T-Fuzzy Soft Homomorphisms of Ideal Structures

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Abstract: In this paper, we introduce the notion of temporal fuzzy soft sub RR-ideal and temporal fuzzy soft RR- r-ideal with examples. We have proved some interesting results which are very close to the results which are very closer to the results fuzzy soft ideal in BCK-Algebras. Also we have proved some results on T- fuzzy soft RR-ideals in RR-semi group homomorphism.

Key words: soft set, BCK-algebra, soft complement, temporal fuzzy soft set, RR-ideals, RR-semi group, soft union, soft intersection, homomorphisms

INTRODUCTION

There are many problems in economy, engineering, environmental and social sciences that may not be successfully modelled by the classical mathematics because of various types of uncertainties. Zadeh [19] introduced the notion of a fuzzy set in 1965 to deal with such kinds of problems. Molodtsov [16] introduced the concept of soft sets that can be seen as a new mathematical theory for dealing with uncertainty. Molodtsov applied this theory to several directions, and then formulated the notions of soft number, soft derivative, soft integral, etc. The soft set theory has been applied to many different fields with great success. Maji et al. [[12]-[14]] worked on theoretical study of soft sets in detail, and [2003] presented an application of soft set in the decision making problem using the reduction of rough sets. Zou and Xiao [20] presented data analysis approaches of soft sets under incomplete information. Majumdar and Samanta[15] studied the similarity measure of soft sets. Ali et al. Introduced the analysis of several operations on soft sets.

2 BASIC DEFINITIONS

Throughout the paper, U refers to an initial universe, E is a set of parameters and P(U) is the power set of U. $\subset$ and $\supset$ stand for proper subset and super set, respectively. In this section, we cite the fundamental definitions that will be used in the sequel;

**Definition 2.1:** An Algebraic system $\langle X, *, 0 \rangle$ of type $(2,0)$ is called a BCK-algebra if it satisfies the following conditions;

(BCK-1) $(x*y) * (x*z) * (z*y) = 0$
(BCK-2) $(x*(x*y)) * y = 0$
(BCK-3) $x*x = 0$
(BCK-4) $0*x = 0$
(BCK-5) $x*y = 0$ and $y*x = 0 \Rightarrow x = y$, for all $x,y,z \in X$.

**Definition 2.2:** A temporal fuzzy soft subset $\delta$ of $X$ is called a temporal left fuzzy soft RR-ideal if

(TFRRl-1) $\delta (0,t) \geq \delta (x,t)$
(TFRRl-2) $\delta (x,t) \geq \inf \{ \delta (x*y,t) , \delta (y,t) \}$
(TFRRl-3) $\delta (x*a,t) \geq \inf \{ \delta (x,t), \delta (a,t) \}$, for all $x,y,a \in X$ and $t \in T$.

A temporal fuzzy soft subset $\delta$ is called a temporal right fuzzy soft RR-ideal if it satisfies (TFRR-1), (TFRR-2) and (TFRR-4) $\delta (ax,t) \geq \inf \{ \delta (x*y,t) , \delta (a,t) \}$, for all $x,y,a \in X$ and $t \in T$.

A temporal fuzzy soft subset $\delta$ of $X$ is called a temporal fuzzy soft RR-ideal if it is both left and right temporal fuzzy soft RR-ideal of $X$.

**Example 2.3:** Let $X = \{0,1,2,3,4\}$ be a RR-semi group defined by the following cayley tables;

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Define a temporal fuzzy soft subset $\delta : X \times T \rightarrow [0,1]$ by $\delta (0,t) = 0.3$ and $\delta (x,t) = 0.7$, for all $x \neq 0$. Then by usual calculations, we can prove that $\delta$ is a temporal left fuzzy soft RR-ideal of $X$.

