e_2, \left\{\frac{u_1{}^{t_3}}{0.3}, \frac{u_2{}^{t_3}}{0.5}, \frac{u_3{}^{t_3}}{0.4}, \frac{u_4{}^{t_3}}{0.3}\right\}\right),$$
$$\left(e_3, \left\{\frac{u_1{}^{t_3}}{0.7}, \frac{u_2{}^{t_3}}{0.4}, \frac{u_3{}^{t_3}}{0.2}, \frac{u_4{}^{t_3}}{0.1}\right\}\right)\Bigg\}.$$

Proposition 3.19. *If (F_Λ, E) is a T-EFSS over U, then*

1. $(F^c_\Lambda, A)^c = (F_\Lambda, A)\,,$
2. $(T_\sim \phi)^c = (T_\sim A)\,,$
3. $\widetilde{c}(T_\phi) = (T_A)\,,$
4. $(T_\sim A)^c = (T_\sim \phi)\,,$
5. $(T_A)^c = (T_\phi)\,.$

Proof. The proof is straightforward. □

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4 Union and Intersection

In this section, we introduce the definitions of union and intersection of T-EFSSs, derive their properties, and give some examples.

Definition 4.1. The *union* of two T-EFSSs $(F_\Lambda, A)^t$ and $(G_\Lambda, B)^t$ over U is the T-EFSS $(H_\Lambda, C)^t$, denoted by $(F_\Lambda, A)^t \,\tilde{\cup}\, (F_\Lambda, A)^t$, such that $C = A \cup B \subset E$ and defined as follows:

$$H^t_\Lambda(\epsilon) = \begin{cases} F^t_\Lambda(\epsilon), & \text{if } \epsilon \in A - B, \\ G^t_\Lambda(\epsilon), & \text{if } \epsilon \in B - A, \\ F^t_\Lambda(\epsilon)\tilde{\cup}G^t_\Lambda(\epsilon), & \text{if } \epsilon \in A \cap B, \end{cases}$$

where $\tilde{\cup}$ denotes the fuzzy soft union.

Example 4.2. Consider Example 3.2. Suppose $(F_\Lambda, A)^t$ and $(G_\Lambda, B)^t$ are two effective time-fuzzy soft sets over U such that

$$(F_\Lambda, A)^t = \Bigg\{ \left(e_1, \left\{\frac{{u_1}^{t_1}}{0.6}, \frac{{u_2}^{t_1}}{0.3}, \frac{{u_3}^{t_1}}{0.2}, \frac{{u_4}^{t_1}}{0.4}\right\}\right), \left(e_2, \left\{\frac{{u_1}^{t_1}}{0.5}, \frac{{u_2}^{t_1}}{0.3}, \frac{{u_3}^{t_1}}{0.2}, \frac{{u_4}^{t_1}}{0.7}\right\}\right),$$
$$\left(e_2, \left\{\frac{{u_1}^{t_2}}{0.5}, \frac{{u_2}^{t_2}}{0.3}, \frac{{u_3}^{t_2}}{0.2}, \frac{{u_4}^{t_2}}{0.7}\right\}\right), \left(e_3, \left\{\frac{{u_1}^{t_3}}{0.3}, \frac{{u_2}^{t_3}}{0.6}, \frac{{u_3}^{t_3}}{0.8}, \frac{{u_4}^{t_3}}{0.9}\right\}\right) \Bigg\}.$$

$$(G_\Lambda, B)^t = \Bigg\{ \left(e_1, \left\{\frac{{u_1}^{t_1}}{0.4}, \frac{{u_2}^{t_1}}{0.5}, \frac{{u_3}^{t_1}}{0.2}, \frac{{u_4}^{t_1}}{0.7}\right\}\right), \left(e_3, \left\{\frac{{u_1}^{t_2}}{0.5}, \frac{{u_2}^{t_2}}{0.6}, \frac{{u_3}^{t_2}}{0.9}, \frac{{u_4}^{t_2}}{0.4}\right\}\right),$$
$$\left(e_3, \left\{\frac{{u_1}^{t_3}}{0.5}, \frac{{u_2}^{t_3}}{0.8}, \frac{{u_3}^{t_3}}{0.6}, \frac{{u_4}^{t_3}}{0.9}\right\}\right) \Bigg\}.$$

$$(H_\Lambda, C)^t = \Bigg\{ \left(e_1, \left\{\frac{{u_1}^{t_1}}{0.6}, \frac{{u_2}^{t_1}}{0.5}, \frac{{u_3}^{t_1}}{0.2}, \frac{{u_4}^{t_1}}{0.7}\right\}\right), \left(e_2, \left\{\frac{{u_1}^{t_1}}{0.5}, \frac{{u_2}^{t_1}}{0.3}, \frac{{u_3}^{t_1}}{0.2}, \frac{{u_4}^{t_1}}{0.7}\right\}\right),$$
$$\left(e_2, \left\{\frac{{u_1}^{t_2}}{0.5}, \frac{{u_2}^{t_2}}{0.3}, \frac{{u_3}^{t_2}}{0.2}, \frac{{u_4}^{t_2}}{0.7}\right\}\right), \left(e_3, \left\{\frac{{u_1}^{t_2}}{0.5}, \frac{{u_2}^{t_2}}{0.6}, \frac{{u_3}^{t_2}}{0.9}, \frac{{u_4}^{t_2}}{0.4}\right\}\right),$$
$$\left(e_3, \left\{\frac{{u_1}^{t_3}}{0.5}, \frac{{u_2}^{t_3}}{0.8}, \frac{{u_3}^{t_3}}{0.8}, \frac{{u_4}^{t_3}}{0.9}\right\}\right) \Bigg\}.$$

Proposition 4.3. *If $(F_\Lambda, A)^t$, $(G_\Lambda, B)^t$, and $(H_\Lambda, C)^t$ are three T-EFSSs over U, then*

1. $(F_\Lambda, A)^t\tilde{\cup}\left((G_\Lambda, B)^t\tilde{\cup}(H_\Lambda, C)^t\right) = \left((F_\Lambda, A)^t\tilde{\cup}(G_\Lambda, B)^t\right)\tilde{\cup}(H_\Lambda, C)^t$,
2. $(F_\Lambda, A)^t\tilde{\cup}(F_\Lambda, A)^t = (F_\Lambda, A)^t$.

