NSS

Neutrosophic Sets and Systems, Vol. 47, 2021

University of New Mexico

Neutrosophic implicative UP-filters, neutrosophic comparative UP-filters, and neutrosophic shift UP-filters of UP-algebras

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Abstract. The notions of neutrosophic UP-subalgebras, neutrosophic near UP-filters, neutrosophic UP-filters, neutrosophic UP-ideals, and neutrosophic strong UP-ideals were introduced by Songsaeng and Iampan [M. Songsaeng, A. Iampan, Neutrosophic set theory applied to UP-algebras, Eur. J. Pure Appl. Math., 12 (2019), 1382-1409]. In this paper, we introduce the notions of neutrosophic implicative UP-filters, neutrosophic comparative UP-filters, and neutrosophic shift UP-filters of UP-algebras by applying the notions of implicative UP-filters, comparative UP-filters, and shift UP-filters of UP-algebras to neutrosophic set, and investigate some of their important properties. Relations between neutrosophic implicative UP-filters (resp., neutrosophic comparative UP-filters, neutrosophic shift UP-filters) and their level subsets are considered.

Keywords: UP-algebra; neutrosophic implicative UP-filter; neutrosophic comparative UP-filter; neutrosophic shift UP-filter

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1. **Introduction**

A fuzzy set f in a nonempty set S is a function from S to the closed interval $[0,1]$. The concept of a fuzzy set in a nonempty set was first considered by Zadeh [27]. The fuzzy set theories developed by Zadeh and others have found many applications in the domain of mathematics and elsewhere. The notion of neutrosophic sets was introduced by Smarandache [19] in 1999 which is a more general platform that extends the notions of classic sets, (intuitionistic) fuzzy sets and interval valued (intuitionistic) fuzzy sets (see [19, 20]). Neutrosophic set theory is applied to various part which is referred to the site

http://fs.unm.edu/neutrosophy.htm.

The above-mentioned section has been derived from [24]. Wang et al. [26] introduced the notion of interval neutrosophic sets in 2005. The notion of neutrosophic $\mathcal{N}$-structures and their applications in semigroups was introduced by Khan et al. [12] in 2017. The notion of neutrosophic sets was applied to many logical algebras (see [7, 11–13, 16]).

The notions of neutrosophic UP-subalgebras, neutrosophic near UP-filters, neutrosophic UP-filters, neutrosophic UP-ideals, and neutrosophic strong UP-ideals were introduced by Songsaeng and Iampan [22] in 2019. In this paper, we introduce the notions of neutrosophic implicative UP-filters, neutrosophic comparative UP-filters, and neutrosophic shift UP-filters of UP-algebras by applying the notions of implicative UP-filters, comparative UP-filters, and shift UP-filters of UP-algebras to neutrosophic set, and investigated some of their important properties. Relations between neutrosophic implicative UP-filters (resp., neutrosophic comparative UP-filters, neutrosophic shift UP-filters) and their level subsets are considered.

2. Basic results on UP-algebras

Before we begin our study, we will give the definition and useful properties of UP-algebras.

Definition 2.1. [4] An algebra $X = (X, \cdot, 0)$ of type $(2, 0)$ is called a *UP-algebra*, where X is a nonempty set, $\cdot$ is a binary operation on X, and 0 is a fixed element of X (i.e., a nullary operation) if it satisfies the following axioms:

$$(\forall x, y, z \in X)((y \cdot z) \cdot ((x \cdot y) \cdot (x \cdot z)) = 0), \tag{1}$$

$$(\forall x \in X)(0 \cdot x = x), \tag{2}$$

$$(\forall x \in X)(x \cdot 0 = 0), \text{ and} \tag{3}$$

$$(\forall x, y \in X)(x \cdot y = 0, y \cdot x = 0 \Rightarrow x = y). \tag{4}$$

From [4], we know that the notion of UP-algebras is a generalization of KU-algebras (see [15]).

For examples of UP-algebras, see [1, 2, 5, 14, 17, 18].

The binary relation $\leq$ on a UP-algebra $X = (X, \cdot, 0)$ is defined as follows:

$$(\forall x, y \in X)(x \leq y \Leftrightarrow x \cdot y = 0) \tag{5}$$

and the following assertions are valid (see [4, 5]).

$$(\forall x \in X)(x \leq x), \tag{6}$$

$$(\forall x, y, z \in X)(x \leq y, y \leq z \Rightarrow x \leq z), \tag{7}$$

$$(\forall x, y, z \in X)(x \leq y \Rightarrow z \cdot x \leq z \cdot y), \tag{8}$$

$$(\forall x, y, z \in X)(x \leq y \Rightarrow y \cdot z \leq x \cdot z), \tag{9}$$

$$(\forall x, y, z \in X)(x \leq y \cdot x, \text{ in particular, } y \cdot z \leq x \cdot (y \cdot z)), \tag{10}$$

$$(\forall x, y \in X)(y \cdot x \leq x \Leftrightarrow x = y \cdot x), \tag{11}$$

$$(\forall x, y \in X)(x \leq y \cdot y), \tag{12}$$

$$(\forall a, x, y, z \in X)(x \cdot (y \cdot z) \leq x \cdot ((a \cdot y) \cdot (a \cdot z))), \tag{13}$$

$$(\forall a, x, y, z \in X)(((a \cdot x) \cdot (a \cdot y)) \cdot z \leq (x \cdot y) \cdot z), \tag{14}$$

$$(\forall x, y, z \in X)((x \cdot y) \cdot z \leq y \cdot z), \tag{15}$$

$$(\forall x, y, z \in X)(x \leq y \Rightarrow x \leq z \cdot y), \tag{16}$$

$$(\forall x, y, z \in X)((x \cdot y) \cdot z \leq x \cdot (y \cdot z)), \text{ and} \tag{17}$$

$$(\forall a, x, y, z \in X)((x \cdot y) \cdot z \leq y \cdot (a \cdot z)). \tag{18}$$

Definition 2.2. [3, 4, 6, 8–10, 21] A nonempty subset S of a UP-algebra $X = (X, \cdot, 0)$ is called

(1) a *UP-subalgebra* of X if it satisfies the following condition:

$$(\forall x, y \in S)(x \cdot y \in S), \tag{19}$$

(2) a *near UP-filter* of X if it satisfies the following condition:

$$(\forall x, y \in X)(y \in S \Rightarrow x \cdot y \in S). \tag{20}$$

(3) a *UP-filter* of X if it satisfies the following conditions:

$$\text{the constant } 0 \text{ of } X \text{ is in } S, \tag{21}$$

$$(\forall x, y \in X)(x \cdot y \in S, x \in S \Rightarrow y \in S), \tag{22}$$

(4) an *implicative UP-filter* of X if it satisfies the condition (21) and the following condition:

$$(\forall x, y, z \in X)(x \cdot (y \cdot z) \in S, x \cdot y \in S \Rightarrow x \cdot z \in S), \tag{23}$$

(5) a *comparative UP-filter* of X if it satisfies the condition (21) and the following condition:

$$(\forall x, y, z \in X)(x \cdot ((y \cdot z) \cdot y) \in S, x \in S \Rightarrow y \in S), \tag{24}$$

(6) a *shift UP-filter* of X if it satisfies the condition (21) and the following condition:

$$(\forall x, y, z \in X)(x \cdot (y \cdot z) \in S, x \in S \Rightarrow ((z \cdot y) \cdot y) \cdot z \in S), \tag{25}$$

(7) a *UP-ideal* of X if it satisfies the condition (21) and the following condition:

$$(\forall x, y, z \in X)(x \cdot (y \cdot z) \in S, y \in S \Rightarrow x \cdot z \in S), \tag{26}$$

(8) a *strong UP-ideal* of X if it satisfies the condition (21) and the following condition:

$$(\forall x, y, z \in X)((z \cdot y) \cdot (z \cdot x) \in S, y \in S \Rightarrow x \in S). \tag{27}$$

Guntasow et al. [3] proved that the only strong UP-ideal of a UP-algebra X is X.

3. NSs in UP-algebras

In 1999, Smarandache [19] introduced the notion of neutrosophic sets as the following definition.

A *neutrosophic set* (briefly, NS) in a nonempty set X is a structure of the form:

$$\Lambda = \{(x, \lambda_T(x), \lambda_I(x), \lambda_F(x)) \mid x \in X\} \tag{28}$$

where $\lambda_T : X \to [0, 1]$ is a *truth membership function*, $\lambda_I : X \to [0, 1]$ is an *indeterminate membership function*, and $\lambda_F : X \to [0, 1]$ is a *false membership function*.

For our convenience, we will denote a NS as $\Lambda = (X, \lambda_T, \lambda_I, \lambda_F) = (X, \lambda_{T,I,F}) = \{(x, \lambda_T(x), \lambda_I(x), \lambda_F(x)) \mid x \in X\}$.

Definition 3.1. [19] Let Λ be a NS in a nonempty set X. The NS $\overline{\Lambda} = (X, \overline{\lambda}_{T,I,F})$ in X defined by

$$(\forall x \in X)\begin{pmatrix} \overline{\lambda}_T(x) = 1 - \lambda_T(x) \\ \overline{\lambda}_I(x) = 1 - \lambda_I(x) \\ \overline{\lambda}_F(x) = 1 - \lambda_F(x) \end{pmatrix} \tag{29}$$

is called the *complement* of Λ in X. For all NS Λ in a nonempty set X, we have $\Lambda = \overline{\overline{\Lambda}}$.

In what follows, let X denote a UP-algebra $(X, \cdot, 0)$ unless otherwise specified.

Songsaeng and Iampan [23] introduced the new concepts of neutrosophic sets in UP-algebras: neutrosophic UP-subalgebras, neutrosophic near UP-filters, neutrosophic UP-filters, neutrosophic UP-ideals, and neutrosophic strong UP-ideals.

Definition 3.2. A NS Λ in X is called

(1) a *neutrosophic UP-subalgebra* of X if it satisfies the following conditions:

$$(\forall x, y \in X)(\lambda_T(x \cdot y) \geq \min\{\lambda_T(x), \lambda_T(y)\}), \tag{30}$$

$$(\forall x, y \in X)(\lambda_I(x \cdot y) \leq \max\{\lambda_I(x), \lambda_I(y)\}), \tag{31}$$

$$(\forall x, y \in X)(\lambda_F(x \cdot y) \geq \min\{\lambda_F(x), \lambda_F(y)\}), \tag{32}$$

(2) a *neutrosophic near UP-filter* of X if it satisfies the following conditions:

$$(\forall x, y \in X)(\lambda_T(x \cdot y) \geq \lambda_T(y)), \tag{33}$$

$$(\forall x, y \in X)(\lambda_I(x \cdot y) \leq \lambda_I(y)), \tag{34}$$

$$(\forall x, y \in X)(\lambda_F(x \cdot y) \geq \lambda_F(y)), \tag{35}$$

(3) a *neutrosophic UP-filter* of X if it satisfies the following conditions:

$$(\forall x \in X)(\lambda_T(0) \geq \lambda_T(x)), \tag{36}$$

$$(\forall x \in X)(\lambda_I(0) \leq \lambda_I(x)), \tag{37}$$

$$(\forall x \in X)(\lambda_F(0) \geq \lambda_F(x)), \tag{38}$$

$$(\forall x, y \in X)(\lambda_T(y) \geq \min\{\lambda_T(x \cdot y), \lambda_T(x)\}), \tag{39}$$

$$(\forall x, y \in X)(\lambda_I(y) \leq \max\{\lambda_I(x \cdot y), \lambda_I(x)\}), \tag{40}$$

$$(\forall x, y \in X)(\lambda_F(y) \geq \min\{\lambda_F(x \cdot y), \lambda_F(x)\}), \tag{41}$$

(4) a *neutrosophic UP-ideal* of X if it satisfies the following conditions: (36), (37), (38), and

$$(\forall x, y, z \in X)(\lambda_T(x \cdot z) \geq \min\{\lambda_T(x \cdot (y \cdot z)), \lambda_T(y)\}), \tag{42}$$

$$(\forall x, y, z \in X)(\lambda_I(x \cdot z) \leq \max\{\lambda_I(x \cdot (y \cdot z)), \lambda_I(y)\}), \tag{43}$$

$$(\forall x, y, z \in X)(\lambda_F(x \cdot z) \geq \min\{\lambda_F(x \cdot (y \cdot z)), \lambda_F(y)\}), \tag{44}$$

(5) a *neutrosophic strong UP-ideal* of X if it satisfies the following conditions: (36), (37), (38), and

$$(\forall x, y, z \in X)(\lambda_T(x) \geq \min\{\lambda_T((z \cdot y) \cdot (z \cdot x)), \lambda_T(y)\}), \tag{45}$$

$$(\forall x, y, z \in X)(\lambda_I(x) \leq \max\{\lambda_I((z \cdot y) \cdot (z \cdot x)), \lambda_I(y)\}), \tag{46}$$

$$(\forall x, y, z \in X)(\lambda_F(x) \geq \min\{\lambda_F((z \cdot y) \cdot (z \cdot x)), \lambda_F(y)\}). \tag{47}$$

Definition 3.3. [23] A NS Λ in X is said to be *constant* if Λ is a constant function from X to $[0,1]^3$. That is, λ_T, λ_I, and λ_F are constant functions from X to $[0,1]$.