**Definition 2.4:** A temporal fuzzy soft subset $\delta$ of $X$ is called a temporal left fuzzy soft RR-r-ideal if

(TFRRr-1) $\delta (0,t) \geq \delta (x,t)$
(TFRRr-2) $\delta (x*z,t) \geq \inf \{ \delta (x*y,t) * z , \delta (y*z,t) \}$
(TFRRr-3) $\delta (x*a,t) \geq \inf \{ \delta (x,t) , \delta (a,t) \}$, for all $x,y,z,a \in X$ and $t \in T$. 
Example 2.5: Let X= \{0,1,2\} be RR-semi group with following cayley tables;
\[
\begin{array}{ccc}
* & 0 & 1 & 2 \\
0 & 0 & 0 & 0 \\
1 & 2 & 0 & 1 \\
2 & 2 & 1 & 0 \\
\end{array}
\]
\[
\begin{array}{ccc}
\circ & 0 & 1 & 2 \\
0 & 0 & 0 & 0 \\
1 & 0 & 1 & 0 \\
2 & 0 & 0 & 2 \\
\end{array}
\]

Define a temporal fuzzy soft set \(\delta: X \times T \rightarrow [0,1]\) by \(\delta(0,t) = 0.4\) and \(\delta(x,t) = 0.5\), for all \(x \neq 0\). Then by usual calculations, we can prove that \(\delta\) is a temporal left fuzzy soft RR-ideal of \(X\).

**Definition 2.6:** A soft set \(f_A\) over \(U\) is defined as \(f_A: E \rightarrow P(U)\) such that \(f_A(x) = \emptyset\) if \(x \notin A\).

In other words, a soft set \(U\) is a parameterized family of subsets of the universe \(U\). For all \(e \in A\) \(f_A(e)\) may be considered as the set of \(e\)-approximate elements of the soft set \(f_A\). A soft set \(f_A\) over \(U\) can be presented by the set of ordered pairs:
\[
f_A = \{(x, f_A(x)) / x \in E, f_A(x) = P(U)\} 
\]
Clearly, a soft set is not a set. For illustration, Molodtsov consider several examples in (1999).

If \(f_A\) is a soft set over \(U\), then the image of \(f_A\) is defined by Im\((f_A) = \{f_A(a) / a \in A\}\). The set of all soft sets over \(U\) will be denoted by \(S(U)\). Some of the operations of soft sets are listed as follows.

**Definition 2.7:** Let \(f_A, f_B \in S(U)\). If \(f_A(x) \subseteq f_B(x)\), for all \(x \in E\), then \(f_A\) is called a soft subset of \(f_B\) and denoted by \(f_A \subseteq f_B\).\(f_A\) and \(f_B\) are called soft equal, denoted by \(f_A = f_B\) if and only if \(f_A \subseteq f_B\) and \(f_B \subseteq f_A\).

**Definition 2.8:** Let \(f_A, f_B \in S(U)\) and \(\chi\) be a function from \(A\) to \(B\). Then the soft anti-image of \(f_A\) under \(\chi\) denoted by \(\chi(f_A)\), is a soft set over \(U\) defined by,
\[
\chi(f_A)(b) = \{\cap (f_A(a)/a \in A, \chi(a) = b), if \chi^{-1}(b) \neq \emptyset \} \text{ otherwise } \] 
for all \(b \in B\). And the soft preimage of \(f_B\) under \(\chi\), denoted by \(\chi^{-1}(f_B)\), is a soft set over \(U\) defined by \(\chi^{-1}(f_B)(a) = f_B(\chi(a))\), for all \(a \in A\).

**Definition 2.9:** For any subset \(A\) of \(E\), a soft set \(\lambda_A\) over \(U\) is a set, defined by a function \(\lambda_A\), representing the mapping \(\lambda_A: E \rightarrow P(U)\). A soft set over \(U\) can also be represented by the set of ordered pairs \(\lambda_A = \{(x, \lambda_A(x)) / x \in E, \lambda_A(x) \in P(U)\}\). Note that the set of all soft sets over \(U\) will be denoted by \(S(U)\).

