Bol. Soc. Paran. Mat.
©SPM – E-ISSN-2175-1188
SPM: www.spm.uem.br/bspm

(3s.) **v. 2026 (44) 11** : 1–10.
ISSN-0037-8712
doi:10.5269/bspm.82921

On Pythagorean Neutrosophic Implicative UP-Filters

M. Vasu and T. Vigneshwaran*

ABSTRACT: In this paper, we introduce the notion of Pythagorean neutrosophic implicative UP-filters in UP-algebras and examine their fundamental properties. We further explore the relationship between Pythagorean neutrosophic implicative UP-filters and Pythagorean neutrosophic UP-filters. In addition, we establish the concepts of the complement and the level subset associated with a Pythagorean neutrosophic implicative UP-filter.

Keywords: UP-algebra, UP-filter, implicative UP-filter, Pythagorean neutrosophic UP-filter, Pythagorean neutrosophic implicative UP-filter.

Contents

1. Introduction

Algebraic structures play a crucial role in mathematics, providing a foundation for diverse areas of research and applications. Over the years, several algebraic systems such as BCK-algebras [13], BCI-algebras [10], BCH-algebras [9], KU-algebras [18], and UP-algebras [11] have been extensively studied due to their strong connections with logic and their potential applications in theoretical computer science, artificial intelligence, and information systems. In particular, the introduction of UP-algebras by Iampan in 2017 [11] as a generalization of KU-algebras marked a significant development in the field. This new class of algebras quickly gained attention, and many researchers began exploring its properties and possible extensions.

The framework of UP-algebras has since been enriched by incorporating various fuzzy and neutrosophic set theories, reflecting the natural interaction between algebra and uncertainty modeling. Researchers have extended the study of UP-algebras into multiple directions, including their association with fuzzy sets, intuitionistic fuzzy sets, interval-valued fuzzy sets, picture fuzzy sets, bipolar fuzzy sets, and neutrosophic sets. Such extensions have made UP-algebras a versatile platform for addressing problems involving vagueness and indeterminacy. For instance, Somjanta et al. [22] introduced the concept of UP-filters and investigated the role of fuzzy set theory in characterizing UP-subalgebras, UP-ideals, and UP-filters. Later, Jun and Iampan [14] expanded this idea by proposing comparative and allied UP-filters, demonstrating that a comparative UP-filter can be considered as an implicative UP-filter, thereby deepening the structural understanding of UP-algebras.

The theory of fuzzy sets, initiated by Zadeh in 1965 [25], laid the foundation for addressing uncertainties using mathematical tools and has inspired a vast body of subsequent work. Building on this foundation, Atanassov introduced the notion of intuitionistic fuzzy sets in 1986 [5], which further generalized fuzzy sets by incorporating the degree of non-membership alongside membership. The integration of intuitionistic fuzzy sets into UP-algebras was first undertaken by Kesorn et al. in 2015 [16], and further developments were made by Thongngam and Iampan in 2019 [24], who studied intuitionistic fuzzy UP-filters and intuitionistic fuzzy near UP-filters. Beyond UP-algebras, Abdullah and Shadhan [1] extended

* Corresponding author.
2020 *Mathematics Subject Classification:* 08A72, 08A30.
Submitted March 23, 2026. Published June 03, 2026.

the application of intuitionistic fuzzy sets to Q-algebras in 2020, highlighting the broad relevance of these fuzzy concepts. More recently, Songsaeng et al. [23] advanced the theory by investigating neutrosophic implicative UP-filters in 2021, bridging neutrosophic logic with algebraic structures.

Motivated by these developments, we aim to further extend the study of UP-algebras by introducing the concept of Pythagorean neutrosophic implicative UP-filters ($PNIUPF$'s). This work supplements the framework of UP-algebras with the Pythagorean neutrosophic set approach, which allows for a more flexible representation of truth, indeterminacy, and falsity while satisfying the Pythagorean condition. In this paper, we present the formal definition of $PNIUPF$'s, establish their fundamental properties, and illustrate them with examples in the context of UP-algebras. Moreover, we investigate the relationship between $PNIUPF$'s and their associated level subsets and complements, highlighting their structural significance. Finally, we provide concluding remarks and suggest potential directions for future research, thereby paving the way for further exploration of Pythagorean neutrosophic structures within algebraic systems.

