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# 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

## 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:

$$(\forall x, y, z \in X)((y \cdot z) \cdot ((x \cdot y) \cdot (x \cdot z)) = 0), \quad (1)$$

$$(\forall x \in X)(0 \cdot x = x), \quad (2)$$

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

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

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:

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

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

$$(\forall x \in X)(x \leq x), \quad (6)$$

$$(\forall x, y, z \in X)(x \leq y, y \leq z \Rightarrow x \leq z), \quad (7)$$

$$(\forall x, y, z \in X)(x \leq y \Rightarrow z \cdot x \leq z \cdot y), \quad (8)$$

$$(\forall x, y, z \in X)(x \leq y \Rightarrow y \cdot z \leq x \cdot z), \quad (9)$$

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

$$(\forall x, y \in X)(y \cdot x \leq x \Leftrightarrow x = y \cdot x), \quad (11)$$

$$(\forall x, y \in X)(x \leq y \cdot y), \quad (12)$$

$$(\forall a, x, y, z \in X)(x \cdot (y \cdot z) \leq x \cdot ((a \cdot y) \cdot (a \cdot z))), \quad (13)$$

$$(\forall a, x, y, z \in X)((a \cdot x) \cdot (a \cdot y)) \cdot z \leq (x \cdot y) \cdot z, \quad (14)$$

$$(\forall x, y, z \in X)((x \cdot y) \cdot z \leq y \cdot z), \quad (15)$$

$$(\forall x, y, z \in X)(x \leq y \Rightarrow x \leq z \cdot y), \quad (16)$$

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

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

**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:

$$(\forall x, y \in S)(x \cdot y \in S), \quad (19)$$

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

$$(\forall x, y \in X)(y \in S \Rightarrow x \cdot y \in S). \quad (20)$$

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

$$\text{the constant } 0 \text{ of } X \text{ is in } S, \quad (21)$$

$$(\forall x, y \in X)(x \cdot y \in S, x \in S \Rightarrow y \in S), \quad (22)$$

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

$$(\forall x, y, z \in X)(x \cdot (y \cdot z) \in S, x \cdot y \in S \Rightarrow x \cdot z \in S), \quad (23)$$

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

$$(\forall x, y, z \in X)(x \cdot ((y \cdot z) \cdot y) \in S, x \in S \Rightarrow y \in S), \quad (24)$$

(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  $\lambda_T : X \rightarrow [0, 1]$  is a *truth membership function*,  $\lambda_I : X \rightarrow [0, 1]$  is an *indeterminate membership function*, and  $\lambda_F : X \rightarrow [0, 1]$  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  $\Lambda$  be a NS in a nonempty set  $X$ . The NS  $\bar{\Lambda} = (X, \bar{\lambda}_{T,I,F})$  in  $X$  defined by

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

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

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  $\Lambda$  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  $\Lambda$  in  $X$  is said to be *constant* if  $\Lambda$  is a constant function from  $X$  to  $[0, 1]^3$ . That is,  $\lambda_T, \lambda_I,$  and  $\lambda_F$  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  $\Lambda$  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  $\Lambda$  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,  $\Lambda$  is a neutrosophic implicative UP-filter of  $X$ .

**Definition 3.6.** A NS  $\Lambda$  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  $\Lambda$  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,  $\Lambda$  is a neutrosophic comparative UP-filter of  $X$ .

**Definition 3.8.** A NS  $\Lambda$  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  $\Lambda$  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,  $\Lambda$  is a neutrosophic shift UP-filter of  $X$ .

**Theorem 3.10.** [23] A NS  $\Lambda$  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  $\Lambda$  is a neutrosophic implicative UP-filter of  $X$ . Then  $\Lambda$  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,  $\Lambda$  is a neutrosophic UP-ideal of  $X$ .  $\square$

**Example 3.12.** From the Cayley table in Example 3.7, we define a NS  $\Lambda$  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  $\Lambda$  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  $\Lambda$  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  $\Lambda$  is a neutrosophic comparative UP-filter of  $X$ . Then  $\Lambda$  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,  $\Lambda$  is a neutrosophic UP-filter of  $X$ .  $\square$

**Example 3.14.** From Example 3.12, we have  $\Lambda$  is a neutrosophic UP-ideal of  $X$  and so  $\Lambda$  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  $\Lambda$  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  $\Lambda$  is a neutrosophic shift UP-filter of  $X$ . Then  $\Lambda$  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,  $\Lambda$  is a neutrosophic UP-filter of  $X$ .  $\square$