**Definition 2.10:** Let \(\lambda, \mu \in S(U)\). Then
\begin{enumerate}
\item If \(\lambda(e) = \emptyset\) for all \(e \in E\), \(\lambda\) is said to be a null soft set, denoted by \(\emptyset\).
\item If \(\lambda(e) = \mathbb{U}\) for all \(e \in E\), \(\lambda\) is said to be an absolute soft set, denoted by \(\mathbb{U}\).
\item \(\lambda\) is a soft subset of \(\mu\), denoted by \(\lambda \subseteq \mu\), if \(\lambda(e) \subseteq \mu(e)\) for all \(e \in E\).
\item Soft union of \(\lambda\) and \(\mu\), denoted by \(\lambda \cup \mu\), is a soft set over \(U\) and defined by \(\lambda \cup \mu: E \rightarrow P(U)\) such that \((\lambda \cup \mu)(e) = \lambda(e) \cup \mu(e)\) for all \(e \in E\).
\item \(\lambda = \mu\), if \(\lambda \subseteq \mu\) and \(\lambda \supseteq \mu\).
\item Soft intersection of \(\lambda\) and \(\mu\), denoted by \(\lambda \cap \mu\), is a soft set over \(U\) and defined by \(\lambda \cap \mu: E \rightarrow P(U)\) such that \((\lambda \cap \mu)(e) = \lambda(e) \cap \mu(e)\) for all \(e \in E\).
\item Soft complement of \(\lambda\) is denoted by \(\lambda^C\) and defined by \(\lambda^C: E \rightarrow P(U)\) such that \(\lambda^C(e) = U/\lambda(e)\) for all \(e \in E\).
\end{enumerate}
Definition 2.11: Let E be a parameter set, S ⊂ E and \( \lambda : S \rightarrow E \) be an injection function. Then \( SU \lambda(s) \) is called extended parameter set of S and denoted by \( \xi_S \).

If \( S=E \), then extended parameter set of S will be denoted by \( \xi \).

Definition 2.12: A temporal fuzzy set is an object of the form \( A(T) = \{h(x, t), \mu_A(x, t) : (x, t) \in E \times T \} \) where
(a) \( A \subseteq E \) is a fixed set
(b) \( 0 \leq \mu_A(x, t) \leq 1 \) for every \( (x, t) \in E \times T \).
(c) \( \mu_A(x, t) \) are the degrees of membership of the element \( x \in E \) at the time-moment \( t \in T \).

Example 2.13: Suppose that is a temporal fuzzy set (Table 1) defined on \( \{x_1, x_2, x_3\} \) with respect to the time moment set \( \{t_1, t_2\} \):

<table>
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<th>Table 1. Temporal fuzzy set A</th>
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We introduce the notion of temporal fuzzy soft sub RR-ideal and temporal fuzzy soft RR-r-ideal with examples. The constructions of these notions are based on ideal theory.

In this section, we have proved some interesting results which are very closer to the results of fuzzy soft ideal in BCK-algebra’s.

3 PROPERTIES OF T-FUZZY SOFT RR-IDEALS

Theorem 3.1: Every temporal left (resp., right) fuzzy soft RR-r-ideal of X is a temporal left (resp., right) fuzzy soft RR-ideal of X.

Proof: Let \( \delta \) be a temporal left fuzzy soft RR-r-ideal of X. Then \( \delta \) satisfies the conditions of (TFRRR-1) and (TFRRr-2) of definition 3.2.4.

We have \( \delta(x*z, t) \geq \inf \{ \delta(x*y, t)*z, \delta(y*z, t) \} \)
Putting \( z=0 \), we get
\( \delta(x*0, t) \geq \inf \{ \delta(x*y, t)*0, \delta(y*z, t) \} \).

Thus \( \delta(x*t) \geq \inf \{ \delta(x*y, t), \delta(y, t) \} \). Hence \( \delta \) is a temporal left fuzzy soft RR-ideal of X.