Songsaeng and Iampan [23] proved the generalization that the concept of neutrosophic UP-subalgebras is a generalization of neutrosophic near UP-filters, neutrosophic near UP-filters is a generalization of neutrosophic UP-filters, neutrosophic UP-filters is a generalization of neutrosophic UP-ideals, and neutrosophic UP-ideals is a generalization of neutrosophic strong UP-ideals. Moreover, they proved that neutrosophic strong UP-ideals and constant neutrosophic sets coincide.

Definition 3.4. A NS Λ in X is called a *neutrosophic implicative UP-filter* of X if it satisfies the following conditions: (36), (37), (38), and

$$(\forall x, y, z \in X)(\lambda(x \cdot z) \geq \min\{\lambda(x \cdot (y \cdot z)), \lambda(x \cdot y)\}), \tag{48}$$

$$(\forall x, y, z \in X)(\lambda(x \cdot z) \leq \max\{\lambda(x \cdot (y \cdot z)), \lambda(x \cdot y)\}), \tag{49}$$

$$(\forall x, y, z \in X)(\lambda(x \cdot z) \geq \min\{\lambda(x \cdot (y \cdot z)), \lambda(x \cdot y)\}). \tag{50}$$

Example 3.5. Let $X = \{0, 1, 2, 3, 4\}$ be a UP-algebra with a fixed element 0 and a binary operation $\cdot$ defined by the following Cayley table:

$\cdot$	0	1	2	3	4
0	0	1	2	3	4
1	0	0	2	3	4
2	0	0	0	0	4
3	0	1	2	0	4
4	0	0	0	0	0

We define a NS Λ in X as follows:

$$\lambda_T = \begin{pmatrix} 0 & 1 & 2 & 3 & 4 \\ 0.8 & 0.8 & 0.6 & 0.6 & 0.6 \end{pmatrix}, \lambda_I = \begin{pmatrix} 0 & 1 & 2 & 3 & 4 \\ 0.4 & 0.4 & 0.4 & 0.4 & 0.8 \end{pmatrix}, \lambda_F = \begin{pmatrix} 0 & 1 & 2 & 3 & 4 \\ 0.7 & 0.7 & 0.5 & 0.7 & 0.5 \end{pmatrix}.$$

Hence, Λ is a neutrosophic implicative UP-filter of X.

Definition 3.6. A NS Λ in X is called a *neutrosophic comparative UP-filter* of X if it satisfies the following conditions: (36), (37), (38), and

$$(\forall x, y, z \in X)(\lambda(y) \geq \min\{\lambda(x \cdot ((y \cdot z) \cdot y)), \lambda(x)\}), \tag{51}$$

$$(\forall x, y, z \in X)(\lambda(y) \leq \max\{\lambda(x \cdot ((y \cdot z) \cdot y)), \lambda(x)\}), \tag{52}$$

$$(\forall x, y, z \in X)(\lambda(y) \geq \min\{\lambda(x \cdot ((y \cdot z) \cdot y)), \lambda(x)\}). \tag{53}$$

Example 3.7. Let $X = \{0, 1, 2, 3, 4\}$ be a UP-algebra with a fixed element 0 and a binary operation $\cdot$ defined by the following Cayley table:

$\cdot$	0	1	2	3	4
0	0	1	2	3	4
1	0	0	2	2	4
2	0	0	0	1	4
3	0	0	0	0	4
4	0	1	2	3	0

We define a NS Λ in X as follows:

$$\lambda_T = \begin{pmatrix} 0 & 1 & 2 & 3 & 4 \\ 0.6 & 0.6 & 0.6 & 0.6 & 0.4 \end{pmatrix}, \lambda_I = \begin{pmatrix} 0 & 1 & 2 & 3 & 4 \\ 0.4 & 0.4 & 0.4 & 0.4 & 0.8 \end{pmatrix}, \lambda_F = \begin{pmatrix} 0 & 1 & 2 & 3 & 4 \\ 0.7 & 0.7 & 0.7 & 0.7 & 0.5 \end{pmatrix}.$$

Hence, Λ is a neutrosophic comparative UP-filter of X.

Definition 3.8. A NS Λ in X is called a *neutrosophic shift UP-filter* of X if it satisfies the following conditions: (36), (37), (38), and

$$(\forall x, y, z \in X)(\lambda(((z \cdot y) \cdot y) \cdot z) \geq \min\{\lambda(x \cdot (y \cdot z)), \lambda(x)\}), \tag{54}$$

$$(\forall x, y, z \in X(\lambda(((z \cdot y) \cdot y) \cdot z) \leq \max\{\lambda(x \cdot (y \cdot z)), \lambda(x)\}), \tag{55}$$

$$(\forall x, y, z \in X)(\lambda(((z \cdot y) \cdot y) \cdot z) \geq \min\{\lambda(x \cdot (y \cdot z)), \lambda(x)\}). \tag{56}$$

Example 3.9. Let $X = \{0, 1, 2, 3, 4\}$ be a UP-algebra with a fixed element 0 and a binary operation $\cdot$ defined by the following Cayley table:

$\cdot$	0	1	2	3	4
0	0	1	2	3	4
1	0	0	2	3	4
2	0	0	0	2	4
3	0	0	0	0	4
4	0	1	2	3	0

We define a NS Λ in X as follows:

$$\lambda_T = \begin{pmatrix} 0 & 1 & 2 & 3 & 4 \\ 0.6 & 0.6 & 0.6 & 0.6 & 0.4 \end{pmatrix}, \lambda_I = \begin{pmatrix} 0 & 1 & 2 & 3 & 4 \\ 0.4 & 0.4 & 0.8 & 0.8 & 0.8 \end{pmatrix}, \lambda_F = \begin{pmatrix} 0 & 1 & 2 & 3 & 4 \\ 0.9 & 0.9 & 0.7 & 0.7 & 0.7 \end{pmatrix}.$$

Hence, Λ is a neutrosophic shift UP-filter of X.

Theorem 3.10. *[23] A NS Λ in X is constant if and only if it is a neutrosophic strong UP-ideal of X.*

Theorem 3.11. *Every neutrosophic implicative UP-filter of X is a neutrosophic UP-ideal.*

Proof. Assume that Λ is a neutrosophic implicative UP-filter of X. Then Λ satisfies the conditions (36), (37), and (38).

Let $x, y, z \in X$. Then $\lambda_T(x \cdot z) \geq \min\{\lambda_T(x \cdot (y \cdot z)), \lambda_T(x \cdot y)\}$ By generalization of neutrosophic near UP-filter, neutrosophic UP-filter, and the condition 33, we have $\lambda_T(x \cdot z) \geq \min\{\lambda_T(x \cdot (y \cdot z)), \lambda_T(y)\}$,

Let $x, y, z \in X$. Then $\lambda_I(x \cdot z) \leq \max\{\lambda_I(x \cdot (y \cdot z)), \lambda_I(x \cdot y)\}$ By generalization of neutrosophic near UP-filter, neutrosophic UP-filter, and the condition 34, we have $\lambda_I(x \cdot z) \leq \max\{\lambda_I(x \cdot (y \cdot z)), \lambda_I(y)\}$, Let $x, y, z \in X$. Then $\lambda_F(x \cdot z) \geq \min\{\lambda_F(x \cdot (y \cdot z)), \lambda_F(x \cdot y)\}$ By generalization of neutrosophic near UP-filter, neutrosophic UP-filter, and the condition 35, we have $\lambda_F(x \cdot z) \geq \min\{\lambda_F(x \cdot (y \cdot z)), \lambda_F(y)\}$,

Hence, Λ is a neutrosophic UP-ideal of X. □

Example 3.12. From the Cayley table in Example 3.7, we define a NS Λ in X as follows:

$$\lambda_T = \begin{pmatrix} 0 & 1 & 2 & 3 & 4 \\ 1 & 0.7 & 0.6 & 0.6 & 0.4 \end{pmatrix}, \lambda_I = \begin{pmatrix} 0 & 1 & 2 & 3 & 4 \\ 0 & 0.3 & 0.5 & 0.5 & 0.7 \end{pmatrix}, \lambda_F = \begin{pmatrix} 0 & 1 & 2 & 3 & 4 \\ 0.9 & 0.8 & 0.7 & 0.7 & 0.5 \end{pmatrix}.$$

Then Λ is a neutrosophic UP-ideal of X. Since $\lambda_I(2 \cdot 3) = 0.3 > 0 = \max\{\lambda_I(2 \cdot (1 \cdot 3)), \lambda_I(2 \cdot 1)\}$, we have Λ is not a neutrosophic implicative UP-filter of X.

Theorem 3.13. *Every neutrosophic comparative UP-filter of X is a neutrosophic UP-filter.*

Proof. Assume that Λ is a neutrosophic comparative UP-filter of X. Then Λ satisfies the conditions (36), (37), and (38). Next, let $x, y \in X$. Then

$$\begin{aligned}
\lambda_T(y) &\geq \min\{\lambda_T(x \cdot ((y \cdot y) \cdot y)), \lambda_T(x)\} && \text{by (51)} \\
&= \min\{\lambda_T(x \cdot (0 \cdot y)), \lambda_T(x)\} && \text{by (6)} \\
&= \min\{\lambda_T(x \cdot y), \lambda_T(x)\}, && \text{by (2)} \\
\lambda_I(y) &\leq \max\{\lambda_I(x \cdot ((y \cdot y) \cdot y)), \lambda_I(x)\} && \text{by (52)} \\
&= \max\{\lambda_I(x \cdot (0 \cdot y)), \lambda_I(x)\} && \text{by (6)} \\
&= \max\{\lambda_I(x \cdot y), \lambda_I(x)\}, && \text{by (2)} \\
\lambda_F(y) &\geq \min\{\lambda_F(x \cdot ((y \cdot y) \cdot y)), \lambda_F(x)\} && \text{by (53)} \\
&= \min\{\lambda_F(x \cdot (0 \cdot y)), \lambda_F(x)\} && \text{by (6)} \\
&= \min\{\lambda_F(x \cdot y), \lambda_F(x)\}. && \text{by (2)}
\end{aligned}$$

Hence, Λ is a neutrosophic UP-filter of X. □

Example 3.14. From Example 3.12, we have Λ is a neutrosophic UP-ideal of X and so Λ is a neutrosophic UP-filter of X. Since $\lambda_T(1) = 0.7 < 1 = \min\{\lambda_T(0 \cdot ((1 \cdot 3) \cdot 1)), \lambda_T(0)\}$, we have Λ is not a neutrosophic comparative UP-filter of X.