2. Preliminaries

Definition 2.1 [11] An algebra $\tilde{U} = (\tilde{U}, *, 0)$ of type $(2, 0)$ is called a UP-algebra, where $\tilde{U}$ is a nonempty set, $*$ is a binary operation on $\tilde{U}$, and 0 is a fixed element of $\tilde{U}$ if it satisfies the following axioms:

$$(y * z) * ((x * y) * (x * z)) = 0, \quad \forall x, y, z \in \tilde{U}$$
$$0 * x = x, \quad \forall x \in \tilde{U}$$
$$x * 0 = 0, \quad \forall x \in \tilde{U}$$
$$x * y = 0, \; y * x = 0 \Rightarrow x = y, \quad \forall x, y \in \tilde{U}.$$

From [11], we know that the concept of UP-algebras is a generalization of KU-algebras. For ease of study, we write $\tilde{U}$ instead of a UP-algebra $(\tilde{U}, *, 0)$.

Definition 2.2 [15] A non empty subset $\tilde{S}$ of $\tilde{U}$ is called

(i) a UP-subalgebra ($UPSubAlg$) of $\tilde{U}$ if $x * y \in \tilde{S}$, $\forall x, y \in \tilde{S}$,

(ii) a UP-ideal (UPI) of $\tilde{U}$ if $x * (y * z) \in \tilde{S}, \; y \in \tilde{S} \Rightarrow x * z \in \tilde{S}$, $0 \in \tilde{S}$, $\forall \; x, y, z \in \tilde{U}$,

(iii) a UP-filter (UPF) of $\tilde{U}$ if $0 \in \tilde{S}$ and $x \in \tilde{S}$, $x * y \in \tilde{S} \Rightarrow y \in \tilde{S}$, $\forall x, y, z \in \tilde{S}$,

(iv) an implicative UP-filter ($IUPF$) of $\tilde{U}$ if $0 \in \tilde{S}$ and $x * (y * z) \in \tilde{S}$, $x * y \in \tilde{S} \Rightarrow x * z \in \tilde{S}$, $\forall x, y, z \in \tilde{U}$.

From [15], Jun and Iampan show that every $IUPF$ is a UPF, but the converse is not true in general.

Theorem 2.1 *[6] Let $\mathcal{R}$ be a nonempty family of $UPFs$ (resp. $IUPFs$) of $\tilde{U}$. Then $\cap\mathcal{R}$ is a UPF (resp. $IUPF$) of $\tilde{U}$.*

Definition 2.3 [17] A FS ω in $\tilde{M}$ is called

(i) a fuzzy UP-subalgebra ($FUPSubAlg$) of $\tilde{M}$ if $\omega(\tilde{p} * \tilde{q}) \geq min\{\omega(\tilde{p}), \omega(\tilde{q})\}$, for all $\tilde{p}, \tilde{q} \in \tilde{M}$,

(ii) a fuzzy UP-ideal ($FUPI$) of $\tilde{M}$ if $\omega(0) \geq \omega(\tilde{p})$, for all $\tilde{p} \in \tilde{M}$; $\omega(\tilde{p} * \tilde{r}) \geq min\{\omega(\tilde{p} * (\tilde{q} * \tilde{r})), \omega(\tilde{q})\}$, for all $\tilde{p}, \tilde{q}, \tilde{r} \in \tilde{M}$,

(iii) a fuzzy UP-filte ($FUPF$) of $\tilde{M}$ if $\omega(0) \geq \omega(\tilde{p})$, for all $\tilde{p} \in \tilde{M}$ and $\omega(\tilde{q}) \geq min\{\omega(\tilde{p}), \omega(\tilde{p} * \tilde{q})\}$, for all $\tilde{p}, \tilde{q} \in \tilde{M}$,

(iv) a fuzzy implicative UP-filter ($FIUPF$) of $\tilde{M}$ if $\omega(0) \geq \omega(\tilde{p})$ for all $\tilde{p} \in \tilde{M}$ and for all $\tilde{p}, \tilde{q}, \tilde{r} \in \tilde{M}$ $\omega(\tilde{p} * \tilde{r}) \geq min\{\omega(\tilde{p} * (\tilde{q} * \tilde{r})), \omega(\tilde{p} * \tilde{q})\}$.