Example 3.2: Let \( X= \{0,1,2\} \) be RR-semi group with following cayley tables;

\[
\begin{array}{ccc}
* & 0 & 1 & 2 \\
0 & 0 & 0 & 0 \\
1 & 2 & 0 & 1 \\
2 & 2 & 1 & 0 \\
\end{array}
\]

Define a temporal fuzzy soft subset \( \delta : X \times T \rightarrow [0,1] \) by \( \delta(0, t) = 0.7 \) and \( \delta(x, t) = 0.4 \), for all \( x \neq 0 \). Then by usual calculations, we can prove that \( \delta \) is a temporal left fuzzy soft RR-ideal of X. But it is not temporal left fuzzy soft RR-r-ideal of X. Since \( \delta(2*1, t) \leq \inf \{ \delta(2*1, t)*1, \delta(1*1, t) \} \).
Theorem 3.3: Let $\delta$ be a temporal left (resp., right) fuzzy soft RR-ideal of $X$. Then the non-empty level set $\delta^\beta$ is also a temporal left (resp., right) fuzzy soft RR-ideal of $X$.

Proof: we have $\delta$ is a temporal left fuzzy soft RR-ideal of $X$.

If $x,y,a \in \delta^\beta$, then $\delta(x,t) \geq \beta$, $\delta(y,t) \geq \beta$ and $\delta(a,t) \geq \beta$.

(i) We have $\delta(0,t) \geq \delta(x,t) \geq \beta$, thus $\delta(0,t) \geq \delta^\beta(x,t)$.

(ii) Define $\beta = \inf \{ \delta(x+y,t), \delta(y,t) \}$. We have $\delta(x,t) \geq \beta$, then $\delta(x,t) \geq \beta = \inf \{ \delta(x+y,t), \delta(y,t) \}$.

(iii) Define $\beta = \inf \{ \delta(x,t), \delta(a,t) \}$. We have $\delta(xa,t) \geq \beta$, then $\delta(xa,t) \geq \beta = \inf \{ \delta(x+y,t), \delta(a,t) \}$. Hence $\delta^\beta$ is a temporal left fuzzy soft RR-ideal of $X$.

Definition 3.4: Let $\lambda$ and $\delta$ be the temporal fuzzy soft subsets in a set $X$. The Cartesian product $\lambda \times \delta : (X \times T) \times (X \times T) \rightarrow [0,1]$ is defined by $(\lambda \times \delta)(x,y) = \inf \{ \lambda(x,t), \delta(x,t) \}$ for all $x,y \in X$ and $t \in T$.

Theorem 3.5: Let $\lambda$ and $\delta$ be a temporal left (respectively right) fuzzy soft RR-ideal of $X$, then $\lambda \times \delta$ is also temporal left (respectively right) fuzzy soft RR-ideal of $X$.

Proof: For any $(x,y) \in X \times X$ and $t \in T$. We have

(i) $(\lambda \times \delta)(0,0) = \inf \{ \lambda(0,t), \delta(0,t) \}$

\[
\geq \inf \{ \lambda(x,t), \delta(y,t) \}
\]

\[
= (\lambda \times \delta)(x,y).
\]

(ii) For any $(x_1,x_2), (y_1,y_2) \in X \times X$, We have

$(\lambda \times \delta)(x_1,x_2) = \inf \{ \lambda(x_1,t), \delta(x_2,t) \}$

\[
\geq \inf \{ \inf \{ \lambda(x_1,y_1,t), \delta(y_1,t) \}, \inf \{ \delta(x_2,y_2,t) \} \}
\]

\[
= \inf \{ \inf \{ \lambda(x_1,y_1,t), \delta(x_2,y_2,t) \} \}
\]

\[
= \inf \{ \lambda \times \delta(x_1,y_1), \delta(x_2,y_2) \}.
\]

(iii) For any $x,a \in X$ then $xa \in X$ and $(x,y),(a_1,a_2) \in X \times X$, We have