Theorem 3.15. *Every neutrosophic shift UP-filter of X is a neutrosophic UP-filter.*

Proof. Assume that Λ is a neutrosophic shift UP-filter of X. Then Λ satisfies the conditions (36), (37), and (38). Next, let $x, y \in X$. Then

$$\begin{aligned}
\lambda_T(y) &= \lambda_T(((y \cdot 0) \cdot 0) \cdot y) && \text{by (2) and (3)} \\
&\geq \min\{\lambda_T(x \cdot (0 \cdot y)), \lambda_T(x)\} && \text{by (54)} \\
&= \min\{\lambda_T(x \cdot y), \lambda_T(x)\}, && \text{by (2)} \\
\lambda_I(y) &= \lambda_I(((y \cdot 0) \cdot 0) \cdot y) && \text{by (2) and (3)} \\
&\leq \max\{\lambda_I(x \cdot (0 \cdot y)), \lambda_I(x)\} && \text{by (55)} \\
&= \max\{\lambda_I(x \cdot y), \lambda_I(x)\}, && \text{by (2)} \\
\lambda_F(y) &= \lambda_F(((y \cdot 0) \cdot 0) \cdot y) && \text{by (2) and (3)} \\
&\geq \min\{\lambda_F(x \cdot (0 \cdot y)), \lambda_F(x)\} && \text{by (56)} \\
&= \min\{\lambda_F(x \cdot y), \lambda_F(x)\}. && \text{by (2)}
\end{aligned}$$

Hence, Λ is a neutrosophic UP-filter of X. □

Example 3.16. From Example 3.12, we have Λ is a neutrosophic UP-ideal of X and so Λ is a neutrosophic UP-filter of X. Since $\lambda_T(((1 \cdot 2) \cdot 2) \cdot 1) = 0.7 < 1 = \min\{\lambda_T(0 \cdot (2 \cdot 1)), \lambda_T(0)\}$, we have Λ is not a neutrosophic shift UP-filter of X.

Theorem 3.17. *Every neutrosophic strong UP-ideal of X is a neutrosophic implicative UP-filter.*

Proof. Assume that Λ is a neutrosophic strong UP-ideal of X. Then Λ satisfies the conditions (36), (37), and (38). By Theorem 3.10, we have Λ is constant. Then for all $x \in X, \lambda_T(x) = \lambda_T(0), \lambda_I(x) = \lambda_I(0)$, and $\lambda_F(x) = \lambda_F(0)$. Next, let $x, y, z \in X$. Then

$$\begin{aligned}
\lambda_T(x \cdot z) &= \lambda_T(x \cdot y) && \text{by } \lambda_T \text{ is constant} \\
&\geq \min\{\lambda_T(x \cdot (y \cdot z)), \lambda_T(x \cdot y)\}, \\
\lambda_I(x \cdot z) &= \lambda_I(x \cdot y) && \text{by } \lambda_I \text{ is constant} \\
&\leq \max\{\lambda_I(x \cdot (y \cdot z)), \lambda_I(x \cdot y)\}, \\
\lambda_F(x \cdot z) &= \lambda_F(x \cdot y) && \text{by } \lambda_F \text{ is constant} \\
&\geq \min\{\lambda_F(x \cdot (y \cdot z)), \lambda_F(x \cdot y)\}.
\end{aligned}$$

Hence, Λ is a neutrosophic implicative UP-filter of X. □

Example 3.18. From Example 3.5, we have Λ is a neutrosophic implicative UP-filter of X. Since Λ is not constant, it follows from Theorem 3.10 that it is not a neutrosophic strong UP-ideal of X.

Theorem 3.19. *Every neutrosophic strong UP-ideal of X is a neutrosophic comparative UP-filter.*

Proof. Assume that Λ is a neutrosophic strong UP-ideal of X. Then Λ satisfies the conditions (36), (37), and (38). By Theorem 3.10, we have Λ is constant. Then for all $x \in X, \lambda_T(x) = \lambda_T(0), \lambda_I(x) = \lambda_I(0)$, and $\lambda_F(x) = \lambda_F(0)$. Next, let $x, y, z \in X$. Then

$$\begin{aligned}
\lambda_T(y) &= \lambda_T(x) && \text{by } \lambda_T \text{ is constant} \\
&\geq \min\{\lambda_T(x \cdot ((y \cdot z) \cdot y)), \lambda_T(x)\}, \\
\lambda_I(y) &= \lambda_I(x) && \text{by } \lambda_I \text{ is constant} \\
&\leq \max\{\lambda_I(x \cdot ((y \cdot z) \cdot y)), \lambda_I(x)\}, \\
\lambda_F(y) &= \lambda_F(x) && \text{by } \lambda_F \text{ is constant} \\
&\geq \min\{\lambda_F(x \cdot ((y \cdot z) \cdot y)), \lambda_F(x)\}.
\end{aligned}$$

Hence, Λ is a neutrosophic comparative UP-filter of X. □

Example 3.20. From Example 3.7, we have Λ is a neutrosophic comparative UP-filter of X. Since Λ is not constant, it follows from Theorem 3.10 that it is not a neutrosophic strong UP-ideal of X.

Theorem 3.21. *Every neutrosophic strong UP-ideal of X is a neutrosophic shift UP-filter.*

Proof. Assume that Λ is a neutrosophic strong UP-ideal of X. Then Λ satisfies the conditions (36), (37), and (38). By Theorem 3.10, we have Λ is constant. Then for all $x \in X, \lambda_T(x) = \lambda_T(0), \lambda_I(x) = \lambda_I(0)$, and $\lambda_F(x) = \lambda_F(0)$. Next, let $x, y, z \in X$. Then

$$\begin{aligned}
\lambda_T(((z \cdot y) \cdot y) \cdot z) &= \lambda_T(x) && \text{by } \lambda_T \text{ is constant} \\
&\geq \min\{\lambda_T(x \cdot (y \cdot z)), \lambda_T(x)\}, \\
\lambda_I(((z \cdot y) \cdot y) \cdot z) &= \lambda_I(x) && \text{by } \lambda_I \text{ is constant} \\
&\leq \max\{\lambda_I(x \cdot (y \cdot z)), \lambda_I(x)\}, \\
\lambda_F(((z \cdot y) \cdot y) \cdot z) &= \lambda_F(x) && \text{by } \lambda_F \text{ is constant} \\
&\geq \min\{\lambda_F(x \cdot (y \cdot z)), \lambda_F(x)\}.
\end{aligned}$$

Hence, Λ is a neutrosophic shift UP-filter of X. □

Example 3.22. From Example 3.9, we have Λ is a neutrosophic shift UP-filter of X. Since Λ is not constant, it follows from Theorem 3.10 that it is not a neutrosophic strong UP-ideal of X.

Example 3.23. From Example 3.5, we have Λ is a neutrosophic implicative UP-filter of X. Since $\lambda_T(((3\cdot 2)\cdot 2)\cdot 3) = 0.6 < 0.8 = \min\{\lambda_T(0\cdot(2\cdot 3)), \lambda_T(0)\}$, we have Λ is not a neutrosophic shift UP-filter of X.

Example 3.24. From Example 3.9, we have Λ is a neutrosophic shift UP-filter of X. Since $\lambda_F(2\cdot 3) = 0.7 < 0.9 = \min\{\lambda_F(2\cdot(2\cdot 3)), \lambda_F(2\cdot 2)\}$, we have Λ is not a neutrosophic implicative UP-filter of X.

By Theorems 3.11, 3.13, 3.15, 3.17, 3.19, and 3.21 and Examples 3.12, 3.14, 3.16, 3.18, 3.20, and 3.22, we have that the notion of neutrosophic UP-ideals is a generalization of neutrosophic implicative UP-filters, the notion of neutrosophic UP-filters is a generalization of neutrosophic comparative UP-filters, the notion of neutrosophic UP-filters is a generalization of neutrosophic shift UP-filters, and the notions of neutrosophic implicative UP-filters, neutrosophic comparative UP-filters, neutrosophic shift UP-filters is a generalization of neutrosophic strong UP-ideals.

Theorem 3.25. *If Λ is a neutrosophic UP-ideal of X satisfying the following condition:*

$$(\forall x, y, z \in X)\begin{pmatrix}\lambda_T(x\cdot(y\cdot z)) \geq \lambda_T(y) \Rightarrow \lambda_T(y) \geq \lambda_T(x\cdot y)\\ \lambda_I(x\cdot(y\cdot z)) \leq \lambda_I(y) \Rightarrow \lambda_I(y) \leq \lambda_I(x\cdot y)\\ \lambda_F(x\cdot(y\cdot z)) \geq \lambda_F(y) \Rightarrow \lambda_F(y) \geq \lambda_F(x\cdot y)\end{pmatrix}, \tag{57}$$

then Λ is a neutrosophic implicative UP-filter of X.

Proof. Assume that Λ is a neutrosophic UP-ideal of X satisfying the condition (57). Then Λ satisfies the conditions (36), (37), and (38). Next, let $x, y, z \in X$. Then

$$\begin{aligned}
\lambda_T(x\cdot z) &\geq \min\{\lambda_T(x\cdot(y\cdot z)), \lambda_T(y)\} && \text{by (42)}\\
&\geq \min\{\lambda_T(x\cdot(y\cdot z)), \lambda_T(x\cdot y)\}, && \text{by (57) for } \lambda_T\\
\lambda_I(x\cdot z) &\leq \max\{\lambda_I(x\cdot(y\cdot z)), \lambda_I(y)\} && \text{by (43)}\\
&\leq \max\{\lambda_I(x\cdot(y\cdot z)), \lambda_I(x\cdot y)\}, && \text{by (57) for } \lambda_I\\
\lambda_F(x\cdot z) &\geq \min\{\lambda_F(x\cdot(y\cdot z)), \lambda_F(y)\} && \text{by (44)}\\
&\geq \min\{\lambda_F(x\cdot(y\cdot z)), \lambda_F(x\cdot y)\}. && \text{by (57) for } \lambda_F
\end{aligned}$$

Hence, Λ is a neutrosophic implicative UP-filter of X. □

Theorem 3.26. *If Λ is a neutrosophic UP-filter of X satisfying the following condition:*

$$(\forall x, y, z \in X)\begin{pmatrix}\lambda_T(x) \geq \lambda_T(x \cdot y) \Rightarrow \lambda_T(x \cdot y) \geq \lambda_T(x \cdot ((y \cdot z) \cdot y)) \\ \lambda_I(x) \leq \lambda_I(x \cdot y) \Rightarrow \lambda_I(x \cdot y) \leq \lambda_I(x \cdot ((y \cdot z) \cdot y)) \\ \lambda_F(x) \geq \lambda_F(x \cdot y) \Rightarrow \lambda_F(x \cdot y) \geq \lambda_F(x \cdot ((y \cdot z) \cdot y))\end{pmatrix}, \tag{58}$$

then Λ is a neutrosophic comparative UP-filter of X.

Proof. Assume that Λ is a neutrosophic UP-filter of X satisfying the condition (58). Then Λ satisfies the conditions (36), (37), and (38). Next, let $x, y, z \in X$. Then

$$\begin{aligned}
\lambda_T(y) &\geq \min\{\lambda_T(x \cdot y), \lambda_T(x)\} && \text{by (39)} \\
&\geq \min\{\lambda_T(x \cdot ((y \cdot z) \cdot y)), \lambda_T(x)\}, && \text{by (58) for } \lambda_T \\
\lambda_I(y) &\leq \max\{\lambda_I(x \cdot y), \lambda_I(x)\} && \text{by (40)} \\
&\leq \max\{\lambda_I(x \cdot ((y \cdot z) \cdot y)), \lambda_I(x)\}, && \text{by (58) for } \lambda_I \\
\lambda_F(y) &\geq \min\{\lambda_F(x \cdot y), \lambda_F(x)\} && \text{by (41)} \\
&\geq \min\{\lambda_F(x \cdot ((y \cdot z) \cdot y)), \lambda_F(x)\}. && \text{by (58) for } \lambda_F
\end{aligned}$$

Hence, Λ is a neutrosophic comparative UP-filter of X. □

Theorem 3.27. *If Λ is a neutrosophic UP-filter of X satisfying the following condition:*

$$(\forall x, y, z \in X)\begin{pmatrix}\lambda_T(x) \geq \lambda_T(x \cdot (((z \cdot y) \cdot y) \cdot z)) \\ \Rightarrow \lambda_T(x \cdot (((z \cdot y) \cdot y) \cdot z)) \geq \lambda_T(x \cdot (y \cdot z)) \\ \lambda_I(x) \leq \lambda_I(x \cdot (((z \cdot y) \cdot y) \cdot z)) \\ \Rightarrow \lambda_I(x \cdot (((z \cdot y) \cdot y) \cdot z)) \leq \lambda_I(x \cdot (y \cdot z)) \\ \lambda_F(x) \geq \lambda_F(x \cdot (((z \cdot y) \cdot y) \cdot z)) \\ \Rightarrow \lambda_F(x \cdot (((z \cdot y) \cdot y) \cdot z)) \geq \lambda_F(x \cdot (y \cdot z))\end{pmatrix}, \tag{59}$$

then Λ is a neutrosophic shift UP-filter of X.