**Example 3.16.** From Example 3.12, we have  $\Lambda$  is a neutrosophic UP-ideal of  $X$  and so  $\Lambda$  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  $\Lambda$  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  $\Lambda$  is a neutrosophic strong UP-ideal of  $X$ . Then  $\Lambda$  satisfies the conditions (36), (37), and (38). By Theorem 3.10, we have  $\Lambda$  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,  $\Lambda$  is a neutrosophic implicative UP-filter of  $X$ .  $\square$

**Example 3.18.** From Example 3.5, we have  $\Lambda$  is a neutrosophic implicative UP-filter of  $X$ . Since  $\Lambda$  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  $\Lambda$  is a neutrosophic strong UP-ideal of  $X$ . Then  $\Lambda$  satisfies the conditions (36), (37), and (38). By Theorem 3.10, we have  $\Lambda$  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,  $\Lambda$  is a neutrosophic comparative UP-filter of  $X$ .  $\square$

**Example 3.20.** From Example 3.7, we have  $\Lambda$  is a neutrosophic comparative UP-filter of  $X$ . Since  $\Lambda$  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  $\Lambda$  is a neutrosophic strong UP-ideal of  $X$ . Then  $\Lambda$  satisfies the conditions (36), (37), and (38). By Theorem 3.10, we have  $\Lambda$  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,  $\Lambda$  is a neutrosophic shift UP-filter of  $X$ .  $\square$

**Example 3.22.** From Example 3.9, we have  $\Lambda$  is a neutrosophic shift UP-filter of  $X$ . Since  $\Lambda$  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  $\Lambda$  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  $\Lambda$  is not a neutrosophic shift UP-filter of  $X$ .

**Example 3.24.** From Example 3.9, we have  $\Lambda$  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  $\Lambda$  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  $\Lambda$  is a neutrosophic UP-ideal of  $X$  satisfying the following condition:*

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

*then  $\Lambda$  is a neutrosophic implicative UP-filter of  $X$ .*

*Proof.* Assume that  $\Lambda$  is a neutrosophic UP-ideal of  $X$  satisfying the condition (57). Then  $\Lambda$  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,  $\Lambda$  is a neutrosophic implicative UP-filter of  $X$ .  $\square$

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

$$(\forall x, y, z \in X) \left( \begin{array}{l} \lambda_T(x) \geq \lambda_T(x \cdot y) \Rightarrow \lambda_T(x \cdot y) \geq \lambda_T(x \cdot ((y \cdot z) \cdot y)) \\ \lambda_I(x) \leq \lambda_I(x \cdot y) \Rightarrow \lambda_I(x \cdot y) \leq \lambda_I(x \cdot ((y \cdot z) \cdot y)) \\ \lambda_F(x) \geq \lambda_F(x \cdot y) \Rightarrow \lambda_F(x \cdot y) \geq \lambda_F(x \cdot ((y \cdot z) \cdot y)) \end{array} \right), \quad (58)$$

*then  $\Lambda$  is a neutrosophic comparative UP-filter of  $X$ .*

*Proof.* Assume that  $\Lambda$  is a neutrosophic UP-filter of  $X$  satisfying the condition (58). Then  $\Lambda$  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,  $\Lambda$  is a neutrosophic comparative UP-filter of  $X$ .  $\square$

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

$$(\forall x, y, z \in X) \left( \begin{array}{l} \lambda_T(x) \geq \lambda_T(x \cdot (((z \cdot y) \cdot y) \cdot z)) \\ \Rightarrow \lambda_T(x \cdot (((z \cdot y) \cdot y) \cdot z)) \geq \lambda_T(x \cdot (y \cdot z)) \\ \lambda_I(x) \leq \lambda_I(x \cdot (((z \cdot y) \cdot y) \cdot z)) \\ \Rightarrow \lambda_I(x \cdot (((z \cdot y) \cdot y) \cdot z)) \leq \lambda_I(x \cdot (y \cdot z)) \\ \lambda_F(x) \geq \lambda_F(x \cdot (((z \cdot y) \cdot y) \cdot z)) \\ \Rightarrow \lambda_F(x \cdot (((z \cdot y) \cdot y) \cdot z)) \geq \lambda_F(x \cdot (y \cdot z)) \end{array} \right), \quad (59)$$

*then  $\Lambda$  is a neutrosophic shift UP-filter of  $X$ .*

*Proof.* Assume that  $\Lambda$  is a neutrosophic UP-filter of  $X$  satisfying the condition (59). Then  $\Lambda$  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,  $\Lambda$  is a neutrosophic shift UP-filter of  $X$ .  $\square$