An intuitionistic fuzzy set (IFS) in a nonempty set $\tilde{S}$ is an object having the form $F = \{(\tilde{p}, \omega_F(\tilde{p}), \delta_F(\tilde{p})) \mid \tilde{p} \in \tilde{S}\}$, where $\omega_F : \tilde{S} \to [0,1]$ and $\delta_F : \tilde{S} \to [0,1]$ denote the degree of membership and degree of nonmembership, respectively, and $0 \leq \omega_F(\tilde{p}) + \delta_F(\tilde{p}) \leq 1$, for all $\tilde{p} \in \tilde{S}$. We shall use the symbol $F = (\omega_F, \delta_F)$ for the IFS $F = \{(\tilde{p}, \omega_F(\tilde{p}), \delta_F(\tilde{p})) \mid \tilde{p} \in \tilde{S}\}$ for the sake of notational simplicity.

Kesorn et al. [16] and Thongngam and Iampan [24] introduced the concepts of intuitionistic fuzzy UP-subalgebras, intuitionistic fuzzy UP-ideals, and intuitionistic fuzzy UP-filters of UP-algebras as follows.

Definition 2.4 [16] An IFS $F = (\omega_F, \delta_F)$ in $\tilde{M}$ is called an intuitionistic fuzzy UP-subalgebra ($IFUPSubAlg$) of $\tilde{M}$ if $\omega_F(\tilde{p} * \tilde{q}) \geq \min\{\omega_F(\tilde{p}), \omega_F(\tilde{q})\}$, for all $\tilde{p}, \tilde{q} \in \tilde{M}$,
$\delta_F(\tilde{p} * \tilde{q}) \leq \max\{\delta_F(\tilde{p}), \delta_F(\tilde{q})\}$, for all $\tilde{p}, \tilde{q} \in \tilde{M}$.

Definition 2.5 [16] An IFS $F = (\omega_F, \delta_F)$ in $tildeM$ is called an intuitionistic fuzzy UP-ideal ($IFUPI$) of $\tilde{M}$ if $\omega_F(0) \geq \omega_F(\tilde{p})$, for all $\tilde{p} \in \tilde{M}$,
$\delta_F(0) \leq \delta_F(\tilde{p})$, for all $\tilde{p} \in \tilde{M}$,
$\omega_F(\tilde{p} * \tilde{r}) \geq \min\{\omega_F(\tilde{p} * (\tilde{q} * \tilde{r})), \omega_F(\tilde{q})\}$, for all $\tilde{p}, \tilde{q}, \tilde{r} \in \tilde{M}$
$\delta_F(\tilde{p} * \tilde{r}) \leq \max\{\delta_F(\tilde{p} * (\tilde{q} * \tilde{r})), \delta_F(\tilde{q})\}$, for all $\tilde{p}, \tilde{q}, \tilde{r} \in \tilde{M}$.

Definition 2.6 [24] An IFS $F = (\omega_F, \delta_F)$ in $\tilde{M}$ is called an intuitionistic fuzzy UP-filter ($IFUPF$) of $\tilde{M}$ if $\omega_F(0) \geq \omega_F(\tilde{p})$, for all $\tilde{p} \in \tilde{M}$,
$\delta_F(0) \leq \delta_F(\tilde{p})$, for all $\tilde{p} \in \tilde{M}$,
$\omega_F(\tilde{q}) \geq min\{\omega_F(\tilde{p} * \tilde{q}), \omega_F(\tilde{p})\}$, for all $\tilde{p}, \tilde{q} \in \tilde{M}$,
$\delta_F(\tilde{q}) \leq max\{\delta_F(\tilde{p} * \tilde{q}), \delta_F(\tilde{p})\}$, for all $\tilde{p}, \tilde{q} \in \tilde{M}$.