Proof. Assume that Λ is a neutrosophic UP-filter of X satisfying the condition (59). Then Λ satisfies the conditions (36), (37), and (38). Next, let $x, y, z \in X$. Then

$$\begin{aligned}
\lambda_T(((z \cdot y) \cdot y) \cdot z) &\geq \min\{\lambda_T(x \cdot (((z \cdot y) \cdot y) \cdot z), \lambda_T(x)\} && \text{by (39)} \\
&\geq \min\{\lambda_T(x \cdot (y \cdot z)), \lambda_T(x)\}, && \text{by (59) for } \lambda_T \\
\lambda_I(((z \cdot y) \cdot y) \cdot z) &\leq \max\{\lambda_I(x \cdot (((z \cdot y) \cdot y) \cdot z), \lambda_I(x)\} && \text{by (40)} \\
&\leq \max\{\lambda_I(x \cdot (y \cdot z)), \lambda_I(x)\}, && \text{by (59) for } \lambda_I \\
\lambda_F(((z \cdot y) \cdot y) \cdot z) &\geq \min\{\lambda_F(x \cdot (((z \cdot y) \cdot y) \cdot z)), \lambda_F(x)\} && \text{by (41)} \\
&\geq \min\{\lambda_F(x \cdot (y \cdot z)), \lambda_F(x)\}. && \text{by (59) for } \lambda_F
\end{aligned}$$

Hence, Λ is a neutrosophic shift UP-filter of X. □

Theorem 3.28. *If Λ is a NS in X satisfying the following condition:*

$$(\forall a, x, y, z \in X)\left(a \leq x \cdot (y \cdot z) \Rightarrow \begin{cases} \lambda_T(x \cdot z) \geq \min\{\lambda_T(a), \lambda_T(x \cdot y)\} \\ \lambda_I(x \cdot z) \leq \max\{\lambda_I(a), \lambda_I(x \cdot y)\} \\ \lambda_F(x \cdot z) \geq \min\{\lambda_F(a), \lambda_F(x \cdot y)\} \end{cases}\right), \tag{60}$$

then Λ is a neutrosophic implicative UP-filter of X.

Proof. Assume that Λ is a NS in X satisfying the condition (59). Let $x \in X$. By (3), we have $x \cdot (0 \cdot (x \cdot 0)) = 0$, that is, $x \leq 0 \cdot (x \cdot 0)$. It follows from (60) that

$$\begin{aligned} \lambda_T(0) = \lambda_T(0 \cdot 0) &\geq \min\{\lambda_T(x), \lambda_T(0 \cdot x)\} \\ &= \min\{\lambda_T(x), \lambda_T(x)\} = \lambda_T(x), && \text{by (2)} \\ \lambda_I(0) = \lambda_I(0 \cdot 0) &\leq \max\{\lambda_I(x), \lambda_I(0 \cdot x)\} \\ &= \max\{\lambda_I(x), \lambda_I(x)\} = \lambda_I(x), && \text{by (2)} \\ \lambda_F(0) = \lambda_F(0 \cdot 0) &\geq \min\{\lambda_F(x), \lambda_F(0 \cdot x)\} \\ &= \min\{\lambda_F(x), \lambda_F(x)\} = \lambda_F(x). && \text{by (2)} \end{aligned}$$

Next, let $x, y, z \in X$. By (6), we have $(x \cdot (y \cdot z)) \cdot (x \cdot (y \cdot z)) = 0$, that is, $x \cdot (y \cdot z) \leq x \cdot (y \cdot z)$. It follows from (60) that

$$\lambda_T(x \cdot z) \geq \min\{\lambda_T(x \cdot (y \cdot z)), \lambda_T(x \cdot y)\},$$
$$\lambda_I(x \cdot z) \leq \max\{\lambda_I(x \cdot (y \cdot z)), \lambda_I(x \cdot y)\},$$
$$\lambda_F(x \cdot z) \geq \min\{\lambda_F(x \cdot (y \cdot z)), \lambda_F(x \cdot y)\}.$$

Hence, Λ is a neutrosophic implicative UP-filter of X. □

Theorem 3.29. *If Λ is a NS in X satisfying the following condition:*

$$(\forall a, x, y, z \in X)\left(a \leq x \cdot ((y \cdot z) \cdot y) \Rightarrow \begin{cases} \lambda_T(y) \geq \min\{\lambda_T(a), \lambda_T(x)\} \\ \lambda_I(y) \leq \max\{\lambda_I(a), \lambda_I(x)\} \\ \lambda_F(y) \geq \min\{\lambda_F(a), \lambda_F(x)\} \end{cases}\right), \tag{61}$$

then Λ is a neutrosophic comparative UP-filter of X.

Proof. Assume that Λ is a NS in X satisfying the condition (61). Let $x \in X$. By (3), we have $x \cdot (x \cdot ((0 \cdot x) \cdot 0)) = 0$, that is, $x \leq x \cdot ((0 \cdot x) \cdot 0)$. It follows from (61) that

$$\lambda_T(0) \geq \min\{\lambda_T(x), \lambda_T(x)\} = \lambda_T(x),$$
$$\lambda_I(0) \leq \max\{\lambda_I(x), \lambda_I(x)\} = \lambda_I(x),$$
$$\lambda_F(0) \geq \min\{\lambda_F(x), \lambda_F(x)\} = \lambda_F(x).$$

Next, let $x, y, z \in X$. By (6), we have $(x \cdot ((y \cdot z) \cdot y)) \cdot (x \cdot ((y \cdot z) \cdot y)) = 0$, that is, $x \cdot ((y \cdot z) \cdot y) \leq x \cdot ((y \cdot z) \cdot y)$. It follows from (61) that

$$\lambda_T(y) \geq \min\{\lambda_T(x \cdot ((y \cdot z) \cdot y)), \lambda_T(x)\},$$
$$\lambda_I(y) \leq \max\{\lambda_I(x \cdot ((y \cdot z) \cdot y)), \lambda_I(x)\},$$
$$\lambda_F(y) \geq \min\{\lambda_F(x \cdot ((y \cdot z) \cdot y)), \lambda_F(x)\}.$$

Hence, Λ is a neutrosophic comparative UP-filter of X. □

Theorem 3.30. *If Λ is a NS in X satisfying the following condition:*

$$(\forall a, x, y, z \in X)\left(\begin{array}{c} a \leq x \cdot (y \cdot z) \\ \Rightarrow \begin{cases} \lambda_T(((z \cdot y) \cdot y) \cdot z) \geq \min\{\lambda_T(a), \lambda_T(x)\} \\ \lambda_I(((z \cdot y) \cdot y) \cdot z) \leq \max\{\lambda_I(a), \lambda_I(x)\} \\ \lambda_F(((z \cdot y) \cdot y) \cdot z) \geq \min\{\lambda_F(a), \lambda_F(x)\} \end{cases} \end{array}\right), \tag{62}$$

then Λ is a neutrosophic shift UP-filter of X.

Proof. Assume that Λ is a NS in X satisfying the condition (62). Let $x \in X$. By (3), we have $x \cdot (x \cdot (x \cdot 0)) = 0$, that is, $x \leq x \cdot (x \cdot 0)$. It follows from (62) that

$$\lambda_T(0) = \lambda_T(((0 \cdot x) \cdot x) \cdot 0) \geq \min\{\lambda_T(x), \lambda_T(x)\} = \lambda_T(x), \quad \text{by (3)}$$
$$\lambda_I(0) = \lambda_I(((0 \cdot x) \cdot x) \cdot 0) \leq \max\{\lambda_I(x), \lambda_I(x)\} = \lambda_I(x), \quad \text{by (3)}$$
$$\lambda_F(0) = \lambda_F(((0 \cdot x) \cdot x) \cdot 0) \geq \min\{\lambda_F(x), \lambda_F(x)\} = \lambda_F(x). \quad \text{by (3)}$$

Next, let $x, y, z \in X$. By (6), we have $(x \cdot (y \cdot z)) \cdot (x \cdot (y \cdot z)) = 0$, that is, $x \cdot (y \cdot z) \leq x \cdot (y \cdot z)$. It follows from (62) that

$$\lambda_T(((z \cdot y) \cdot y) \cdot z) \geq \min\{\lambda_T(x \cdot (y \cdot z)), \lambda_T(x)\},$$
$$\lambda_I(((z \cdot y) \cdot y) \cdot z) \leq \max\{\lambda_I(x \cdot (y \cdot z)), \lambda_I(x)\},$$
$$\lambda_F(((z \cdot y) \cdot y) \cdot z) \geq \min\{\lambda_F(x \cdot (y \cdot z)), \lambda_F(x)\}.$$

Hence, Λ is a neutrosophic shift UP-filter of X. □

For any fixed numbers $\alpha^+, \alpha^-, \beta^+, \beta^-, \gamma^+, \gamma^- \in [0, 1]$ such that $\alpha^+ > \alpha^-, \beta^+ > \beta^-, \gamma^+ > \gamma^-$ and a nonempty subset G of X, a NS $\Lambda^G[^{\alpha^+, \beta^-, \gamma^+}_{\alpha^-, \beta^+, \gamma^-}] = (X, \lambda_T^G[^{\alpha^+}_{\alpha^-}], \lambda_I^G[^{\beta^-}_{\beta^+}], \lambda_F^G[^{\gamma^+}_{\gamma^-}])$ in X where $\lambda_T^G[^{\alpha^+}_{\alpha^-}], \lambda_I^G[^{\beta^-}_{\beta^+}]$, and $\lambda_F^G[^{\gamma^+}_{\gamma^-}]$ are functions on X which are given as follows:

$$\lambda_T^G[^{\alpha^+}_{\alpha^-}](x) = \begin{cases} \alpha^+ & \text{if } x \in G, \\ \alpha^- & \text{otherwise}, \end{cases}$$

$$\lambda_I^G[^{\beta^-}_{\beta^+}](x) = \begin{cases} \beta^- & \text{if } x \in G, \\ \beta^+ & \text{otherwise,} \end{cases}$$

$$\lambda_F^G[^{\gamma^+}_{\gamma^-}](x) = \begin{cases} \gamma^+ & \text{if } x \in G, \\ \gamma^- & \text{otherwise.} \end{cases}$$

Lemma 3.31. *[23] If the constant* 0 *of* X *is in a nonempty subset* G *of* X*, then a NS* $\Lambda^G[^{\alpha^+,\beta^-,\gamma^+}_{\alpha^-,\beta^+,\gamma^-}]$ *in* X *satisfies the conditions* (36)*,* (37)*, and* (38)*.*

Lemma 3.32. *[23] If a NS* $\Lambda^G[^{\alpha^+,\beta^-,\gamma^+}_{\alpha^-,\beta^+,\gamma^-}]$ *in* X *satisfies the condition* (36) *(resp.,* (37)*,* (38)*), then the constant* 0 *of* X *is in a nonempty subset* G *of* X*.*

Theorem 3.33. *A NS* $\Lambda^G[^{\alpha^+,\beta^-,\gamma^+}_{\alpha^-,\beta^+,\gamma^-}]$ *in* X *is a neutrosophic implicative UP-filter of* X *if and only if a nonempty subset* G *of* X *is an implicative UP-filter of* X*.*

Proof. Assume that $\Lambda^G[^{\alpha^+,\beta^-,\gamma^+}_{\alpha^-,\beta^+,\gamma^-}]$ is neutrosophic implicative UP-filter of X. Since $\Lambda^G[^{\alpha^+,\beta^-,\gamma^+}_{\alpha^-,\beta^+,\gamma^-}]$ satisfies the condition (36), it follows from Lemma 3.32 that $0 \in G$. Next, let $x \cdot (y \cdot z), x \cdot y \in G$. Then $\lambda_T^G[^{\alpha^+}_{\alpha^-}](x \cdot (y \cdot z)) = \alpha^+ = \lambda_T^G[^{\alpha^+}_{\alpha^-}](x \cdot y)$. Thus, by (48), we have

$$\lambda_T^G[^{\alpha^+}_{\alpha^-}](x \cdot z) = \min\{\lambda_T^G[^{\alpha^+}_{\alpha^-}](x \cdot (y \cdot z)), \lambda_T^G[^{\alpha^+}_{\alpha^-}](x \cdot y)\} = \alpha^+ \geq \lambda_T^G[^{\alpha^+}_{\alpha^-}](x \cdot z)$$

and so $\lambda_T^G[^{\alpha^+}_{\alpha^-}](x \cdot z) = \alpha^+$. Thus $x \cdot z \in G$. Hence, G is an implicative UP-filter of X.