**Theorem 3.28.** *If  $\Lambda$  is a NS in  $X$  satisfying the following condition:*

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

*then  $\Lambda$  is a neutrosophic implicative UP-filter of  $X$ .*

*Proof.* Assume that  $\Lambda$  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

$$\begin{aligned} \lambda_T(0) &= \lambda_T(0 \cdot 0) \geq \min\{\lambda_T(x), \lambda_T(0 \cdot x)\} \\ &= \min\{\lambda_T(x), \lambda_T(x)\} = \lambda_T(x), \end{aligned} \quad \text{by (2)}$$

$$\begin{aligned} \lambda_I(0) &= \lambda_I(0 \cdot 0) \leq \max\{\lambda_I(x), \lambda_I(0 \cdot x)\} \\ &= \max\{\lambda_I(x), \lambda_I(x)\} = \lambda_I(x), \end{aligned} \quad \text{by (2)}$$

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

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

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

Hence,  $\Lambda$  is a neutrosophic implicative UP-filter of  $X$ .  $\square$

**Theorem 3.29.** *If  $\Lambda$  is a NS in  $X$  satisfying the following condition:*

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

*then  $\Lambda$  is a neutrosophic comparative UP-filter of  $X$ .*

*Proof.* Assume that  $\Lambda$  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

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

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

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

Hence,  $\Lambda$  is a neutrosophic comparative UP-filter of  $X$ .  $\square$

**Theorem 3.30.** *If  $\Lambda$  is a NS in  $X$  satisfying the following condition:*

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

then  $\Lambda$  is a neutrosophic shift UP-filter of  $X$ .

*Proof.* Assume that  $\Lambda$  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

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

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 (62) that

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

Hence,  $\Lambda$  is a neutrosophic shift UP-filter of  $X$ .  $\square$

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  $\Lambda^G_{[\alpha^-, \beta^+, \gamma^-]} = (X, \lambda^G_{T[\alpha^+]}, \lambda^G_{I[\beta^+]}, \lambda^G_{F[\gamma^-]})$  in  $X$  where  $\lambda^G_{T[\alpha^+]}, \lambda^G_{I[\beta^+]}$ , and  $\lambda^G_{F[\gamma^-]}$  are functions on  $X$  which are given as follows:

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

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

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

**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  $\lambda_T^G[\alpha^-](x \cdot (y \cdot z)) = \alpha^+ = \lambda_T^G[\alpha^-](x \cdot y)$ . Thus, by (48), we have

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

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

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

$$\max\{\lambda_I^G[\beta^-](x \cdot (y \cdot z)), \lambda_I^G[\beta^-](x \cdot y)\} = \beta^- \leq \beta^- = \lambda_I^G[\beta^-](x \cdot z),$$

$$\min\{\lambda_F^G[\gamma^-](x \cdot (y \cdot z)), \lambda_F^G[\gamma^-](x \cdot y)\} = \gamma^+ \geq \gamma^+ = \lambda_F^G[\gamma^-](x \cdot z).$$

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

$$\lambda_T^G[\alpha^-](x \cdot (y \cdot z)) = \alpha^- \text{ or } \lambda_T^G[\alpha^-](x \cdot y) = \alpha^-,$$

$$\lambda_I^G[\beta^-](x \cdot (y \cdot z)) = \beta^+ \text{ or } \lambda_I^G[\beta^-](x \cdot y) = \beta^+,$$

$$\lambda_F^G[\gamma^-](x \cdot (y \cdot z)) = \gamma^- \text{ or } \lambda_F^G[\gamma^-](x \cdot y) = \gamma^-.$$



Thus

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

Therefore,

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

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

**Theorem 3.34.** *A NS  $\Lambda^G[\alpha^-, \beta^+, \gamma^-]$  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  $\Lambda^G[\alpha^-, \beta^+, \gamma^-]$  is a neutrosophic comparative UP-filter of  $X$ . Since  $\Lambda^G[\alpha^-, \beta^+, \gamma^-]$  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  $\lambda_T^G[\alpha^-](x \cdot ((y \cdot z) \cdot y)) = \alpha^+ = \lambda_T^G[\alpha^-](x)$ . Thus, by (51), we have

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

and so  $\lambda_T^G[\alpha^-](y) = \alpha^+$ . 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  $\Lambda^G[\alpha^-, \beta^+, \gamma^-]$  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

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

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

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

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

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

Thus

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

Therefore,

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

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

**Theorem 3.35.** A NS  $\Lambda^G[\alpha^-, \beta^+, \gamma^-]$  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  $\Lambda^G[\alpha^-, \beta^+, \gamma^-]$  is a neutrosophic shift UP-filter of  $X$ . Since  $\Lambda^G[\alpha^-, \beta^+, \gamma^-]$  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  $\lambda_T^G[\alpha^-](x \cdot (y \cdot z)) = \alpha^+ = \lambda_T^G[\alpha^-](x)$ . Thus, by (54), we have