Proof. The proof is straightforward. □

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Definition 4.4. The *intersection* of two T-EFSSs $(F_\Lambda, A)^t$ and $(G_\Lambda, B)^t$ over U is the T-EFSS $(H_\Lambda, C)^t$, denoted by $(F_\Lambda, A)^t \,\widetilde{\cap}\, (G_\Lambda, B)^t$, such that $C = A \cap B \subset E$ and defined as follows:

$$H^t_\Lambda(\epsilon) = \begin{cases} F^t_\Lambda(\epsilon), & \text{if } \epsilon \in A - B, \\ G^t_\Lambda(\epsilon), & \text{if } \epsilon \in B - A, \\ F^t_\Lambda(\epsilon)\tilde{\cap}G^t_\Lambda(\epsilon), & \text{if } \epsilon \in A \cap B, \end{cases}$$

where $\tilde{\cap}$ denotes the fuzzy soft intersection.

Example 4.5. Consider Example 3.2. Let

$$(H_\Lambda, C)^t = \Bigg\{ \left(e_1, \left\{\frac{{u_1}^{t_1}}{0.4}, \frac{{u_2}^{t_1}}{0.3}, \frac{{u_3}^{t_1}}{0.2}, \frac{{u_4}^{t_1}}{0.4}\right\}\right), \left(e_2, \left\{\frac{{u_1}^{t_1}}{0.5}, \frac{{u_2}^{t_1}}{0.3}, \frac{{u_3}^{t_1}}{0.2}, \frac{{u_4}^{t_1}}{0.7}\right\}\right),$$

$$\left(e_2, \left\{\frac{{u_1}^{t_2}}{0.5}, \frac{{u_2}^{t_2}}{0.3}, \frac{{u_3}^{t_2}}{0.2}, \frac{{u_4}^{t_2}}{0.7}\right\}\right), \left(e_3, \left\{\frac{{u_1}^{t_2}}{0.5}, \frac{{u_2}^{t_2}}{0.6}, \frac{{u_3}^{t_2}}{0.9}, \frac{{u_4}^{t_2}}{0.4}\right\}\right),$$

$$\left(e_3, \left\{\frac{{u_1}^{t_3}}{0.3}, \frac{{u_2}^{t_3}}{0.6}, \frac{{u_3}^{t_3}}{0.6}, \frac{{u_4}^{t_3}}{0.9}\right\}\right) \Bigg\}.$$

Proposition 4.6. *If $(F_\Lambda, A)^t$, $(G_\Lambda, B)^t$, and $(H_\Lambda, C)^t$ are three T-EFSSs over U, then*

1. $(F_\Lambda, A)^t \,\widetilde{\cap}\, \left((G_\Lambda, B)^t \,\widetilde{\cap}\, (H_\Lambda, C)^t\right) = \left((F_\Lambda, A)^t \,\widetilde{\cap}\, (G_\Lambda, B)^t\right) \widetilde{\cap}\, (H_\Lambda, C)^t$,
2. $(F_\Lambda, A)^t \,\widetilde{\cap}\, (F_\Lambda, A)^t = (F_\Lambda, A)^t$.

Proof. The proof is straightforward. □

==

Proposition 4.7. *If $(F, A)_t$, $(G, B)_t$, and $(H, C)_t$ are three T-FSSs over U, then*

1. $(F_\Lambda, A)^t \,\widetilde{\cup}\, \left((G_\Lambda, B)^t \,\widetilde{\cap}\, (H_\Lambda, C)^t\right) = \left((F_\Lambda, A)^t \,\widetilde{\cup}\, (G_\Lambda, B)^t\right) \widetilde{\cap} \left((F_\Lambda, A)^t \,\widetilde{\cup}\, (H_\Lambda, C)^t\right)$,
2. $(F_\Lambda, A)^t \,\widetilde{\cap}\, (G_\Lambda, B)^t \,\widetilde{\cup}\, (H_\Lambda, C)^t = \left((F_\Lambda, A)^t \,\widetilde{\cap}\, (G_\Lambda, B)^t\right) \widetilde{\cup} \left((F_\Lambda, A)^t \,\widetilde{\cap}\, (H_\Lambda, C)^t\right)$.

Proof. The proof is straightforward □

Proposition 4.8. *If $(F_\Lambda, A)^t$ and $(G_\Lambda, B)^t$ are two T-EFSSs over U, then*

1. $\left((F_\Lambda, A)^t \,\widetilde{\cup}\, (G_\Lambda, B)^t\right)^c = (F_\Lambda, A)^c_t \,\widetilde{\cap}\, (F_\Lambda, A)^c_t$,
2. $\left((F_\Lambda, A)^t \,\widetilde{\cap}\, (G_\Lambda, B)^t\right)^c = \left((F_\Lambda, A)^t\right)^c \widetilde{\cup}\, (G_\Lambda, B)^t)^c$.

Proof. The proof is straightforward □

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5 AND and OR operations

In this part, we define the AND and OR operations for T-EFSSs, deduce their characteristics, and provide some illustrations.

Definition 5.1. If $(F_\Lambda, A)^t$ and $(G_\Lambda, B)^t$ are two T-EFSS over U, then "$(F_\Lambda, A)^t$ AND $(G_\Lambda, B)^t$" denoted by $(F_\Lambda, A)^t \wedge (G_\Lambda, B)^t$, is defined by

$$(F_\Lambda, A)^t \wedge (G_\Lambda, B)^t = (H_\Lambda, A \times B)_t$$

such that $H^t_\Lambda = F^t_\Lambda \widetilde{\bigcap} G^t_\Lambda$, where $\widetilde{\bigcap}$ is time-effective fuzzy intersection.

Example 5.2. Consider Example 3.2. Let Suppose $(F_\Lambda, A)^t$ and $(G_\Lambda, B)^t$ are two time-effective fuzzy soft sets over U such that