$(\lambda \times \delta)(x_1,y_1)(a_1,a_2) = (\lambda \times \delta)(x_1,x_2)$

\[
= \min \{ \lambda(x_1,t), \delta(a_2,t) \}
\]

\[
\geq \min \{ \inf \{ \lambda(x_1,t), \delta(a_2,t) \} \}, \inf \{ \delta(y_1,t), \delta(a_2,t) \} \}
\]

\[
\geq \inf \{ \inf \{ \lambda(x_1,t), \delta(a_2,t) \} \}, \inf \{ \delta(y_1,t), \delta(a_2,t) \} \}
\]

\[
= \inf \{ \lambda \times \delta(x_1,y_1), \delta(a_2,t) \}.
\]

Theorem 3.6: Let $\lambda$ and $\delta$ be temporal fuzzy subsets of $X$ such that $((\lambda \times \mu))$ is temporal left (respectively right) fuzzy soft RR-ideal of $X \times X$. Then

(i) either $\lambda(0,t) \geq \lambda(x,t)$ or $\delta(0,t) \geq \delta(x,t)$

(ii) if $\lambda(0,t) \geq \lambda(x,t)$ then either $\lambda(0,t) \geq \lambda(x,t)$ or $\delta(0,t) \geq \delta(x,t)$

(iii) if $\delta(0,t) \geq \delta(x,t)$, then either $\lambda(0,t) \geq \lambda(x,t)$ or $\lambda(0,t) \geq \delta(x,t)$ for all $x \in X$ and $t \in T$.

Proof: By using reduction and absurdity, we can prove the theorem easily.

Theorem 3.7: Let $\lambda$ and $\delta$ be the temporal fuzzy subset of $X$. If $\lambda \times \delta$ is a left (respectively right) fuzzy soft RR-ideal of $X \times X$, then either $\lambda$ or $\delta$ is a temporal left (respectively right) fuzzy soft RR-ideal of $X$.

By theorem 3.6 of (i), without loss of generality, we assume that $\lambda(0,t) \geq \delta(x,t)$ for all $x \in X$. And $t \in T$. By theorem 3.3.6 of (iii) that either $\lambda(0,t) \geq \lambda(x,t)$ or $\lambda(0,t) \geq \delta(x,t)$ for all $x \in X$ and $t \in T$.

If $\lambda(0,t) \geq \delta(x,t)$, then $(\lambda \times \delta)(0,x) = \inf \{ \lambda(0,t), \delta(x,t) \}$

Since $\lambda \times \delta$ is a temporal left fuzzy soft RR-ideal of $X \times X$, therefore for all $(x_1,x_2), (y_1,y_2), (a_1,a_2) \in X \times X$ and $t \in T$, then
\[
(λ \times δ)(x_1, x_2) \geq \inf \{ (λ \times δ)(x_1, x_2) \ast (y_1, y_2), t \}, (λ \times δ)(y_1, y_2), t \} \text{ and } \\
(λ \times δ)((x_1, x_2), (a_1, a_2)) \geq \inf \{ (λ \times δ)(x_1, x_2), (λ \times δ)(a_1, a_2), t \} \\
(λ \times δ)(x_1, x_2) \geq \inf \{ (λ \times δ)(x_1, y_1), t \}, (λ \times δ)(y_1, y_2), t \} \text{ and } \\
(λ \times δ)((x_1, x_2), (a_1, a_2)) \geq \inf \{ (λ \times δ)(x_1, x_2), (λ \times δ)(a_1, a_2), t \} \\
\]

\[
\text{If } x_1 = y_1 = a_1 = 0 \\
(λ \times δ)(0, x_2) \geq \inf \{ (λ \times δ)(0, x_2), (λ \times δ)(0, y_2), t \} \text{ and } \\
(λ \times δ)((0, x_2), (0, a_2)) \geq \inf \{ (λ \times δ)(0, x_2), (λ \times δ)(0, a_2), t \} \\
\]

Using (1), we get
\[
δ(x_2, t) \geq \inf \{ δ((x_2, y_2), t), δ(y_2, t) \} \text{ and } δ(x_2a_2, t) \geq \inf \{ δ((x_2, a_2), t), δ(a_2, t) \} \\
\]

**Definition 3.8:** Let X and Y be a RR-semi group. A mapping \( f: X \to Y \) of RR-semi group is called a homomorphism if
\[
f(x \ast y) = f(x) \ast f(y) \quad \text{and} \quad f(x \ast y) = f(x) \ast f(y) \quad \text{for all } x, y \in X.
\]

Note that if \( f: X \to Y \) is a homomorphism of RR-semi group, then \( f(0) = 0 \).