Conversely, assume that G is an implicative UP-filter of X. Since $0 \in G$, it follows from Lemma 3.31 that $\Lambda^G[^{\alpha^+,\beta^-,\gamma^+}_{\alpha^-,\beta^+,\gamma^-}]$ satisfies the conditions (36), (37), and (38). Next, let $x, y, z \in X$.

Case 1: $x \cdot (y \cdot z), x \cdot y \in G$. Then $\lambda_T^G[^{\alpha^+}_{\alpha^-}](x \cdot (y \cdot z)) = \lambda_T^G[^{\alpha^+}_{\alpha^-}](x \cdot y) = \alpha^+, \lambda_I^G[^{\beta^-}_{\beta^+}](x \cdot (y \cdot z)) = \lambda_I^G[^{\beta^-}_{\beta^+}](x \cdot y) = \beta^-$, and $\lambda_F^G[^{\gamma^+}_{\gamma^-}](x \cdot (y \cdot z)) = \lambda_F^G[^{\gamma^+}_{\gamma^-}](x \cdot y) = \gamma^+$. Since G is an implicative UP-filter of X, we have $x \cdot z \in G$ and so $\lambda_T^G[^{\alpha^+}_{\alpha^-}](x \cdot z) = \alpha^+, \lambda_I^G[^{\beta^-}_{\beta^+}](x \cdot z) = \beta^-$, and $\lambda_F^G[^{\gamma^+}_{\gamma^-}](x \cdot z) = \gamma^+$. Thus

$$\min\{\lambda_T^G[^{\alpha^+}_{\alpha^-}](x \cdot (y \cdot z)), \lambda_T^G[^{\alpha^+}_{\alpha^-}](x \cdot y)\} = \alpha^+ \geq \alpha^+ = \lambda_T^G[^{\alpha^+}_{\alpha^-}](x \cdot z),$$
$$\max\{\lambda_I^G[^{\beta^-}_{\beta^+}](x \cdot (y \cdot z)), \lambda_I^G[^{\beta^-}_{\beta^+}](x \cdot y)\} = \beta^- \leq \beta^- = \lambda_I^G[^{\beta^-}_{\beta^+}](x \cdot z),$$
$$\min\{\lambda_F^G[^{\gamma^+}_{\gamma^-}](x \cdot (y \cdot z)), \lambda_F^G[^{\gamma^+}_{\gamma^-}](x \cdot y)\} = \gamma^+ \geq \gamma^+ = \lambda_F^G[^{\gamma^+}_{\gamma^-}](x \cdot z).$$

Case 2: $x \cdot (y \cdot z) \notin G$ or $x \cdot y \notin G$. Then

$$\lambda_T^G[^{\alpha^+}_{\alpha^-}](x \cdot (y \cdot z)) = \alpha^- \text{ or } \lambda_T^G[^{\alpha^+}_{\alpha^-}](x \cdot y) = \alpha^-,$$
$$\lambda_I^G[^{\beta^-}_{\beta^+}](x \cdot (y \cdot z)) = \beta^+ \text{ or } \lambda_I^G[^{\beta^-}_{\beta^+}](x \cdot y) = \beta^+,$$
$$\lambda_F^G[^{\gamma^+}_{\gamma^-}](x \cdot (y \cdot z)) = \gamma^- \text{ or } \lambda_F^G[^{\gamma^+}_{\gamma^-}](x \cdot y) = \gamma^-.$$

Thus

$$\min\{\lambda_T^G[^{\alpha^+}_{\alpha^-}](x\cdot(y\cdot z)),\lambda_T^G[^{\alpha^+}_{\alpha^-}](x\cdot y)\}=\alpha^-,$$
$$\max\{\lambda_I^G[^{\beta^-}_{\beta^+}](x\cdot(y\cdot z)),\lambda_I^G[^{\beta^-}_{\beta^+}](x\cdot y)\}=\beta^+,$$
$$\min\{\lambda_F^G[^{\gamma^+}_{\gamma^-}](x\cdot(y\cdot z)),\lambda_F^G[^{\gamma^+}_{\gamma^-}](x\cdot y)\}=\gamma^-.$$

Therefore,

$$\lambda_T^G[^{\alpha^+}_{\alpha^-}](x\cdot z)\geq\alpha^-=\min\{\lambda_T^G[^{\alpha^+}_{\alpha^-}](x\cdot(y\cdot z)),\lambda_T^G[^{\alpha^+}_{\alpha^-}](x\cdot y)\},$$
$$\lambda_I^G[^{\beta^-}_{\beta^+}](x\cdot z)\leq\beta^+=\max\{\lambda_I^G[^{\beta^-}_{\beta^+}](x\cdot(y\cdot z)),\lambda_I^G[^{\beta^-}_{\beta^+}](x\cdot y)\},$$
$$\lambda_F^G[^{\gamma^+}_{\gamma^-}](x\cdot z)\geq\gamma^-=\min\{\lambda_F^G[^{\gamma^+}_{\gamma^-}](x\cdot(y\cdot z)),\lambda_F^G[^{\gamma^+}_{\gamma^-}](x\cdot y)\}.$$

Hence, $\Lambda^G[^{\alpha^+,\beta^-,\gamma^+}_{\alpha^-,\beta^+,\gamma^-}]$ is a neutrosophic implicative UP-filter of X. □

Theorem 3.34. *A NS $\Lambda^G[^{\alpha^+,\beta^-,\gamma^+}_{\alpha^-,\beta^+,\gamma^-}]$ in X is a neutrosophic comparative UP-filter of X if and only if a nonempty subset G of X is a comparative UP-filter of X.*

Proof. Assume that $\Lambda^G[^{\alpha^+,\beta^-,\gamma^+}_{\alpha^-,\beta^+,\gamma^-}]$ is a neutrosophic comparative UP-filter of X. Since $\Lambda^G[^{\alpha^+,\beta^-,\gamma^+}_{\alpha^-,\beta^+,\gamma^-}]$ satisfies the condition (36), it follows from Lemma 3.32 that $0\in G$. Next, let $x,y\in X$ be such that $x\cdot((y\cdot z)\cdot y),x\in G$. Then $\lambda_T^G[^{\alpha^+}_{\alpha^-}](x\cdot((y\cdot z)\cdot y))=\alpha^+=\lambda_T^G[^{\alpha^+}_{\alpha^-}](x)$. Thus, by (51), we have

$$\lambda_T^G[^{\alpha^+}_{\alpha^-}](y)\geq\min\{\lambda_T^G[^{\alpha^+}_{\alpha^-}](x\cdot((y\cdot z)\cdot y)),\lambda_T^G[^{\alpha^+}_{\alpha^-}](x)\}=\alpha^+\geq\lambda_T^G[^{\alpha^+}_{\alpha^-}](y)$$

and so $\lambda_T^G[^{\alpha^+}_{\alpha^-}](y)=\alpha^+$. Thus $y\in G$. Hence, G is a comparative UP-filter of X.

Conversely, assume that G is a comparative UP-filter of X. Since $0\in G$, it follows from Lemma 3.31 that $\Lambda^G[^{\alpha^+,\beta^-,\gamma^+}_{\alpha^-,\beta^+,\gamma^-}]$ satisfies the conditions (36), (37), and (38). Next, let $x,y,z\in X$.

Case 1: $x\cdot((y\cdot z)\cdot y)\in G$ and $x\in G$. Then

$$\lambda_T^G[^{\alpha^+}_{\alpha^-}](x\cdot((y\cdot z)\cdot y))=\alpha^+=\lambda_T^G[^{\alpha^+}_{\alpha^-}](x),$$
$$\lambda_I^G[^{\beta^-}_{\beta^+}](x\cdot((y\cdot z)\cdot y))=\beta^-=\lambda_I^G[^{\beta^-}_{\beta^+}](x),$$
$$\lambda_F^G[^{\gamma^+}_{\gamma^-}](x\cdot((y\cdot z)\cdot y))=\gamma^+=\lambda_F^G[^{\gamma^+}_{\gamma^-}](x).$$

Since G is a comparative UP-filter of X, we have $y\in G$ and so $\lambda_T^G[^{\alpha^+}_{\alpha^-}](y)=\alpha^+$, $\lambda_I^G[^{\beta^-}_{\beta^+}](y)=\beta^-$, and $\lambda_F^G[^{\gamma^+}_{\gamma^-}](y)=\gamma^+$. Thus

$$\lambda_T^G[^{\alpha^+}_{\alpha^-}](y)=\alpha^+\geq\alpha^+=\min\{\lambda_T^G[^{\alpha^+}_{\alpha^-}](x\cdot((y\cdot z)\cdot y)),\lambda_T^G[^{\alpha^+}_{\alpha^-}](x)\},$$
$$\lambda_I^G[^{\beta^-}_{\beta^+}](y)=\beta^-\leq\beta^-=\max\{\lambda_I^G[^{\beta^-}_{\beta^+}](x\cdot((y\cdot z)\cdot y)),\lambda_I^G[^{\beta^-}_{\beta^+}](x)\},$$
$$\lambda_F^G[^{\gamma^+}_{\gamma^-}](y)=\gamma^+\geq\gamma^+=\min\{\lambda_F^G[^{\gamma^+}_{\gamma^-}](x\cdot((y\cdot z)\cdot y)),\lambda_F^G[^{\gamma^+}_{\gamma^-}](x)\}.$$

Case 2: $x \cdot ((y \cdot z) \cdot y) \notin G$ or $x \notin G$. Then

$$\lambda_T^G[^{\alpha^+}_{\alpha^-}](x \cdot ((y \cdot z) \cdot y)) = \alpha^- \text{ or } \lambda_T^G[^{\alpha^+}_{\alpha^-}](x) = \alpha^-,$$
$$\lambda_I^G[^{\beta^-}_{\beta^+}](x \cdot ((y \cdot z) \cdot y)) = \beta^+ \text{ or } \lambda_I^G[^{\beta^-}_{\beta^+}](x) = \beta^+,$$
$$\lambda_F^G[^{\gamma^+}_{\gamma^-}](x \cdot ((y \cdot z) \cdot y)) = \gamma^- \text{ or } \lambda_F^G[^{\gamma^+}_{\gamma^-}](x) = \gamma^-.$$

Thus

$$\min\{\lambda_T^G[^{\alpha^+}_{\alpha^-}](x \cdot ((y \cdot z) \cdot y)), \lambda_T^G[^{\alpha^+}_{\alpha^-}](x)\} = \alpha^-,$$
$$\max\{\lambda_I^G[^{\beta^-}_{\beta^+}](x \cdot ((y \cdot z) \cdot y)), \lambda_I^G[^{\beta^-}_{\beta^+}](x)\} = \beta^+,$$
$$\min\{\lambda_F^G[^{\gamma^+}_{\gamma^-}](x \cdot ((y \cdot z) \cdot y)), \lambda_F^G[^{\gamma^+}_{\gamma^-}](x)\} = \gamma^-.$$