$$\begin{aligned}
(F_\Lambda, A)^t = \Bigg\{ & \left(e_1^{t_1}, \left\{\frac{u_1^{t_{1,1}}}{0.6}, \frac{u_2^{t_{1,1}}}{0.3}, \frac{u_3^{t_{1,1}}}{0.2}, \frac{u_4^{t_{1,1}}}{0.3}\right\}\right), \\
& \left(e_1^{t_1}, \left\{\frac{u_1^{t_{1,2}}}{0.4}, \frac{u_2^{t_{1,2}}}{0.3}, \frac{u_3^{t_{1,2}}}{0.2}, \frac{u_4^{t_{1,2}}}{0.4}\right\}\right), \\
& \left(e_1^{t_1}, \left\{\frac{u_1^{t_{1,3}}}{0.1}, \frac{u_2^{t_{1,3}}}{0.3}, \frac{u_3^{t_{1,3}}}{0.2}, \frac{u_4^{t_{1,3}}}{0.4}\right\}\right), \\
& \left(e_2^{t_1}, \left\{\frac{u_1^{t_{1,1}}}{0.5}, \frac{u_2^{t_{1,1}}}{0.3}, \frac{u_3^{t_{1,1}}}{0.2}, \frac{u_4^{t_{1,1}}}{0.3}\right\}\right), \\
& \left(e_2^{t_1}, \left\{\frac{u_1^{t_{1,2}}}{0.4}, \frac{u_2^{t_{1,2}}}{0.3}, \frac{u_3^{t_{1,2}}}{0.2}, \frac{u_4^{t_{1,2}}}{0.7}\right\}\right), \\
& \left(e_2^{t_1}, \left\{\frac{u_1^{t_{1,3}}}{0.1}, \frac{u_2^{t_{1,3}}}{0.3}, \frac{u_3^{t_{1,3}}}{0.2}, \frac{u_4^{t_{1,3}}}{0.7}\right\}\right), \\
& \left(e_2^{t_2}, \left\{\frac{u_1^{t_{2,1}}}{0.4}, \frac{u_2^{t_{2,1}}}{0.5}, \frac{u_3^{t_{2,1}}}{0.2}, \frac{u_4^{t_{2,1}}}{0.3}\right\}\right), \\
& \left(e_2^{t_2}, \left\{\frac{u_1^{t_{2,2}}}{0.4}, \frac{u_2^{t_{2,2}}}{0.6}, \frac{u_3^{t_{2,2}}}{0.5}, \frac{u_4^{t_{2,2}}}{0.3}\right\}\right), \\
& \left(e_2^{t_2}, \left\{\frac{u_1^{t_{2,3}}}{0.1}, \frac{u_2^{t_{2,3}}}{0.6}, \frac{u_3^{t_{2,3}}}{0.7}, \frac{u_4^{t_{2,3}}}{0.3}\right\}\right), \\
& \left(e_3^{t_3}, \left\{\frac{u_1^{t_{3,1}}}{0.3}, \frac{u_2^{t_{3,1}}}{0.5}, \frac{u_3^{t_{3,1}}}{0.2}, \frac{u_4^{t_{3,1}}}{0.3}\right\}\right), \\
& \left(e_3^{t_3}, \left\{\frac{u_1^{t_{3,2}}}{0.3}, \frac{u_2^{t_{3,2}}}{0.6}, \frac{u_3^{t_{3,2}}}{0.5}, \frac{u_4^{t_{3,2}}}{0.7}\right\}\right), \\
& \left(e_3^{t_3}, \left\{\frac{u_1^{t_{3,3}}}{0.1}, \frac{u_2^{t_{3,3}}}{0.6}, \frac{u_3^{t_{3,3}}}{0.7}, \frac{u_4^{t_{3,3}}}{0.9}\right\}\right) \Bigg\}.
\end{aligned}$$

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Definition 5.3. If $(F_\Lambda, A)^t$ and $(G_\Lambda, B)^t$ are two T-EFSS over U then "$(F_\Lambda, A)^t$ OR $(G_\Lambda, B)^t$" denoted by $(F_\Lambda, A)^t \vee (G_\Lambda, B)^t$, is defined by

$$(F_\Lambda, A)^t \vee (G_\Lambda, B)^t = (H_\Lambda, A \times B)^t$$

, where $\widetilde{\bigcup}$ is time-effective fuzzy union.

Example 5.4. Consider Example 3.2 we have U then " $(F_\Lambda, A)^t$ OR $(G_\Lambda, B)^t$" denoted by $(H_\Lambda, C)^t$= $(F_\Lambda, A)^t \bigvee (G_\Lambda, B)^t$ where $(H_\Lambda, C)^t =$

$$\Bigg\{ \left(\left(e_1^{t_1}, e_1^{t_1}\right), \left\{ \frac{u_1{}^{t_{1,1}}}{0.8}, \frac{u_2{}^{t_{1,1}}}{0.5}, \frac{u_3{}^{t_{1,1}}}{0.2}, \frac{u_4{}^{t_{1,1}}}{0.4} \right\} \right), \left(\left(e_1^{t_1}, e_3^{t_2}\right), \left\{ \frac{u_1{}^{t_{1,2}}}{0.6}, \frac{u_2{}^{t_{1,2}}}{0.8}, \frac{u_3{}^{t_{1,2}}}{0.5}, \frac{u_4{}^{t_{1,2}}}{0.7} \right\} \right),$$

$$\left(\left(e_1^{t_1}, e_3^{t_3}\right), \left\{ \frac{u_1{}^{t_{1,3}}}{0.6}, \frac{u_2{}^{t_{1,3}}}{0.6}, \frac{u_3{}^{t_{1,3}}}{0.7}, \frac{u_4{}^{t_{1,3}}}{0.9} \right\} \right), \left(\left(e_2^{t_1}, e_1^{t_1}\right), \left\{ \frac{u_1{}^{t_{1,1}}}{0.8}, \frac{u_2{}^{t_{1,1}}}{0.5}, \frac{u_3{}^{t_{1,1}}}{0.2}, \frac{u_4{}^{t_{1,1}}}{0.7} \right\} \right),$$

$$\left(\left(e_2^{t_1}, e_3^{t_2}\right), \left\{ \frac{u_1{}^{t_{1,2}}}{0.5}, \frac{u_2{}^{t_{1,2}}}{0.8}, \frac{u_3{}^{t_{1,2}}}{0.5}, \frac{u_4{}^{t_{1,2}}}{0.7} \right\} \right), \left(\left(e_2^{t_1}, e_3^{t_3}\right), \left\{ \frac{u_1{}^{t_{1,3}}}{0.5}, \frac{u_2{}^{t_{1,3}}}{0.6}, \frac{u_3{}^{t_{1,3}}}{0.7}, \frac{u_4{}^{t_{1,3}}}{0.9} \right\} \right),$$

$$\left(\left(e_2^{t_2}, e_1^{t_1}\right), \left\{ \frac{u_1{}^{t_{2,1}}}{0.8}, \frac{u_2{}^{t_{2,1}}}{0.6}, \frac{u_3{}^{t_{2,1}}}{0.8}, \frac{u_4{}^{t_{2,1}}}{0.3} \right\} \right), \left(\left(e_2^{t_2}, e_3^{t_2}\right), \left\{ \frac{u_1{}^{t_{2,2}}}{0.4}, \frac{u_2{}^{t_{2,2}}}{0.8}, \frac{u_3{}^{t_{2,2}}}{0.8}, \frac{u_4{}^{t_{2,2}}}{0.7} \right\} \right),$$

$$\left(\left(e_2^{t_2}, e_3^{t_3}\right), \left\{ \frac{u_1{}^{t_{2,3}}}{0.4}, \frac{u_2{}^{t_{2,3}}}{0.6}, \frac{u_3{}^{t_{2,3}}}{0.8}, \frac{u_4{}^{t_{2,3}}}{0.9} \right\} \right), \left(\left(e_3^{t_3}, e_1^{t_1}\right), \left\{ \frac{u_1{}^{t_{3,1}}}{0.8}, \frac{u_2{}^{t_{3,1}}}{0.6}, \frac{u_3{}^{t_{3,1}}}{0.8}, \frac{u_4{}^{t_{3,1}}}{0.9} \right\} \right),$$