Definition 2.7 [19] Let X be a non-empty set (Universe) A Pythagorean neutrosophic set (briefly, PNS) T and F as dependent neutrosophic components A on X is an object of the form $\mathcal{P} = \{\langle x, \mu_{\mathcal{P}}(x), \nu_{\mathcal{P}}(x), \lambda_{\mathcal{P}}(x)\rangle | x \in X\}$,
where $\mu_{\mathcal{P}}(x)$, $\nu_{\mathcal{P}}(x)$, $\lambda_{\mathcal{P}}(x)$ are the truth, indeterminacy and false respectively such that $\mu, \nu, \lambda \in [0,1]$. Here when μ and λ are dependent components, then for all x in X; (i) $\mu + \lambda \leq 1$, (ii) $0 \leq \mu^2 + \lambda^2 \leq 1$, (iii) $0 \leq \mu^2 + \nu^2 + \lambda^2 \leq 2$.

We define these basic operations on PNS which can be described as follows: Let X be a nonempty set (universe). A Pythagorean Neutrosophic set μ and λ as dependent neutrosophic components $\mathcal{P}$ and $\mathcal{Q}$ of the form $\mathcal{P} = \{\langle x, \mu_{\mathcal{P}}(x), \nu_{\mathcal{P}}(x), \lambda_{\mathcal{P}}(x)\rangle | x \in X\}$ and $\mathcal{Q} = \{\langle x, \mu_{\mathcal{Q}}(x), \nu_{\mathcal{Q}}(x), \lambda_{\mathcal{Q}}(x)\rangle | x \in X\}$. The complement of $\mathcal{P}$ is $\mathcal{P}^c = \{\langle x, \lambda_{\mathcal{P}}(x), 1 - \nu_{\mathcal{P}}(x), \mu_{\mathcal{P}}(x)\rangle | x \in X\}$. The union and intersection of $\mathcal{P}$ and $\mathcal{Q}$ are

(i) $\mathcal{P} \cup \mathcal{Q} = \{max(\mu_{\mathcal{P}}, \mu_{\mathcal{Q}}), min(\nu_{\mathcal{P}}, \nu_{\mathcal{Q}}), min(\lambda_{\mathcal{P}}, \lambda_{\mathcal{Q}})\}$;

(ii) $\mathcal{P} \cap \mathcal{Q} = \{min(\mu_{\mathcal{P}}, \mu_{\mathcal{Q}}), max(\nu_{\mathcal{P}}, \nu_{\mathcal{Q}}), max(\lambda_{\mathcal{P}}, \lambda_{\mathcal{Q}})\}$.

3. Pythagorean Neutrosophic Implicative UP-Filters

In this section, we introduce the concept of $PNIUPF$'s, and we investigate properties of $PNIUPF$'s in UP-algebras.

Definition 3.1 An PNS $A = \{\langle x, \mu_A(x), \nu_A(x), \lambda_A(x) | x \in \tilde{U}\rangle\}$ in $\tilde{U}$ is called a $PNUP$-subalgebra ($PNUPSubAlg$) of $\tilde{U}$ if

$$\mu_A(x * y) \geq \min\{\mu_A(x), \mu_A(y)\}, \quad \forall x, y \in \tilde{U},$$
$$\nu_A(x * y) \leq \max\{\nu_A(x), \nu_A(y)\}, \quad \forall x, y \in \tilde{U},$$
$$\lambda_A(x * y) \leq \max\{\lambda_A(x), \lambda_A(y)\}, \quad \forall x, y \in \tilde{U}.$$