Therefore,

$$\lambda_T^G[^{\alpha^+}_{\alpha^-}](y) \geq \alpha^- = \min\{\lambda_T^G[^{\alpha^+}_{\alpha^-}](x \cdot ((y \cdot z) \cdot y)), \lambda_T^G[^{\alpha^+}_{\alpha^-}](x)\},$$
$$\lambda_I^G[^{\beta^-}_{\beta^+}](y) \leq \beta^+ = \max\{\lambda_I^G[^{\beta^-}_{\beta^+}](x \cdot ((y \cdot z) \cdot y)), \lambda_I^G[^{\beta^-}_{\beta^+}](x)\},$$
$$\lambda_F^G[^{\gamma^+}_{\gamma^-}](y) \geq \gamma^- = \min\{\lambda_F^G[^{\gamma^+}_{\gamma^-}](x \cdot ((y \cdot z) \cdot y)), \lambda_F^G[^{\gamma^+}_{\gamma^-}](x)\}.$$

Hence, $\Lambda^G[^{\alpha^+,\beta^-,\gamma^+}_{\alpha^-,\beta^+,\gamma^-}]$ is a neutrosophic comparative UP-filter of X. □

Theorem 3.35. *A NS $\Lambda^G[^{\alpha^+,\beta^-,\gamma^+}_{\alpha^-,\beta^+,\gamma^-}]$ in X is a neutrosophic shift UP-filter of X if and only if a nonempty subset G of X is a shift UP-filter of X.*

Proof. Assume that $\Lambda^G[^{\alpha^+,\beta^-,\gamma^+}_{\alpha^-,\beta^+,\gamma^-}]$ is a neutrosophic shift UP-filter of X. Since $\Lambda^G[^{\alpha^+,\beta^-,\gamma^+}_{\alpha^-,\beta^+,\gamma^-}]$ satisfies the condition (36), it follows from Lemma 3.32 that $0 \in G$. Next, let $x, y, z \in X$ be such that $x \cdot (y \cdot z) \in G$ and $x \in G$. Then $\lambda_T^G[^{\alpha^+}_{\alpha^-}](x \cdot (y \cdot z)) = \alpha^+ = \lambda_T^G[^{\alpha^+}_{\alpha^-}](x)$. Thus, by (54), we have

$$\lambda_T^G[^{\alpha^+}_{\alpha^-}](((z \cdot y) \cdot y) \cdot z) \geq \min\{\lambda_T^G[^{\alpha^+}_{\alpha^-}](x \cdot (y \cdot z)), \lambda_T^G[^{\alpha^+}_{\alpha^-}](y)\} = \alpha^+ \geq \lambda_T^G[^{\alpha^+}_{\alpha^-}](((z \cdot y) \cdot y) \cdot z)$$

and so $\lambda_T^G[^{\alpha^+}_{\alpha^-}](((z \cdot y) \cdot y) \cdot z) = \alpha^+$. Thus $((z \cdot y) \cdot y) \cdot z \in G$. Hence, G is a shift UP-filter of X.

Conversely, assume that G is a shift UP-filter of X. Since $0 \in G$, it follows from Lemma 3.31 that $\Lambda^G[^{\alpha^+,\beta^-,\gamma^+}_{\alpha^-,\beta^+,\gamma^-}]$ satisfies the conditions (36), (37), and (38). Next, let $x, y, z \in X$.

Case 1: $x \cdot (y \cdot z) \in G$ and $x \in G$. Then

$$\lambda_T^G[^{\alpha^+}_{\alpha^-}](x \cdot (y \cdot z)) = \alpha^+ = \lambda_T^G[^{\alpha^+}_{\alpha^-}](x),$$
$$\lambda_I^G[^{\beta^-}_{\beta^+}](x \cdot (y \cdot z)) = \beta^- = \lambda_I^G[^{\beta^-}_{\beta^+}](x),$$
$$\lambda_F^G[^{\gamma^+}_{\gamma^-}](x \cdot (y \cdot z)) = \gamma^+ = \lambda_F^G[^{\gamma^+}_{\gamma^-}](x).$$

Thus

$$\min\{\lambda_T^G[^{\alpha^+}_{\alpha^-}](x\cdot(y\cdot z)),\lambda_T^G[^{\alpha^+}_{\alpha^-}](x)\}=\alpha^+,$$
$$\max\{\lambda_I^G[^{\beta^-}_{\beta^+}](x\cdot(y\cdot z)),\lambda_I^G[^{\beta^-}_{\beta^+}](x)\}=\beta^-,$$
$$\min\{\lambda_F^G[^{\gamma^+}_{\gamma^-}](x\cdot(y\cdot z)),\lambda_F^G[^{\gamma^+}_{\gamma^-}](x)\}=\gamma^+.$$

Since G is a shift UP-filter of X, we have $((z\cdot y)\cdot y)\cdot z\in G$ and so $\lambda_T^G[^{\alpha^+}_{\alpha^-}](((z\cdot y)\cdot y)\cdot z)=\alpha^+,\lambda_I^G[^{\beta^-}_{\beta^+}](((z\cdot y)\cdot y)\cdot z)=\beta^-$, and $\lambda_F^G[^{\gamma^+}_{\gamma^-}](((z\cdot y)\cdot y)\cdot z)=\gamma^+$. Thus

$$\lambda_T^G[^{\alpha^+}_{\alpha^-}](((z\cdot y)\cdot y)\cdot z)=\alpha^+\geq\alpha^+=\min\{\lambda_T^G[^{\alpha^+}_{\alpha^-}](x\cdot(y\cdot z)),\lambda_T^G[^{\alpha^+}_{\alpha^-}](x)\},$$
$$\lambda_I^G[^{\beta^-}_{\beta^+}](((z\cdot y)\cdot y)\cdot z)=\beta^-\leq\beta^-=\max\{\lambda_I^G[^{\beta^-}_{\beta^+}](x\cdot(y\cdot z)),\lambda_I^G[^{\beta^-}_{\beta^+}](x)\},$$
$$\lambda_F^G[^{\gamma^+}_{\gamma^-}](((z\cdot y)\cdot y)\cdot z)=\gamma^+\geq\gamma^+=\min\{\lambda_F^G[^{\gamma^+}_{\gamma^-}](x\cdot(y\cdot z)),\lambda_F^G[^{\gamma^+}_{\gamma^-}](x)\}.$$

Case 2: $x\cdot(y\cdot z)\notin G$ or $x\notin G$. Then

$$\lambda_T^G[^{\alpha^+}_{\alpha^-}](x\cdot(y\cdot z))=\alpha^-\text{ or }\lambda_T^G[^{\alpha^+}_{\alpha^-}](x)=\alpha^-,$$
$$\lambda_I^G[^{\beta^-}_{\beta^+}](x\cdot(y\cdot z))=\beta^+\text{ or }\lambda_I^G[^{\beta^-}_{\beta^+}](x)=\beta^+,$$
$$\lambda_F^G[^{\gamma^+}_{\gamma^-}](x\cdot(y\cdot z))=\gamma^-\text{ or }\lambda_F^G[^{\gamma^+}_{\gamma^-}](x)=\gamma^-.$$

Thus

$$\min\{\lambda_T^G[^{\alpha^+}_{\alpha^-}](x\cdot(y\cdot z)),\lambda_T^G[^{\alpha^+}_{\alpha^-}](x)\}=\alpha^-,$$
$$\max\{\lambda_I^G[^{\beta^-}_{\beta^+}](x\cdot(y\cdot z)),\lambda_I^G[^{\beta^-}_{\beta^+}](x)\}=\beta^+,$$
$$\min\{\lambda_F^G[^{\gamma^+}_{\gamma^-}](x\cdot(y\cdot z)),\lambda_F^G[^{\gamma^+}_{\gamma^-}](x)\}=\gamma^-.$$

Therefore,

$$\lambda_T^G[^{\alpha^+}_{\alpha^-}](((z\cdot y)\cdot y)\cdot z)\geq\alpha^-=\min\{\lambda_T^G[^{\alpha^+}_{\alpha^-}](x\cdot(y\cdot z)),\lambda_T^G[^{\alpha^+}_{\alpha^-}](x)\},$$
$$\lambda_I^G[^{\beta^-}_{\beta^+}](((z\cdot y)\cdot y)\cdot z)\leq\beta^+=\max\{\lambda_I^G[^{\beta^-}_{\beta^+}](x\cdot(y\cdot z)),\lambda_I^G[^{\beta^-}_{\beta^+}](x)\},$$
$$\lambda_F^G[^{\gamma^+}_{\gamma^-}](((z\cdot y)\cdot y)\cdot z)\geq\gamma^-=\min\{\lambda_F^G[^{\gamma^+}_{\gamma^-}](x\cdot(y\cdot z)),\lambda_F^G[^{\gamma^+}_{\gamma^-}](x)\}.$$

Hence, $\Lambda^G[^{\alpha^+,\beta^-,\gamma^+}_{\alpha^-,\beta^+,\gamma^-}]$ is a neutrosophic shift UP-filter of X. □

4. **Level subsets of a NS**

In this section, we discuss the relationships between neutrosophic implicative UP-filters (resp., neutrosophic comparative UP-filters, neutrosophic shift UP-filters) of UP-algebras and their level subsets.

Definition 4.1. [21] Let f be a fuzzy set in A. For any $t \in [0,1]$, the sets

$$U(f;t) = \{x \in X \mid f(x) \geq t\},$$
$$L(f;t) = \{x \in X \mid f(x) \leq t\},$$
$$E(f;t) = \{x \in X \mid f(x) = t\}$$

are called an *upper t-level subset*, a *lower t-level subset*, and an *equal t-level subset* of f, respectively.

Theorem 4.2. *A NS Λ in X is a neutrosophic implicative UP-filter of X if and only if for all $\alpha, \beta, \gamma \in [0,1]$, the sets $U(\lambda_T;\alpha), L(\lambda_I;\beta)$, and $U(\lambda_F;\gamma)$ are implicative UP-filters of X if $U(\lambda_T;\alpha), L(\lambda_I;\beta)$, and $U(\lambda_F;\gamma)$ are nonempty.*

Proof. Assume that Λ is a neutrosophic implicative UP-filter of X. Let $\alpha, \beta, \gamma \in [0,1]$ be such that $U(\lambda_T;\alpha), L(\lambda_I;\beta)$, and $U(\lambda_F;\gamma)$ are nonempty.

Let $x \in U(\lambda_T;\alpha)$. Then $\lambda_T(x) \geq \alpha$. By (36), we have $\lambda_T(0) \geq \lambda_T(x) \geq \alpha$. Thus $0 \in U(\lambda_T;\alpha)$. Next, let $x \cdot (y \cdot z), x \cdot y \in U(\lambda_T;\alpha)$. Then $\lambda_T(x \cdot (y \cdot z)) \geq \alpha$ and $\lambda_T(x \cdot y) \geq \alpha$. By (48), we have $\lambda_F(x \cdot z) \geq \min\{\lambda_F(x \cdot (y \cdot z)), \lambda_F(x \cdot y)\} \geq \alpha$. Thus $x \cdot z \in U(\lambda_T;\alpha)$.

Let $x \in L(\lambda_I;\beta)$. Then $\lambda_I(x) \leq \beta$. By (37), we have $\lambda_I(0) \leq \lambda_I(x) \leq \beta$. Thus $0 \in L(\lambda_I;\beta)$. Next, let $x \cdot (y \cdot z), x \cdot y \in L(\lambda_I;\beta)$. Then $\lambda_I(x \cdot (y \cdot z)) \leq \beta$ and $\lambda_I(x \cdot y) \geq \beta$. By (49), we have $\lambda_I(x \cdot z) \leq \max\{\lambda_I(x \cdot (y \cdot z)), \lambda_I(x \cdot y)\} \leq \beta$. Thus $x \cdot z \in L(\lambda_I;\beta)$.

Let $x \in U(\lambda_F;\gamma)$. Then $\lambda_F(x) \geq \gamma$. By (38), we have $\lambda_F(0) \geq \lambda_F(x) \geq \gamma$. Thus $0 \in U(\lambda_F;\gamma)$. Next, let $x \cdot (y \cdot z), x \cdot y \in U(\lambda_F;\gamma)$. Then $\lambda_F(x \cdot (y \cdot z)) \geq \gamma$ and $\lambda_F(x \cdot y) \geq \gamma$. By (50), we have $\lambda_F(x \cdot z) \geq \min\{\lambda_F(x \cdot (y \cdot z)), \lambda_F(x \cdot y)\} \geq \gamma$. Thus $x \cdot z \in U(\lambda_F;\gamma)$.