$$\left(\left(e_3^{t_3}, e_3^{t_2}\right), \left\{ \frac{u_1{}^{t_{3,2}}}{0.4}, \frac{u_2{}^{t_{3,2}}}{0.8}, \frac{u_3{}^{t_{3,2}}}{0.8}, \frac{u_4{}^{t_{3,2}}}{0.9} \right\} \right), \left(\left(e_3^{t_3}, e_3^{t_3}\right), \left\{ \frac{u_1{}^{t_{3,3}}}{0.1}, \frac{u_2{}^{t_{3,3}}}{0.6}, \frac{u_3{}^{t_{3,3}}}{0.8}, \frac{u_4{}^{t_{3,3}}}{0.9} \right\} \right) \Bigg\},$$

6 A application with a Neutrosophic of Time-Effective Fuzzy Soft Sets in Decision Making

In this part, we demonstrate how time-efficient fuzzy soft set theory can be applied to a problem of decision-making.

Example 6.1. Consider a scenario where one of the broadcasting channels wants to consult experts to assess their program through the debate of a contentious topic and get their assessment of the circumstances. The following criteria were utilized by the show's creators to decide how to assess their results: Their four alternatives are as follows: $U = \{u_1,\ u_2,\ u_3, u_4\}$,. Suppose there are five parameters $E = \{e_1, e_2, e_3, e_4, e_5,\}$, choose the experts for the programs. For i = 1, 2, 3, 4, 5 the parameters e_i $(i = 1, 2, 3, 4, 5)$ stand for "this criteria to discriminate", "this criteria is independent of the other criteria ", "this criteria measures one thing ", "the universal criteria ", "the criteria that is important to some of the stakeholders". $T = \{t_1, t_2, t_3\}$ and let $\widetilde{E} = \{a_1, a_2, a_3, a_4\}$ be a set of effective parameters.

Suppose that the effective set over $\widetilde{E}$ for all $\{u_1, u_2, u_3\}$ given an expert as follows:

$$\Lambda_{t_1}(u_1) = \left\{ \frac{a_1^{t_1}}{1}, \frac{a_2^{t_1}}{0.2}, \frac{a_3^{t_1}}{0.8}, \frac{a_4^{t_1}}{0} \right\},\ \Lambda_{t_1}(u_2) = \left\{ \frac{a_1^{t_1}}{0.8}, \frac{a_2^{t_1}}{0}, \frac{a_3^{t_1}}{0.5}, \frac{a_4^{t_1}}{0.4} \right\},\ \Lambda_{t_1}(u_3) = \left\{ \frac{a_1^{t_1}}{0.6}, \frac{a_2^{t_1}}{0.7}, \frac{a_3^{t_1}}{0.3}, \frac{a_4^{t_1}}{1} \right\},$$

$$\Lambda_{t_1}(u_4) = \left\{ \frac{a_1^{t_1}}{0.1}, \frac{a_2^{t_1}}{0.2}, \frac{a_3^{t_1}}{0.3}, \frac{a_4^{t_1}}{1} \right\}.$$

$$\Lambda_{t_2}(u_1) = \left\{ \frac{a_1^{t_2}}{0.2}, \frac{a_2^{t_2}}{1}, \frac{a_3^{t_2}}{0}, \frac{a_4^{t_2}}{0.5} \right\},\ \Lambda_{t_2}(u_2) = \left\{ \frac{a_1^{t_2}}{0.6}, \frac{a_2^{t_2}}{0.5}, \frac{a_3^{t_2}}{0}, \frac{a_4^{t_2}}{0.9} \right\},\ \Lambda_{t_2}(u_3) = \left\{ \frac{a_1^{t_2}}{1}, \frac{a_2^{t_2}}{0}, \frac{a_3^{t_2}}{0.4}, \frac{a_4^{t_2}}{0.6} \right\},$$

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$$\Lambda_{t_2}(u_4) = \left\{\frac{a_1^{t_2}}{0.6}, \frac{a_2^{t_2}}{0.7}, \frac{a_3^{t_2}}{0.3}, \frac{a_4^{t_2}}{1}\right\}.$$

$$\Lambda_{t_3}(u_1) = \left\{\frac{a_1^{t_3}}{0.6}, \frac{a_2^{t_3}}{1}, \frac{a_3^{t_3}}{1}, \frac{a_4^{t_3}}{0.5}\right\},\ \Lambda_{t_3}(u_2) = \left\{\frac{a_1^{t_3}}{0.9}, \frac{a_2^{t_3}}{0.5}, \frac{a_3^{t_3}}{0}, \frac{a_4^{t_3}}{0.7}\right\},\ \Lambda_{t_3}(u_3) = \left\{\frac{a_1^{t_3}}{0.7}, \frac{a_2^{t_3}}{1}, \frac{a_3^{t_3}}{0.7}, \frac{a_4^{t_3}}{0.4}\right\},$$

$$\Lambda_{t_3}(u_4) = \left\{\frac{a_1^{t_3}}{0.7}, \frac{a_2^{t_3}}{0.5}, \frac{a_3^{t_3}}{0.3}, \frac{a_4^{t_3}}{0.7}\right\}.$$

$$\Lambda_{t_3}(u_1) = \left\{\frac{a_1^{t_3}}{0.6}, \frac{a_2^{t_3}}{1}, \frac{a_3^{t_3}}{1}, \frac{a_4^{t_3}}{0.5}\right\},\ \Lambda_{t_3}(u_2) = \left\{\frac{a_1^{t_3}}{0.9}, \frac{a_2^{t_3}}{0.5}, \frac{a_3^{t_3}}{0}, \frac{a_4^{t_3}}{0.7}\right\},\ \Lambda_{t_3}(u_3) = \left\{\frac{a_1^{t_3}}{0.7}, \frac{a_2^{t_3}}{1}, \frac{a_3^{t_3}}{0.7}, \frac{a_4^{t_3}}{0.4}\right\},$$

$$\Lambda_{t_3}(u_4) = \left\{\frac{a_1^{t_3}}{0.7}, \frac{a_2^{t_3}}{0.5}, \frac{a_3^{t_3}}{0.3}, \frac{a_4^{t_3}}{0.7}\right\}.$$

These results allow us to identify the best option for the decision. The committee creates the following time-effective fuzzy soft set following a serious deliberation, as shown in example 3.2.