**Definition 3.9:** Let \( f: X \to Y \) be a mapping of RR-semi group and \( δ \) be a t-fuzzy soft set of Y. Then \( δ' \) is the pre-image of \( δ \) under \( f \) if \( δf = \delta \) (\( f(x, t) \)) for all \( x \in X \) and \( t \in T \).

### 4. Relations among T-fuzzy soft homomorphism’s ideals

In this section, we have proved some results on t- fuzzy soft RR-ideals in RR-semi group homomorphism.

**Theorem 4.1:** Let \( f: X \to Y \) be a homomorphism. If \( δ \) is a t- left (resp., right) fuzzy soft RR-ideal of Y, then \( δ' \) is a t- left (resp., right) fuzzy soft RR-ideal of X.

**Proof:** (i) For any \( x \in X \) and \( t \in T \), then
\[
δ'(x, t) = \delta(f(x, t)) \leq \delta(0, t) = \delta'(0, t).
\]

(ii) For any \( x, y \in X \) and \( t \in T \), then
\[
δf(x, t) = \delta(f(x, t)) \geq \inf \{ δ(f(x, y), t), δ(y, t) \} = \inf \{ δ(x, t), δ'(y, t) \}
\]

(iii) For any \( x, a \in X \) and \( t \in T \). Then
\[
δf(xa, t) = \delta(f(xa, t)) = \delta(f(x, t)) \ast f(y, t)
\]
\[
\geq \inf \{ \delta(f(x, t)), \delta f(a, t) \}
\]
\[
= \inf \{ δ'(x, t), δ'(y, t) \}
\]

Hence \( δ' \) is a t- fuzzy soft RR-ideal of X.

**Theorem 4.2:** Let \( f: X \to Y \) be epimorphism. If \( δ' \) is a t- left (resp., right) fuzzy soft RR-deal of Y, then \( δ \) is a t- left (resp., right) fuzzy soft RR-deal of X.

**Proof:** (i) Let \( y \in Y \), then there exits \( x \in X \) such that \( f(x) = y \). Then
\[
δ(y, t) = \delta(f(x, t)) = δ'(x, t) \leq δ'(0, t) = δ(0, t).
\]

(ii) Let \( x, y \in Y \) and \( t \in T \). Then there exists \( a, b \in X \) such that \( f(a, t) = x \) and \( f(b, t) = y \).

Then \( δ(x, t) = δ(f(x, t)) = δ'(a, t) \geq \inf \{ δ'(a, b, t), δ'(b, t) \} \leq \inf \{ δf(a, b, t), δ(b, t) \} \)
\[
= \inf \{ δf(a, b, t), δ(b, t) \} = \inf \{ δ(x, y, t), δ(y, t) \}
\]

Let \( x, a \in Y \) and let \( t \in T \). Then, there exist a \( f, m \in X \), such that \( f(0) = x \), \( f(m) = a \). Then
\[
δ(xa, t) = \delta(f(xa, t)) = \delta'(x, t) \geq \inf \{ δ'(x, t), δ'(y, t) \} = \inf \{ δ(x, t), δ(y, t) \}.
\]
Conclusion

This provides sufficient motivation to researchers to review various concepts and results from the realm of abstract algebra in the broader framework of fuzzy setting. One of the structures that are most extensively used and discussed in mathematics and its applications is lattice theory. As it is well known, it is considered as a relational ordered structure, on one hand, and as algebra, on the other hand.

REFERENCES