Hence, $U(\lambda_T;\alpha), L(\lambda_I;\beta)$, and $U(\lambda_F;\gamma)$ are implicative UP-filters of X.

Conversely, assume that for all $\alpha, \beta, \gamma \in [0,1]$, the sets $U(\lambda_T;\alpha), L(\lambda_I;\beta)$, and $U(\lambda_F;\gamma)$ are implicative UP-filters of X if $U(\lambda_T;\alpha), L(\lambda_I;\beta)$, and $U(\lambda_F;\gamma)$ are nonempty.

Let $x \in X$. Then $\lambda_T(x) \in [0,1]$. Choose $\alpha = \lambda_T(x)$. Thus $\lambda_T(x) \geq \alpha$, so $x \in U(\lambda_T;\alpha) \neq \emptyset$. By assumption, we have $U(\lambda_T;\alpha)$ is an implication UP-filter of X and so $0 \in U(\lambda_T;\alpha)$. Thus $\lambda_T(0) \geq \alpha = \lambda_T(x)$. Next, let $x, y, z \in X$. Then $\lambda_T(x \cdot (y \cdot z)), \lambda_T(x \cdot y) \in [0,1]$. Choose $\alpha = \min\{\lambda_T(x \cdot (y \cdot z)), \lambda_T(x \cdot y)\}$. Thus $\lambda_T(x \cdot (y \cdot z)) \geq \alpha$ and $\lambda_T(x \cdot y) \geq \alpha$, so $x \cdot (y \cdot z), x \cdot y \in U(\lambda_T;\alpha) \neq \emptyset$. By assumption, we have $U(\lambda_T;\alpha)$ is an implication UP-filter of X and so $x \cdot z \in U(\lambda_T;\alpha)$. Thus $\lambda_T(x \cdot z) \geq \alpha = \min\{\lambda_T(x \cdot (y \cdot z)), \lambda_T(x \cdot y)\}$.

Let $x \in X$. Then $\lambda_I(x) \in [0,1]$. Choose $\beta = \lambda_I(x)$. Thus $\lambda_I(x) \leq \beta$, so $x \in L(\lambda_I;\beta) \neq \emptyset$. By assumption, we have $L(\lambda_I;\beta)$ is an implicative UP-filter of X and so $0 \in L(\lambda_I;\beta)$. Thus $\lambda_I(0) \leq \beta = \lambda_I(x)$. Next, let $x, y, z \in X$. Then $\lambda_T(x \cdot (y \cdot z)), \lambda_T(x \cdot y) \in [0,1]$. Choose $\beta = \max\{\lambda_T(x \cdot (y \cdot z)), \lambda_T(x \cdot y)\}$. Thus $\lambda_T(x \cdot (y \cdot z)) \leq \beta$ and $\lambda_T(x \cdot y) \leq \beta$, so $x \cdot (y \cdot z), x \cdot y \in$

$L(\lambda_T;\beta) \neq \emptyset$. By assumption, we have $L(\lambda_T;\beta)$ is an implication UP-filter of X and so $x \cdot z \in L(\lambda_T;\beta)$. Thus $\lambda_T(x \cdot z) \leq \beta = \max\{\lambda_T(x \cdot (y \cdot z)), \lambda_T(x \cdot y)\}$.

Let $x \in X$. Then $\lambda_F(x) \in [0,1]$. Choose $\gamma = \lambda_F(x)$. Thus $\lambda_F(x) \geq \gamma$, so $x \in U(\lambda_F;\gamma) \neq \emptyset$. By assumption, we have $U(\lambda_F;\gamma)$ is an implicative UP-filter of X and so $0 \in U(\lambda_F;\gamma)$. Thus $\lambda_F(0) \geq \gamma = \lambda_F(x)$. Next, let $x, y, z \in X$. Then $\lambda_T(x \cdot (y \cdot z)), \lambda_T(x \cdot y) \in [0,1]$. Choose $\gamma = \min\{\lambda_T(x \cdot (y \cdot z)), \lambda_T(x \cdot y)\}$. Thus $\lambda_T(x \cdot (y \cdot z)) \geq \gamma$ and $\lambda_T(x \cdot y) \geq \gamma$, so $x \cdot (y \cdot z), x \cdot y \in U(\lambda_T;\gamma) \neq \emptyset$. By assumption, we have $U(\lambda_T;\gamma)$ is an implication UP-filter of X and so $x \cdot z \in U(\lambda_T;\gamma)$. Thus $\lambda_T(x \cdot z) \geq \gamma = \min\{\lambda_T(x \cdot (y \cdot z)), \lambda_T(x \cdot y)\}$.

Therefore, Λ is a neutrosophic implicative UP-filter of X. □

Theorem 4.3. *A NS Λ in X is a neutrosophic comparative UP-filter of X if and only if for all $\alpha, \beta, \gamma \in [0,1]$, the sets $U(\lambda_T;\alpha), L(\lambda_I;\beta)$, and $U(\lambda_F;\gamma)$ are comparative UP-filters of X if $U(\lambda_T;\alpha), L(\lambda_I;\beta)$, and $U(\lambda_F;\gamma)$ are nonempty.*

Proof. Assume that Λ is a neutrosophic comparative UP-filter of X. Let $\alpha, \beta, \gamma \in [0,1]$ be such that $U(\lambda_T;\alpha), L(\lambda_I;\beta)$, and $U(\lambda_F;\gamma)$ are nonempty.

Let $x \in U(\lambda_T;\alpha)$. Then $\lambda_T(x) \geq \alpha$. By (36), we have $\lambda_T(0) \geq \lambda_T(x) \geq \alpha$. Thus $0 \in U(\lambda_T;\alpha)$. Next, let $x, y, z \in X$ be such that $x \cdot ((y \cdot z) \cdot y), x \in U(\lambda_T;\alpha)$. Then $\lambda_T(x \cdot ((y \cdot z) \cdot y)) \geq \alpha$ and $\lambda_T(x) \geq \alpha$, so α is an lower bound of $\{\lambda_T(x \cdot ((y \cdot z) \cdot y)), \lambda_T(x)\}$. By (51), we have $\lambda_T(y) \geq \min\{\lambda_T(x \cdot ((y \cdot z) \cdot y)), \lambda_T(x)\} \geq \alpha$. Thus $y \in U(\lambda_T;\alpha)$.

Let $x \in L(\lambda_I;\beta)$. Then $\lambda_I(x) \leq \beta$. By (37), we have $\lambda_I(0) \leq \lambda_I(x) \leq \beta$. Thus $0 \in L(\lambda_I;\beta)$. Next, let $x, y, z \in X$ be such that $x \cdot ((y \cdot z) \cdot y), x \in L(\lambda_I;\beta)$. Then $\lambda_I(x \cdot ((y \cdot z) \cdot y)) \leq \beta$ and $\lambda_I(x) \leq \beta$, so β is a upper bound of $\{\lambda_I(x \cdot ((y \cdot z) \cdot y)), \lambda_I(x)\}$. By (52), we have $\lambda_I(y) \leq \max\{\lambda_I(x \cdot ((y \cdot z) \cdot y)), \lambda_I(x)\} \leq \beta$ Thus $y \in L(\lambda_I;\beta)$.

Let $x \in U(\lambda_F;\gamma)$. Then $\lambda_F(x) \geq \gamma$. By (38), we have $\lambda_F(0) \geq \lambda_F(x) \geq \gamma$. Thus $0 \in U(\lambda_F;\gamma)$. Next, let $x, y, z \in X$ be such that $x \cdot ((y \cdot z) \cdot y), x \in U(\lambda_F;\gamma)$. Then $\lambda_F(x \cdot ((y \cdot z) \cdot y)) \geq \gamma$ and $\lambda_F(x) \geq \gamma$, so γ is an lower bound of $\{\lambda_F(x \cdot ((y \cdot z) \cdot y)), \lambda_F(x)\}$. By (53), we have $\lambda_F(y) \geq \min\{\lambda_F(x \cdot ((y \cdot z) \cdot y)), \lambda_F(x)\} \geq \gamma$. Thus $y \in U(\lambda_F;\gamma)$.

Hence, $U(\lambda_T;\alpha), L(\lambda_I;\beta)$, and $U(\lambda_F;\gamma)$ are comparative UP-filters of X.

Conversely, assume that for all $\alpha, \beta, \gamma \in [0,1]$, the sets $U(\lambda_T;\alpha), L(\lambda_I;\beta)$, and $U(\lambda_F;\gamma)$ are UP-filters of X if $U(\lambda_T;\alpha), L(\lambda_I;\beta)$, and $U(\lambda_F;\gamma)$ are nonempty.

Let $x \in X$. Then $\lambda_T(x) \in [0,1]$. Choose $\alpha = \lambda_T(x)$. Thus $\lambda_T(x) \geq \alpha$, so $x \in U(\lambda_T;\alpha) \neq \emptyset$. By assumption, we have $U(\lambda_T;\alpha)$ is a comparative UP-filter of X and so $0 \in U(\lambda_T;\alpha)$. Thus $\lambda_T(0) \geq \alpha = \lambda_T(x)$. Next, let $x, y, z \in X$. Then $\lambda_T(x \cdot ((y \cdot z) \cdot y)), \lambda_T(x) \in [0,1]$. Choose $\alpha = \min\{\lambda_T(x \cdot ((y \cdot z) \cdot y)), \lambda_T(x)\}$. Thus $\lambda_T(x \cdot ((y \cdot z) \cdot y)) \geq \alpha$ and $\lambda_T(x) \geq \alpha$, so $x \cdot ((y \cdot z) \cdot y), x \in U(\lambda_T;\alpha) \neq \emptyset$. By assumption, we have $U(\lambda_T;\alpha)$ is a comparative UP-filter of X and so $y \in U(\lambda_T;\alpha)$. Thus $\lambda_T(y) \geq \alpha = \min\{\lambda_T(x \cdot ((y \cdot z) \cdot y)), \lambda_T(x)\}$.

Let $x \in X$. Then $\lambda_I(x) \in [0,1]$. Choose $\beta = \lambda_I(x)$. Thus $\lambda_I(x) \leq \beta$, so $x \in L(\lambda_I;\beta) \neq \emptyset$. By assumption, we have $L(\lambda_I;\beta)$ is a comparative UP-filter of X and so $0 \in L(\lambda_I;\beta)$. Thus $\lambda_I(0) \leq \beta = \lambda_I(x)$. Next, let $x,y,z \in X$. Then $\lambda_I(x \cdot ((y \cdot z) \cdot y)), \lambda_I(x) \in [0,1]$. Choose $\beta = \max\{\lambda_I(x \cdot ((y \cdot z) \cdot y)), \lambda_I(x)\}$. Thus $\lambda_I(x \cdot ((y \cdot z) \cdot y)) \leq \beta$ and $\lambda_I(x) \leq \beta$, so $x \cdot ((y \cdot z) \cdot y), x \in L(\lambda_I;\beta) \neq \emptyset$. By assumption, we have $L(\lambda_I;\beta)$ is a comparative UP-filter of X and so $y \in L(\lambda_I;\beta)$. Thus $\lambda_I(y) \leq \beta = \max\{\lambda_I(x \cdot ((y \cdot z) \cdot y)), \lambda_I(x)\}$.

Let $x \in X$. Then $\lambda_F(x) \in [0,1]$. Choose $\gamma = \lambda_F(x)$. Thus $\lambda_F(x) \geq \gamma$, so $x \in U(\lambda_F;\gamma) \neq \emptyset$. By assumption, we have $U(\lambda_F;\gamma)$ is a comparative UP-filter of X and so $0 \in U(\lambda_F;\gamma)$. Thus $\lambda_F(0) \geq \gamma = \lambda_F(x)$. Next, let $x,y,z \in X$. Then $\lambda_F(x \cdot ((y \cdot z) \cdot y)), \lambda_F(x) \in [0,1]$. Choose $\gamma = \min\{\lambda_F(x \cdot ((y \cdot z) \cdot y)), \lambda_F(x)\}$. Thus $\lambda_F(x \cdot ((y \cdot z) \cdot y)) \geq \gamma$ and $\lambda_F(x) \geq \gamma$, so $x \cdot ((y \cdot z) \cdot y), x \in U(\lambda_F;\gamma) \neq \emptyset$. By assumption, we have $U(\lambda_F;\gamma)$ is a comparative UP-filter of X and so $y \in U(\lambda_F;\gamma)$. Thus $\lambda_F(y) \geq \gamma = \min\{\lambda_F(x \cdot ((y \cdot z) \cdot y)), \lambda_F(x)\}$.