$$\begin{aligned}
(F,E)_t = \Bigg\{ & \left(e_1, \left\{\frac{{u_1}^{t_1}}{0.6}, \frac{{u_2}^{t_1}}{0.3}, \frac{{u_3}^{t_1}}{0.2}, \frac{{u_4}^{t_1}}{0.4}\right\}\right), \left(e_2, \left\{\frac{{u_1}^{t_1}}{0.5}, \frac{{u_2}^{t_1}}{0.3}, \frac{{u_3}^{t_1}}{0.2}, \frac{{u_4}^{t_1}}{0.7}\right\}\right), \\
& \left(e_3, \left\{\frac{{u_1}^{t_1}}{0.3}, \frac{{u_2}^{t_1}}{0.6}, \frac{{u_3}^{t_1}}{0.8}, \frac{{u_4}^{t_1}}{0.9}\right\}\right), \left(e_4, \left\{\frac{{u_1}^{t_1}}{0.5}, \frac{{u_2}^{t_1}}{0.4}, \frac{{u_3}^{t_1}}{0.6}, \frac{{u_4}^{t_1}}{0.8}\right\}\right), \\
& \left(e_5, \left\{\frac{{u_1}^{t_1}}{0.9}, \frac{{u_2}^{t_1}}{0.2}, \frac{{u_3}^{t_1}}{0.4}, \frac{{u_4}^{t_1}}{0.8}\right\}\right), \left(e_1, \left\{\frac{{u_1}^{t_2}}{0.7}, \frac{{u_2}^{t_2}}{0.4}, \frac{{u_3}^{t_2}}{0.1}, \frac{{u_4}^{t_2}}{0.3}\right\}\right), \\
& \left(e_2, \left\{\frac{{u_1}^{t_2}}{0.3}, \frac{{u_2}^{t_2}}{0.1}, \frac{{u_3}^{t_2}}{0.2}, \frac{{u_4}^{t_2}}{0.6}\right\}\right), \left(e_3, \left\{\frac{{u_1}^{t_2}}{0.7}, \frac{{u_2}^{t_2}}{0.8}, \frac{{u_3}^{t_2}}{0.6}, \frac{{u_4}^{t_2}}{0.4}\right\}\right), \\
& \left(e_4, \left\{\frac{{u_1}^{t_2}}{0.9}, \frac{{u_2}^{t_2}}{0.3}, \frac{{u_3}^{t_2}}{0.4}, \frac{{u_4}^{t_2}}{0.7}\right\}\right), \left(e_5, \left\{\frac{{u_1}^{t_2}}{0.2}, \frac{{u_2}^{t_2}}{0.7}, \frac{{u_3}^{t_2}}{0.8}, \frac{{u_4}^{t_2}}{0.5}\right\}\right), \\
& \left(e_1, \left\{\frac{{u_1}^{t_3}}{0.7}, \frac{{u_2}^{t_3}}{0.8}, \frac{{u_3}^{t_3}}{0.6}, \frac{{u_4}^{t_3}}{0.4}\right\}\right), \left(e_2, \left\{\frac{{u_1}^{t_3}}{0.7}, \frac{{u_2}^{t_3}}{0.5}, \frac{{u_3}^{t_3}}{0.6}, \frac{{u_4}^{t_3}}{0.4}\right\}\right), \\
& \left(e_3, \left\{\frac{{u_1}^{t_3}}{0.6}, \frac{{u_2}^{t_3}}{0.4}, \frac{{u_3}^{t_3}}{0.5}, \frac{{u_4}^{t_3}}{0.7}\right\}\right), \left(e_4, \left\{\frac{{u_1}^{t_3}}{0.6}, \frac{{u_2}^{t_3}}{0.7}, \frac{{u_3}^{t_3}}{0.5}, \frac{{u_4}^{t_3}}{0.3}\right\}\right), \\
& \left(e_5, \left\{\frac{{u_1}^{t_3}}{0.7}, \frac{{u_2}^{t_3}}{0.2}, \frac{{u_3}^{t_3}}{0.6}, \frac{{u_4}^{t_3}}{0.3}\right\}\right) \Bigg\}.
\end{aligned}$$

6.1 Algorithm

1. Bring up the data table representation of $(F_\Lambda, A)^t$ as in Table 1.
2. Bring up the data table representation of $F\,(E)$ as in Table 2, where $F\,(E)$ defined as follows:

$$F\,(e) = \left\{ \frac{u}{\sum_{i=1}^{n} t_i F_t(e) \setminus n \sum_{i=1}^{n} F_t(e)} : u \in U, e \in E \right\}$$

   where $n = |T|$.

3. Use Roy & Maji's algorithm for $F\,(E)$.

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====================================9999999999999999999999999999 p2cmp2cmp2cmp2cmp2cmp2cm

U u_1 u_2 u_3 u_4

Table 0 – continued

Continued on next page

U	u_1	u_2	u_3	u_4
(e_1, t_1)	0.6	0.3	0.2	0.4
(e_1, t_2)	0.7	0.4	0.1	0.3
(e_1, t_3)	0.7	0.8	0.6	0.4
(e_2, t_1)	0.5	0.3	0.2	0.7
(e_2, t_2)	0.3	0.1	0.2	0.6
(e_2, t_3)	0.7	0.5	0.6	0.4
(e_3, t_1)	0.3	0.6	0.8	0.9
(e_3, t_2)	0.7	0.8	0.6	0.4
(e_3, t_3)	0.6	0.4	0.5	0.7
(e_4, t_1)	0.5	0.4	0.6	0.8
(e_4, t_2)	0.9	0.3	0.4	0.7
(e_4, t_3)	0.6	0.7	0.5	0.3
(e_5, t_1)	0.9	0.2	0.4	0.8
(e_5, t_2)	0.2	0.7	0.8	0.5
(e_5, t_3)	0.7	0.2	0.6	0.3

Next, by using relation in step (2), we compute the $F(E)$ to convert the time fuzzy soft set to fuzzy soft set. To illustrate this step, we calculate $F(e_1)$ for u_1 as shown below.

$$F(e_1) = \left\{ \frac{u_1}{\sum_{i=1}^{3} t_i F_t(e) \big/ 3 \sum_{i=1}^{3} F_t(e)} : u \in U, e \in E \right\}$$
$$= \left\{ \frac{u_1}{((1*0.80)+(2*0.82)+(3*0.93)) \big/ 3(0.80+0.82+0.93)} \right\}$$
$$= \left\{ \frac{u_1}{5.23 \big/ 7.65} \right\}$$
$$= \frac{u_1}{o.68}.$$

The conversion for u_i with all parameters can be done in a similar way. The results of the conversion are shown in the next table. p2cmp2cmp2cmp2cmp2cmp2cm

U u_1 u_2 u_3 u_4

Table 0 – continued

Continued on next page

U	u_1	u_2	u_3	u_4
e_1	0.68	0.95	0.69	0.68
e_2	0.69	0.69	0.69	0.64
e_3	0.70	0.67	0.65	0.65

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e_4	0.68	0.69	0.66	0.63
e_5	0.66	0.68	0.67	0.63

A comparison table is a square table in which the number of rows and the number of columns are equal. Rows and columns are both labeled by the object names u_1,u_2,u_3,...,u_n of the universe, and the entries c_{ij}, $i, j = 1, 2, ..., n$, are given by c_{ij}= the number of parameters for which the membership value of u_i exceeds or is equal to the membership value of u_j. Clearly, $0 \leq c_{ij} \leq m$, $\forall_{i,j}$, where m is the number of parameters. The comparison table of the above resultant-time fuzzy soft is shown below.