Definition 3.2 An PNS $A = \{\langle x, \mu_A(x), \nu_A(x), \lambda_A(x) | x \in \tilde{U}\rangle\}$ in $\tilde{U}$ is called a $PNUP$-ideal ($PNUPI$) of $\tilde{U}$ if

$$\begin{aligned}
&\mu_A(0) \geq \mu_A(x),\ \nu_A(0) \leq \nu_A(x),\ \lambda_A(0) \leq \lambda_A(x), \quad \forall x \in \tilde{U},\\
&\mu_A(x * y) \geq \min\{\mu_A(x * (y * z)), \mu_A(y)\},\\
&\nu_A(x * y) \leq \max\{\nu_A(x * (y * z)), \nu_A(y)\},\\
&\lambda_A(x * y) \leq \max\{\lambda_A(x * (y * z)), \lambda_A(y)\}, \quad \forall x, y, z \in \tilde{U}.
\end{aligned}$$

Definition 3.3 An PNS $A = \{\langle x, \mu_A(x), \nu_A(x), \lambda_A(x) | x \in X\rangle\}$ in $\tilde{U}$ is called a $PNUP$-filter of $\tilde{U}$ if

$$\begin{aligned}
&\mu_A(0) \geq \mu_A(x), \quad \nu_A(0) \leq \nu_A(x), \quad \lambda_A(0) \leq \lambda_A(x), \quad \forall x \in X,\\
&\mu_A(y) \geq \min\{\mu_A(x * y), \mu_A(x)\}, \quad \forall x, y \in X,\\
&\nu_A(y) \leq \max\{\nu_A(x * y), \nu_A(x)\},\\
&\lambda_A(y) \leq \max\{\lambda_A(x * y), \lambda_A(x)\}.
\end{aligned}$$

Definition 3.4 A PNS $A = \{\langle x, \mu_A(x), \nu_A(x), \lambda_A(x) | x \in \tilde{U}\rangle\}$ in $\tilde{U}$ is called a PN implicative UP-filter ($PNIUPF$) of $\tilde{U}$ if

$$\begin{aligned}
&\mu_A(0) \geq \mu_A(x), \quad \nu_A(0) \leq \nu_A(x), \quad \lambda_A(0) \leq \lambda_A(x), \quad \forall x \in X,\\
&\mu_A(x * z) \geq \min\{\mu_A(x * (y * z)), \mu_A(x * y)\}, \quad \forall x, y, z \in X,\\
&\nu_A(x * z) \leq \max\{\nu_A(x * (y * z)), \nu_A(x * y)\},\\
&\lambda_A(x * z) \leq \max\{\lambda_A(x * (y * z)), \lambda_A(x * y)\}.
\end{aligned}$$

Example 3.1 *Consider a UP-algebra $X = (X, *, 0)$ where $X = \{0, a, b, c, d\}$ is defined in the following table*

$*$	0	a	b	c	d
0	0	a	b	c	d
a	0	0	0	0	d
b	0	a	0	0	d
c	0	a	b	0	d
d	0	a	b	c	0

and a PNS on X is defined as

X	0	a	b	c	d
μ	0.5	0.4	0.4	0.4	0.3
ν	0.5	0.7	0.7	0.7	0.9
λ	0.4	0.5	0.5	0.5	0.8

Now, we can verify that PNS of X is a $PNIUPF$ of X.

Theorem 3.1 *Every PN implicative UP-filter of X is PN UP-filter.*

Proof: Let $A = \{\langle x, \mu_A(x), \nu_A(x), \lambda_A(x) | x \in X\rangle\}$ be an PN implicative UP-filter of $\tilde{U}$. Then for all $x, y \in X$, $\mu_A(0) \geq \mu_A(x)$, $\nu_A(0) \leq \nu_A(x)$, $\lambda_A(0) \leq \lambda_A(x)$,

$$\begin{aligned}
\mu_A(y) = \mu_A(0 * y) &\geq \min\{\mu_A(0 * (x * y)), \mu_A(0 * x)\},\\
&= \min\{\mu_A(x * y), \mu_A(x)\},\\
\nu_A(y) = \nu_A(0 * y) &\leq \max\{\nu_A(0 * (x * y)), \nu_A(0 * x)\},\\
&= \max\{\nu_A(x * y), \nu_A(x)\},\\
\lambda_A(y) = \lambda_A(0 * y) &\leq \max\{\lambda_A(0 * (x * y)), \lambda_A(0 * x)\},\\
&= \max\{\lambda_A(x * y), \lambda_A(x)\}.
\end{aligned}$$