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

and so  $\lambda_T^G[\alpha^-](x \cdot ((z \cdot y) \cdot y) \cdot z) = \alpha^+$ . 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  $\Lambda^G[\alpha^-, \beta^+, \gamma^-]$  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

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

Thus

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

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

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

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

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

Thus

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

Therefore,

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

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

#### 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  $\Lambda$  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  $\Lambda$  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  $\lambda_I(x \cdot y) \leq \beta$ . 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  $\lambda_I(x \cdot (y \cdot z)), \lambda_I(x \cdot y) \in [0, 1]$ . Choose  $\beta = \max\{\lambda_I(x \cdot (y \cdot z)), \lambda_I(x \cdot y)\}$ . Thus  $\lambda_I(x \cdot (y \cdot z)) \leq \beta$  and  $\lambda_I(x \cdot y) \leq \beta$ , so  $x \cdot (y \cdot z), x \cdot y \in L(\lambda_I; \beta)$ .

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$L(\lambda_T; \beta) \neq \emptyset$ . 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,  $\Lambda$  is a neutrosophic implicative UP-filter of  $X$ .  $\square$

**Theorem 4.3.** *A NS  $\Lambda$  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  $\Lambda$  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  $\alpha$  is a 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  $\beta$  is an 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  $\gamma$  is a 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,  $\Lambda$  is a neutrosophic comparative UP-filter of  $X$ .  $\square$

**Theorem 4.4.** *A NS  $\Lambda$  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  $\Lambda$  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  $\alpha$  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  $\beta$  is an 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  $\lambda_F(x) \geq \gamma$ , so  $\gamma$  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  $\lambda_F(x \cdot (y \cdot z)), \lambda_F(x) \in [0, 1]$ . 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,  $\Lambda$  is a neutrosophic shift UP-filter of  $X$ .  $\square$

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

$$\begin{aligned}
 ULU_\Lambda(\alpha, \beta, \gamma) &= \{x \in X \mid \lambda_T \geq \alpha, \lambda_I \leq \beta, \lambda_F \geq \gamma\}, \\
 LUL_\Lambda(\alpha, \beta, \gamma) &= \{x \in X \mid \lambda_T \leq \alpha, \lambda_I \geq \beta, \lambda_F \leq \gamma\}, \\
 E_\Lambda(\alpha, \beta, \gamma) &= \{x \in X \mid \lambda_T = \alpha, \lambda_I = \beta, \lambda_F = \gamma\}
 \end{aligned}$$

are called a  $ULU$ - $(\alpha, \beta, \gamma)$ -level subset, a  $LUL$ - $(\alpha, \beta, \gamma)$ -level subset, and an  $E$ - $(\alpha, \beta, \gamma)$ -level subset of  $\Lambda$ , respectively.

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

**Corollary 4.6.** A NS  $\Lambda$  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.

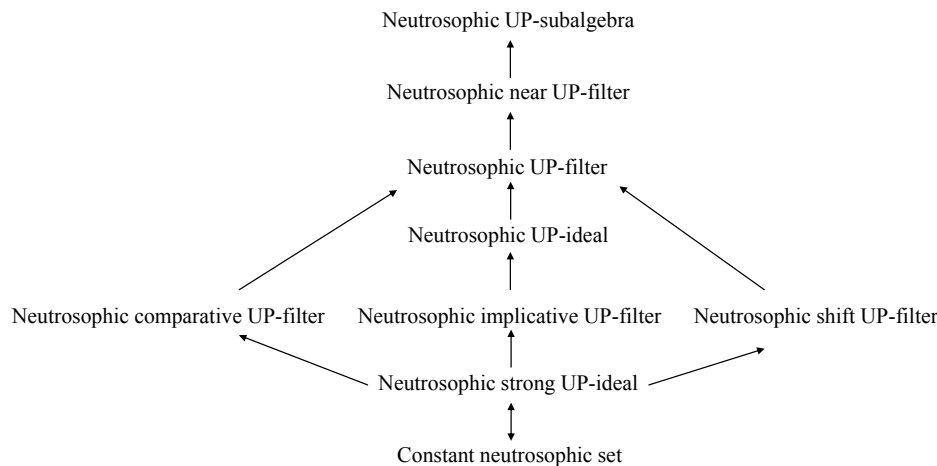


FIGURE 1. NSs in UP-algebras

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.

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