For example, from the data in table 6.1, the comparison for u_4 with u_2 equals 0 because all membership values of u_4 are less than the membership values of u_2, but by comparing the membership values of u_4 with u_1 and u_3, we get $u_4 = 1$ because there is one value for u_4 that exceeds the membership value of $u_1(0.68 = 0.68)$ and $u_3(0.65 = 0.65)$.

p2cmp2cmp2cmp2cmp2cmp2cm

U u_1 u_2 u_3 u_4

Table 0 – continued

Continued on next page

U	u_1	u_2	u_3	u_4
u_1	5	2	3	5
u_2	4	5	5	5
u_3	3	1	5	5
u_4	1	0	1	5

After the construction of the comparison table from the resultant time fuzzy soft set, the optimal decision is taken based on the maximum score computed from the comparison table. So now we compute the row-sum (r_i), column-sum (t_j) and score (S_i) for each u_i as shown below (Table 6). c—c c c c

U r_i t_j S_J

Table 0 – continued

$Ur_1r_[0, 1]r_0$

Continued on next page

U	r_i	t_j	S_J
u_1	15	13	2
u_2	19	8	1
u_3	14	14	0
u_4	7	20	-13

From the above score table, we can see that choice u_1 has the highest accepting scores, choice u_2 has the highest waiting scores, and choice u_4 rejects.

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7 Time-effective fuzzy soft set with Neutrosophic membership degree

The hypothetical application of time-effective fuzzy soft set theory with neutrosophic in a decision-making problem that we present in this section shows that this approach can be effectively used to solve problems in a variety of fields that involve uncertainty. In order to solve time-neutrosophic soft-based decision-making problems, we propose the following algorithm: It should be noted that Maji's algorithm will be referred to by its acronym, MA.

Example 7.1. It is not enough to measure the performance of governments through various opinion polls, so the performance of governments should be measured through performance indicators covering the following areas: functions and responsibilities. Suppose that there is a company of strategic studies. This company wants to conduct a study to evaluate the performance of the governments in three countries through specific parameters for three previous time periods, and these parameters are mentioned below. Let $U = \{u_1,\ u_2,\ u_3\}$, be a set of governments. There may be three parameters. Let $E = \{e_1, e_2, e_3\}$ be a set of decision parameters to evaluate the performance of governments. For i = 1, 2, 3, the parameters e_i $(i = 1, 2, 3)$ stand for "the effectiveness of the fight against corruption", "effective management of natural resources", "savings and investment", and let $T = \{t_1, t_2, t_3\}$. From the findings of this study, it will be clear to identify the best government that satisfies the above mentioned parameters.

Let $U = \{u_1, u_2, u_3, u_4\}$ be a set of universes. $E = \{e_1, e_2, e_3\}$ a set of parameters and $T = \{t_1, t_2, t_3,\}$ be a set of time, and let $\widetilde{E} = \{a_1, a_2, a_3, a_4\}$ be a set of effective parameters. Let the time-effective fuzzy soft set F with neutrosofic membership degree defined as follows:

$$F_{\widetilde{E}_1}\left(e_1^N\right) = \left\{\frac{{u_1}^{t_1}}{(0.6, 0.2, 0.8)}, \frac{{u_2}^{t_1}}{(0.2, 0.6, 0.7)}, \frac{{u_3}^{t_1}}{(0.4, 0.2, 0.7)}\right\},$$
$$F_{\widetilde{E}_1}\left(e_2^N\right) = \left\{\frac{{u_1}^{t_1}}{(0.4, 0.2, 0.7)}, \frac{{u_2}^{t_1}}{(0.2, 0.6, 0.8)}, \frac{{u_3}^{t_1}}{(0.6, 0.2, 0.8)}\right\},$$

$$F_{\widetilde{E}_1}\left(e_3^N\right) = \left\{\frac{{u_1}^{t_1}}{(0.2, 0.6, 0.8)}, \frac{{u_2}^{t_1}}{(0.4, 0.2, 0.7)}, \frac{{u_3}^{t_1}}{(0.6, 0.2, 0.8)}\right\},$$

$$F_{\widetilde{E}_2}\left(e_1^N\right) = \left\{\frac{{u_1}^{t_2}}{(0.5, 0.6, 0.7)}, \frac{{u_2}^{t_2}}{(0.7, 0.8, 0.9)}, \frac{{u_3}^{t_2}}{(0.9, 0.8, 0.9)}\right\},$$

$$F_{\widetilde{E}_2}\left(e_2^N\right) = \left\{\frac{{u_1}^{t_2}}{(0.9, 0.6, 0.8)}, \frac{{u_2}^{t_2}}{(0.5, 0.7, 0.8)}, \frac{{u_3}^{t_2}}{(0.3, 0.4, 0.5)}\right\},$$

$$F_{\widetilde{E}_2}\left(e_3^N\right) = \left\{\frac{{u_1}^{t_2}}{(0.5, 0.7, 0.8)}, \frac{{u_2}^{t_2}}{(0.9, 0.6, 0.8)}, \frac{{u_3}^{t_2}}{(0.3, 0.4, 0.5)}\right\},$$

$$F_{\widetilde{E}_3}\left(e_1^N\right) = \left\{\frac{{u_1}^{t_3}}{(0.2, 0.6, 0.8)}, \frac{{u_2}^{t_3}}{(0.4, 0.2, 0.7)}, \frac{{u_3}^{t_3}}{(0.6, 0.2, 0.8)}\right\},$$

$$F_{\widetilde{E}_3}\left(e_2^N\right) = \left\{\frac{{u_1}^{t_3}}{(0.4, 0.2, 0.7)}, \frac{{u_2}^{t_3}}{(0.2, 0.6, 0.8)}, \frac{{u_3}^{t_3}}{(0.6, 0.2, 0.8)}\right\},$$

$$F_{\widetilde{E}_3}\left(e_3^N\right) = \left\{\frac{{u_1}^{t_3}}{(0.6, 0.2, 0.8)}, \frac{{u_2}^{t_3}}{(0.2, 0.6, 0.7)}, \frac{{u_3}^{t_3}}{(0.4, 0.2, 0.7)}\right\}.$$