Hence $A = \{\langle x, \mu_A(x), \nu_A(x), \lambda_A(x)\rangle | x \in X\}$ is a $PNUP$-filter of X. □

Example 3.2 *Consider a UP-algebra $X = (X, *, 0)$ where $X = \{0, a, b, c, d\}$ is defined in the following table*

$*$	0	a	b	c	d
0	0	a	b	c	d
a	0	0	b	c	d
b	0	0	0	c	c
c	0	a	b	0	c
d	0	a	b	0	0

and a PNS on X is defined as

X	0	a	b	c	d
μ	0.8	0.7	0.5	0.4	0.4
ν	0.1	0.3	0.5	0.6	0.8
λ	0	0.2	0.3	0.5	0.5

is $PNUPF$ of X, but not $PNIUPF$ of X. Because, $\mu(c * d) = \mu(c) = 0.4 \ngeq 0.8 = min\{\mu(0), \mu(0)\} = min\{\mu(c * (c * d)), \mu(c * c)\}$.

Theorem 3.2 *A PNS $A = \{\langle x, \mu_A(x), \nu_A(x), \lambda_A(x)\rangle | x \in X\}$ in X is constant then A is a PN implicative UP-filter of X.*

Proof: Suppose that $A = \{\langle x, \mu_A(x), \nu_A(x), \lambda_A(x) | x \in X\rangle\}$ is a constant PNS in X. Then there exist elements $l, m, n \in [0, 1]$ such that $\mu_A(x) = l$, $\nu_A(x) = m$ and $\lambda_A(x) = n \quad \forall x \in X$. Thus $\mu_A(0) = l = \mu_A(x)$, $\nu_A(0) = m = \nu_A(x)$, $\lambda_A(0) = n = \lambda_A(x)$ for all $x \in X$. For all $x, y, z \in \tilde{U}$, $\mu_A(x * z) = l = \min\{l, l\} = \min\{\mu_A(x * (y * z)), \mu_A(x * y)\}$,

$\nu_A(x * z) = m = \max\{m, m\} = \max\{\nu_A(x * (y * z)), \nu_A(x * y)\}$

and $\lambda_A(x * z) = n = \max\{n, n\} = \max\{\lambda_A(x * (y * z)), \lambda_A(x * y)\}$. Hence $A = \{\langle x, \mu_A(x), \nu_A(x), \lambda_A(x) | x \in X\rangle\}$ is a PN implicative UP-filter of X. □

Theorem 3.3 *If a PNS $A = \{\langle x, \mu_A(x), \nu_A(x), \lambda_A(x)\rangle | x \in X\}$ is a PN implicative UP-filter of X iff the fuzzy sets μ_A, ν_A^c and λ_A^c are fuzzy implicative UP-filters of X.*

Proof: Suppose that a PNS $A = \{\langle x, \mu_A(x), \nu_A(x), \lambda_A(x) | x \in X\rangle\}$ is a PN implicative UP-filter of X. Then $\mu_A(0) \geq \mu_A(x)$, $\nu_A(0) \leq \nu_A(x)$, $\lambda_A(0) \leq \lambda_A(x)$, and

$\mu_A(x * z) \geq \min\{\mu_A(x * (y * z)), \mu_A(x * y)\}$

$\nu_A(x * z) \leq \max\{\nu_A(x * (y * z)), \nu_A(x * y)\}$

$\lambda_A(x * z) \leq \max\{\lambda_A(x * (y * z)), \lambda_A(x * y)\} \ \forall \ \ x, y, z \in X$. We have $\nu_A^c(0) = 1 - \nu_A(0) \geq 1 - \nu_A(x) = \nu_A^c(x)$