Therefore, Λ is a neutrosophic comparative UP-filter of X. □

Theorem 4.4. *A NS Λ in X is a neutrosophic shift UP-filter of X if and only if for all $\alpha, \beta, \gamma \in [0,1]$, the sets $U(\lambda_T;\alpha), L(\lambda_I;\beta)$, and $U(\lambda_F;\gamma)$ are shift UP-filters of X if $U(\lambda_T;\alpha), L(\lambda_I;\beta)$, and $U(\lambda_F;\gamma)$ are nonempty.*

Proof. Assume that Λ is a neutrosophic shift UP-filter of X. Let $\alpha, \beta, \gamma \in [0,1]$ be such that $U(\lambda_T;\alpha), L(\lambda_I;\beta)$, and $U(\lambda_F;\gamma)$ are nonempty.

Let $x \in U(\lambda_T;\alpha)$. Then $\lambda_T(x) \geq \alpha$. By (36), we have $\lambda_T(0) \geq \lambda_T(x) \geq \alpha$. Thus $0 \in U(\lambda_T;\alpha)$. Next, let $x,y,z \in X$ be such that $x \cdot (y \cdot z) \in U(\lambda_T;\alpha)$ and $x \in U(\lambda_T;\alpha)$. Then $\lambda_T(x \cdot (y \cdot z)) \geq \alpha$ and $\lambda_T(x) \geq \alpha$, so α is an lower bound of $\{\lambda_T(x \cdot (y \cdot z)), \lambda_T(x)\}$. By (54), we have $\lambda_T(((z \cdot y) \cdot y) \cdot z) \geq \min\{\lambda_T(x \cdot (y \cdot z)), \lambda_T(x)\} \geq \alpha$. Thus $((z \cdot y) \cdot y) \cdot z \in U(\lambda_T;\alpha)$.

Let $x \in L(\lambda_I;\alpha)$. Then $\lambda_I(x) \leq \beta$. By (37), we have $\lambda_I(0) \leq \lambda_I(x) \leq \beta$. Thus $0 \in L(\lambda_I;\beta)$. Next, let $x,y,z \in X$ be such that $x \cdot (y \cdot z) \in L(\lambda_I;\beta)$ and $x \in L(\lambda_I;\beta)$. Then $\lambda_I(x \cdot (y \cdot z)) \leq \beta$ and $\lambda_I(x) \leq \beta$, so β is a upper bound of $\{\lambda_I(x \cdot (y \cdot z)), \lambda_I(x)\}$. By (55), we have $\lambda_I(((z \cdot y) \cdot y) \cdot z) \leq \max\{\lambda_I(x \cdot (y \cdot z)), \lambda_I(x)\} \leq \beta$. Thus $((z \cdot y) \cdot y) \cdot z \in L(\lambda_I;\beta)$.

Let $x \in U(\lambda_F;\gamma)$. Then $\lambda_F(x) \geq \gamma$. By (38), we have $\lambda_F(0) \geq \lambda_F(x) \geq \gamma$. Thus $0 \in U(\lambda_F;\gamma)$. Next, let $x,y,z \in X$ be such that $x \cdot (y \cdot z) \in U(\lambda_F;\gamma)$ and $x \in U(\lambda_F;\gamma)$. Then $\lambda_F(x \cdot (y \cdot z)) \geq \gamma$ and $\lambda_F(y) \geq \gamma$, so γ is an lower bound of $\{\lambda_F(x \cdot (y \cdot z)), \lambda_F(x)\}$. By (56), we have $\lambda_F(((z \cdot y) \cdot y) \cdot z) \geq \min\{\lambda_F(x \cdot (y \cdot z)), \lambda_F(x)\} \geq \gamma$. Thus $((z \cdot y) \cdot y) \cdot z \in U(\lambda_F;\gamma)$.

Hence, $U(\lambda_T;\alpha), L(\lambda_I;\beta)$, and $U(\lambda_F;\gamma)$ are shift UP-filters of X.

Conversely, assume that for all $\alpha, \beta, \gamma \in [0,1]$, the sets $U(\lambda_T;\alpha), L(\lambda_I;\beta)$, and $U(\lambda_F;\gamma)$ are shift UP-filters of X if $U(\lambda_T;\alpha), L(\lambda_I;\beta)$, and $U(\lambda_F;\gamma)$ are nonempty.

Let $x \in X$. Then $\lambda_T(x) \in [0,1]$. Choose $\alpha = \lambda_T(x)$. Thus $\lambda_T(x) \geq \alpha$, so $x \in U(\lambda_T;\alpha) \neq \emptyset$. By assumption, we have $U(\lambda_T;\alpha)$ is a shift UP-filter of X and so $0 \in U(\lambda_T;\alpha)$. Thus

$\lambda_T(0) \geq \alpha = \lambda_T(x)$. Next, let $x, y, z \in X$. Then $\lambda_T(x \cdot (y \cdot z)), \lambda_T(x) \in [0,1]$. Choose $\alpha = \min\{\lambda_T(x \cdot (y \cdot z)), \lambda_T(x)\}$. Thus $\lambda_T(x \cdot (y \cdot z)) \geq \alpha$ and $\lambda_T(x) \geq \alpha$, so $x \cdot (y \cdot z), x \in U(\lambda_T; \alpha) \neq \emptyset$. By assumption, we have $U(\lambda_T; \alpha)$ is a shift UP-filter of X and so $((z \cdot y) \cdot y) \cdot z \in U(\lambda_T; \alpha)$. Thus $\lambda_T(((z \cdot y) \cdot y) \cdot z) \geq \alpha = \min\{\lambda_T(x \cdot (y \cdot z)), \lambda_T(x)\}$.

Let $x \in X$. Then $\lambda_I(x) \in [0,1]$. Choose $\beta = \lambda_I(x)$. Thus $\lambda_I(x) \leq \beta$, so $x \in L(\lambda_I; \beta) \neq \emptyset$. By assumption, we have $L(\lambda_I; \beta)$ is a shift UP-filter of X and so $0 \in L(\lambda_I; \beta)$. Thus $\lambda_I(0) \leq \beta = \lambda_I(x)$. Next, let $x, y, z \in X$. Then $\lambda_I(x \cdot (y \cdot z)), \lambda_I(x) \in [0,1]$. Choose $\beta = \max\{\lambda_I(x \cdot (y \cdot z)), \lambda_I(x)\}$. Thus $\lambda_I(x \cdot (y \cdot z)) \leq \beta$ and $\lambda_I(x) \leq \beta$, so $x \cdot (y \cdot z), x \in L(\lambda_I; \beta) \neq \emptyset$. By assumption, we have $L(\lambda_I; \beta)$ is a shift UP-filter of X and so $((z \cdot y) \cdot y) \cdot z \in L(\lambda_I; \beta)$. Thus $\lambda_I(((z \cdot y) \cdot y) \cdot z) \leq \beta = \max\{\lambda_I(x \cdot (y \cdot z)), \lambda_I(x)\}$.

Let $x \in X$. Then $\lambda_F(x) \in [0,1]$. Choose $\gamma = \lambda_F(x)$. Thus $\lambda_F(x) \geq \gamma$, so $x \in U(\lambda_F; \gamma) \neq \emptyset$. By assumption, we have $U(\lambda_F; \gamma)$ is a shift UP-filter of X and so $0 \in U(\lambda_F; \gamma)$. Thus $\lambda_F(0) \geq \gamma = \lambda_F(x)$. Next, let $x, y, z \in X$. Then $\lambda_F(x \cdot (y \cdot z)), \lambda_F(y) \in [0,1]$. Choose $\gamma = \min\{\lambda_F(x \cdot (y \cdot z)), \lambda_F(x)\}$. Thus $\lambda_F(x \cdot (y \cdot z)) \geq \gamma$ and $\lambda_F(x) \geq \gamma$, so $x \cdot (y \cdot z), x \in U(\lambda_F; \gamma) \neq \emptyset$. By assumption, we have $U(\lambda_F; \gamma)$ is a shift UP-filter of X and so $((z \cdot y) \cdot y) \cdot z \in U(\lambda_F; \gamma)$. Thus $\lambda_F(((z \cdot y) \cdot y) \cdot z) \geq \gamma = \min\{\lambda_F(x \cdot (y \cdot z)), \lambda_F(x)\}$.

Therefore, Λ is a neutrosophic shift UP-filter of X. □

Definition 4.5. [23] Let Λ be a NS in X. For $\alpha, \beta, \gamma \in [0,1]$, the sets

$$ULU_\Lambda(\alpha, \beta, \gamma) = \{x \in X \mid \lambda_T \geq \alpha, \lambda_I \leq \beta, \lambda_F \geq \gamma\},$$

$$LUL_\Lambda(\alpha, \beta, \gamma) = \{x \in X \mid \lambda_T \leq \alpha, \lambda_I \geq \beta, \lambda_F \leq \gamma\},$$

$$E_\Lambda(\alpha, \beta, \gamma) = \{x \in X \mid \lambda_T = \alpha, \lambda_I = \beta, \lambda_F = \gamma\}$$

are called a *ULU-(α, β, γ)-level subset*, a *LUL-(α, β, γ)-level subset*, and an *E-(α, β, γ)-level subset* of Λ, respectively.

The following corollary is straightforward by Theorems 4.2, 4.3, and 4.4.

Corollary 4.6. *A NS Λ in X is a neutrosophic implicative UP-filter (resp., neutrosophic comparative UP-filter, neutrosophic shift UP-filter) of X if and only if for all $\alpha, \beta, \gamma \in [0,1]$, $ULU_\Lambda(\alpha, \beta, \gamma)$ is a implicative UP-filter (resp., comparative UP-filter, shift UP-filter) of X where $ULU_\Lambda(\alpha, \beta, \gamma)$ is nonempty.*

5. **Conclusions**

In this paper, we have introduced the notions of neutrosophic implicative UP-filters, neutrosophic comparative UP-filters, and neutrosophic shift UP-filters of UP-algebras and investigated some of their important properties. Then, we get the diagram of generalization of NSs in UP-algebras as shown in Figure 1.

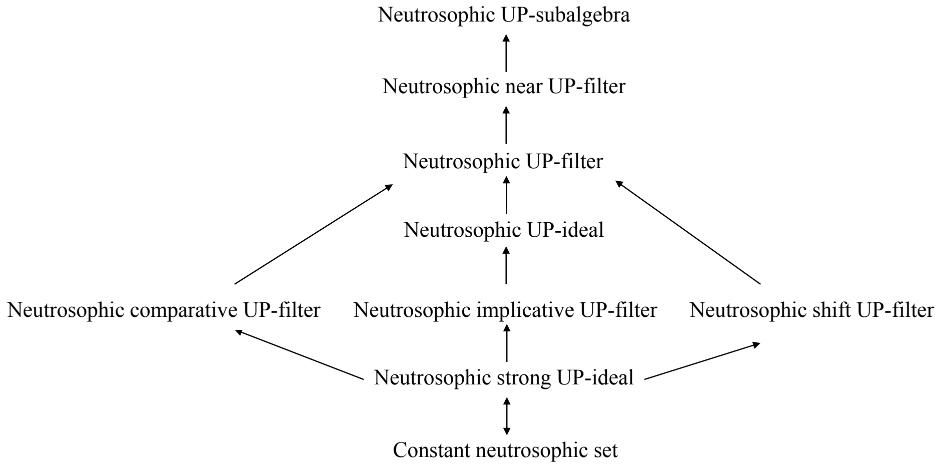

FIGURE 1. NSs in UP-algebras

In our future study, we will study the soft set theory/cubic set theory of neutrosophic implicative UP-filters, neutrosophic comparative UP-filters, and neutrosophic shift UP-filters of UP-algebras.

Acknowledgment

This work was supported by the revenue budget in 2021, School of Science, University of Phayao.

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Received: Aug 1, 2021. Accepted: Dec 2, 2021