Suppose that the effective set over $\widetilde{E}$ for all $\{u_1, u_2, u_3\}$ given by an expert as follows:

$$\Lambda_{t_1}(u_1) = \left\{\frac{a_1^{t_1}}{1}, \frac{a_2^{t_1}}{0.2}, \frac{a_3^{t_1}}{0.8}, \frac{a_4^{t_1}}{0}\right\},\ \Lambda_{t_1}(u_2) = \left\{\frac{a_1^{t_1}}{0.8}, \frac{a_2^{t_1}}{0}, \frac{a_3^{t_1}}{0.5}, \frac{a_4^{t_1}}{0.4}\right\},\ \Lambda_{t_1}(u_3) = \left\{\frac{a_1^{t_1}}{0.6}, \frac{a_2^{t_1}}{0.7}, \frac{a_3^{t_1}}{0.3}, \frac{a_4^{t_1}}{1}\right\}$$

$$\Lambda_{t_2}(u_1) = \left\{\frac{a_1^{t_2}}{0.2}, \frac{a_2^{t_2}}{1}, \frac{a_3^{t_2}}{0}, \frac{a_4^{t_2}}{0.5}\right\},\ \Lambda_{t_2}(u_2) = \left\{\frac{a_1^{t_2}}{0.6}, \frac{a_2^{t_2}}{0.5}, \frac{a_3^{t_2}}{0}, \frac{a_4^{t_2}}{0.9}\right\},\ \Lambda_{t_2}(u_3) = \left\{\frac{a_1^{t_2}}{1}, \frac{a_2^{t_2}}{0}, \frac{a_3^{t_2}}{0.4}, \frac{a_4^{t_2}}{0.6}\right\},$$

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$$\Lambda_{t_3}(u_1) = \left\{\frac{a_1^{t_3}}{0.6}, \frac{a_2^{t_3}}{1}, \frac{a_3^{t_3}}{1}, \frac{a_4^{t_3}}{0.5}\right\}, , \Lambda_{t_3}(u_2) = \left\{\frac{a_1^{t_3}}{0.9}, \frac{a_2^{t_3}}{0.5}, \frac{a_3^{t_3}}{0}, \frac{a_4^{t_3}}{0.7}\right\}, \Lambda_{t_3}(u_3) = \left\{\frac{a_1^{t_3}}{0.7}, \frac{a_3^{t_2}}{1}, \frac{a_3^{t_3}}{0.7}, \frac{a_4^{t_3}}{0.4}\right\},$$

$$F_{\Lambda_{t_1}}(e_1^N) = \left\{\frac{u_1^{t_1}}{(0.6+0.4\left[\frac{1+0.2+0.8+0}{4}\right], 0.2+0.8\left[\frac{1+0.2+0.8+0}{4}\right], 0.2+0.2\left[\frac{1+0.2+0.8+0}{4}\right])}\right.$$
$$\left\{\frac{u_2^{t_1}}{(0.2+0.8\left[\frac{0.8+0+0.5+0.4}{4}\right], 0.6+0.4\left[\frac{0.8+0+0.5+0.4}{4}\right], 0.7+0.3\left[\frac{0.8+0+0.5+0.4}{4}\right])}\right.$$
$$\left\{\frac{u_3^{t_1}}{(0.4+0.6\left[\frac{0.6+0.7+0.3+1}{4}\right], 0.2+0.8\left[\frac{0.6+0.7+0.3+1}{4}\right], 0.7+0.3\left[\frac{0.6+0.7+0.3+1}{4}\right])}\right.$$
$$F_{\Lambda_{t_1}}(e_1^N) = \left\{\frac{{u_1}^{t_1}}{(0.8, 0.6, 0.9))}, \frac{{u_2}^{t_1}}{(0.54, 0.77, 0.8)}, \frac{{u_3}^{t_1}}{(0.79, 0.72, 0.89))}\right\})$$

Then we can find the s $(F_\Lambda, Z)^t$ as consisting of the following collection of approximations:

$$\begin{aligned}
(F_\Lambda, Z)^t = \Bigg\{ & \left(e_1^N, \left\{\frac{{u_1}^{t_1}}{(0.8, 0.6, 0.9)}, \frac{{u_2}^{t_1}}{(0.54, 0.77, 0.80)}, \frac{{u_3}^{t_1}}{(0.79, 0.72, 0.89)}\right\}\right), \\
& \left(e_2^N, \left\{\frac{{u_1}^{t_1}}{(0.70, 0.54, 0.89)}, \frac{{u_2}^{t_1}}{(0.54, .0.77, 0.88)}, \frac{{u_3}^{t_1}}{(0.86, 0.72, 0.93)}\right\}\right), \\
& \left(e_3^N, \left\{\frac{{u_1}^{t_1}}{(0.6, 0.77, 0.93)}, \frac{{u_2}^{t_1}}{(0.7, 0.54, 0.89)}, \frac{{u_3}^{t_1}}{(0.8, 0.54, 0.93)}\right\}\right) \\
& \left({e_1}^N, \left\{\frac{{u_1}^{t_2}}{(0.59, 0.65, 0.71)}, \frac{{u_2}^{t_2}}{(0.75, 0.85, 0.90)}, \frac{{u_3}^{t_2}}{(0.95, 0.80, 0.90)}\right\}\right), \\
& \left(e_2^N, \left\{\frac{{u_1}^{t_2}}{(0.94, 0.76, 0.88)}, \frac{{u_2}^{t_2}}{(0.75, 0.85, 0.90)}, \frac{{u_3}^{t_2}}{(0.65, 0.70, 0.75)}\right\}\right), \\
& \left(e_3^N, \left\{\frac{{u_1}^{t_2}}{(0.71, 0.82, 0.88)}, \frac{{u_2}^{t_2}}{(0.95, 0.80, 0.90)}, \frac{{u_3}^{t_2}}{(0.65, 0.70, 0.75)}\right\}\right), \\
& \left(e_1^N, \left\{\frac{{u_1}^{t_3}}{(0.81, 0.90, 0.95)}, \frac{{u_2}^{t_3}}{(0.71, 0.61, 0.85)}, \frac{{u_3}^{t_3}}{(0.88, 0.76, 0.94)}\right\}\right), \\
& \left({e_2}^N, \left\{\frac{{u_1}^{t_3}}{(0.86, 0.81, 0.93)}, \frac{{u_2}^{t_3}}{(0.61, 0.80, 0.90)}, \frac{{u_3}^{t_3}}{(0.88, 0.76, 0.94)}\right\}\right), \\
& \left(e_3^N, \left\{\frac{{u_1}^{t_3}}{(0.86, 0.81, 0.95)}, \frac{{u_2}^{t_3}}{(0.91, 0.80, 0.85)}, \frac{{u_3}^{t_3}}{(0.82, 0.76, 0.91)}\right\}\right) \Bigg\}.
\end{aligned}$$

7.1 Algorithm

We use Maji's algorithm to determine the best course of action in order to convert the time-effective fuzzy soft set with a neutrophilic membership to a fuzzy soft set. To find the decision, we can apply the following algorithm to convert to a time fuzzy soft set with a neutrophilic membership:

We can satisfy our goal as follows:

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1. Bring up the data table representation of $(F_\Lambda, A)^t$ as in Table **??**.
2. Find the tabular representation of $(F_\Lambda, A)^t$, where $F(E)$ is defined as follows:

$$F(e) = \left\{ \frac{u}{\langle T(e), I(e), F(e) \rangle} : u \in U, e \in E \right\} \tag{1}$$

such that
$T(e) = \frac{\sum_{i=1}^{n} \alpha_{t_i} T_{t_i}(e)}{n \max_{i=1}^{n} \alpha_i(e)}$,
$I(e) = \frac{\sum_{i=1}^{n} \alpha_{t_i} I_{t_i}(e)}{n \max_{i=1}^{n} \alpha_i(e)}$,
$F(e) = \frac{\sum_{i=1}^{n} \alpha_{t_i} F_{t_i}(e)}{n \max_{i=1}^{n} \alpha_i(e)}$,
where $n = |T|$ and α_{t_i} the weight of t_i.

3. Use Maji's algorithm for $F(E)$.
   - Input the Neutrosophic Soft Set $F(E)$.
   - Input e, the choice parameters of the company's strategic is a subset of A
   - Compute the comparison matrix.
   - Compute the score S_i of u_i; $\forall i$.
   - Find $S_k = \max_i S_i$.
   - If k has more than one value, then any one of u_i could be preferable choice.

Then we have the following results, shown in Table **??**.

p3cmp3cmp3cmp3cmp3cmp3cm

U u_1 u_2 u_3
Table 0 – continued

U u_1 u_2 u_3

Continued on next page

U	u_1	u_2	u_3
(e_1, t_1)	(0.80, 0.60 , 0.90)	(0.54, 0.77 ,0.8)	(0.79, 0.72 ,0.80)
(e_1, t_2)	(0.59, 0.65 ,0.71)	(0.77, 0.85 ,0.90)	(0.95, 0.80 , 0.90)
(e_1, t_3)	(0.81, 0.90 ,0.95)	(0.71, 0.61 ,0.85)	(0.88,0.76 , 0.94)
(e_2, t_1)	(0.70, 0.54 ,0.89)	(0.54,0.77,0.88)	(0.86,0.72 ,0.93)
(e_2, t_2)	(0.94,0.76 ,0.88)	(0.75, 0.85 ,0.90)	(0.65, 0.70 ,0.75)
(e_2, t_3)	(0.86, 0.81 , 0.93)	(0.61,0.89 ,0.90)	(0.88,0.76 ,0.94)
(e_3, t_1)	(0.60,0.77 ,0.93)	(0.70, 0.54 ,0.89)	(0.80,0.54 ,0.93)
(e_3, t_2)	(0.71 , 0.82 ,0.88)	(0.95,0.80 ,0.90)	(0.65, 0.70 , 0.75)
(e_3, t_3)	(0.86, 0.81, 0.95)	(0.91, 0.80, 0.85)	(0.82, 0.76, 0.91)

Next, by using relation 1 and supposing that $\alpha_{t_1} = 0.4$, $\alpha_{t_2} = 0.5$, and $\alpha_{t_3} = 0.7$, we compute the $F(E)$ to convert the time-neutrosophic soft set to a time fuzzy soft set. To illustrate this step, we calculate $F(e_1)$ for u_1 as shown below.

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$$F_{u_1}(e_1) = \left\{ \frac{u_1}{\langle T(e_1), I(e_1), F(e_1) \rangle} \right\} \tag{2}$$

Where

$$\begin{aligned} T(e_1) &= \frac{0.4 * 0.8 + 0.5 * 0.59 + 0.7 * 0.81}{3 * \max\{0.4, 0.5, 0.7\}} \\ &= 1.182 / 2.1 \\ &= 0.56. \\ I(e_1) &= \frac{0.4 * 0.6 + 0.5 * 0.65 + 0.7 * 0.81}{3 * \max\{0.4, 0.5, 0.7\}} \\ &= 1.195 / 2.1 \\ &= 0.56. \\ F(e_1) &= \frac{0.4 * 0.9 + 0.5 * 0.71 + 0.7 * 0.95}{3 * \max\{0.4, 0.5, 0.7\}} \\ &= 1.38 / 2.1 \\ &= 0.65. \end{aligned}$$

Then

$$F_{u_1}(e_1) = \left\{ \frac{u_1}{\langle 0.56, 0.56, 0.61 \rangle} \right\}$$

The conversation for u_i with all parameters can be done in a similar way. The results of converting are shown in Table 7.1. c—c c c c c

$U u_1 u_2 u_3$

Table 0 – continued

$U u_1 u_2 u_3$

Continued on next page

e_1	$\langle 0.56, 0.56, 0.61 \rangle$	$\langle 0.52, 0.55, 0.65 \rangle$	$\langle 0.67, 0.58, 0.68 \rangle$
e_2	$\langle 0.64, 0.55, 0.68 \rangle$	$\langle 0.48, 0.64, 0.68 \rangle$	$\langle 0.61, 0.55, 0.66 \rangle$
e_3	$\langle 0.57, 0.61, 0.70 \rangle$	$\langle 0.66, 0.56, 0.66 \rangle$	$\langle 0.58, 0.52, 0.65 \rangle$

c—c c c c c c

U e_1 e_2 e_3

Table 0 – continued

U e_1 e_2 e_3

Continued on next page

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u_1	3	2	1
u_2	0	1	3
u_3	3	3	2

Score of an Object. The score of an object U_i is S_i and is calculated as $S_i = \sum_j c_{ij}$, we compute the score for each u_i as shown below, (Table 7.1). c—c

U S_i

Table 0 – continued

U S_i

Continued on next page

U	S_i
u_1	6
u_2	4
u_3	8

From the above score table, it is clear that the maximum score is 8, scored by u_3, so the decision is in favor of selecting u_3.

8 Conclusion

In this paper,I have introduced the concept of a time- effective fuzzy soft set and studied some 0f its properties. The complement, union, and intersection operations have been defined on the time effective fuzzy soft set. An application of this theory, both with and without Neutrosophic membership in solving a decision making problem is given.

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