$\lambda_A^c(0) = 1 - \lambda_A(0) \geq 1 - \lambda_A(x) = \lambda_A^c(x)$ and similarly $\nu_A^c(x * z) = 1 - \nu_A(x * z) \geq 1 - \max\{\nu_A(x * (y * z)), \nu_A(x * y)\} = \min\{1 - \nu_A(x * (y * z)), 1 - \nu_A(x * y)\} = \min\{\nu_A^c(x * (y * z)), \nu_A^c(x * y)\}$. $\lambda_A^c(x * z) = 1 - \lambda_A(x * z) \geq 1 - \max\{\lambda_A(x * (y * z)), \lambda_A(x * y)\} = \min\{1 - \lambda_A(x * (y * z)), 1 - \lambda_A(x * y)\} = \min\{\lambda_A^c(x * (y * z)), \lambda_A^c(x * y)\}$. Hence the fuzzy sets μ_A, ν_A^c and λ_A^c are fuzzy implicative UP-filters of X. Conversely suppose that the fuzzy set μ_A, ν_A^c and λ_A^c are fuzzy implicative UP-filters of X. Then

$$\begin{aligned}
\mu_A(0) \geq \mu_A(x), \quad \mu_A(x * z) &\geq \min\{\mu_A(x * (y * z)), \mu_A(x * y)\}, \\
\nu_A^c(0) \geq \nu_A^c(x), \quad \nu_A^c(x * z) &\geq \min\{\nu_A^c(x * (y * z)), \nu_A^c(x * y)\}, \\
\lambda_A^c(0) \geq \lambda_A^c(x), \quad \lambda_A^c(x * z) &\geq \min\{\lambda_A^c(x * (y * z)), \lambda_A^c(x * y)\}, \quad \forall x, y, z, \in X.
\end{aligned}$$

Now, $\nu_A^c(0) \geq \nu_A^c(x) \Rightarrow 1 - \nu_A(0) \geq 1 - \nu_A(x) \Rightarrow \nu_A(0) \leq \nu_A(x)$ and

$$\begin{aligned}
\nu_A^c(x * z) &\geq \min\{\nu_A^c(x * (y * z)), \nu_A^c(x * y)\}, \\
1 - \nu_A(x * z) &\geq \min\{1 - \nu_A(x * (y * z)), 1 - \nu_A(x * y)\}, \\
1 - \nu_A(x * z) &\geq 1 - \max\{\nu_A(x * (y * z)), \nu_A(x * y)\}, \\
\nu_A(x * z) &\leq \max\{\nu_A(x * (y * z)), \nu_A(x * y)\}.
\end{aligned}$$

Now, $\lambda_A^c(0) \geq \lambda_A^c(x) \Rightarrow 1 - \lambda_A(0) \geq 1 - \lambda_A(x) \Rightarrow \lambda_A(0) \leq \lambda_A(x)$ and

$$\begin{aligned}
\lambda_A^c(x * z) &\geq \min\{\lambda_A^c(x * (y * z)), \lambda_A^c(x * y)\}, \\
1 - \lambda_A(x * z) &\geq \min\{1 - \lambda_A(x * (y * z)), 1 - \lambda_A(x * y)\}, \\
&= 1 - \max\{\lambda_A(x * (y * z)), \lambda_A(x * y)\}, \\
\lambda_A(x * z) &\leq \max\{\lambda_A(x * (y * z)), \lambda_A(x * y)\},
\end{aligned}$$

Hence, $A = \{\langle x, \mu_A(x), \nu_A(x), \lambda_A(x) | x \in X\rangle\}$ is a PN implicative UP-filter of X. □

Theorem 3.4 *A PNS $A = \{\langle x, \mu_A(x), \nu_A(x), \lambda_A(x) | x \in X\rangle\}$ is a PN implicative UP filter of X if and only if the PNS's $B = \{\langle x, \lambda_A^c, \nu_A, \mu_A^c | x \in X\rangle\}$ is Pythagorean implicative UP filter of X.*

Proof: Suppose that a PNS $A = \{\langle x, \mu_A(x), \nu_A(x), \lambda_A(x) | x \in X\rangle\}$ is a PN implicative UP filter of X, then

$\mu_A(0) \geq \mu_A(x)$, $\mu_A(x * z) \geq min\{\mu_A(x * (y * z)), \mu_A(x * y)\}$
$\nu_A(0) \leq \nu_A(x)$, $\nu_A(x * z) \leq max\{\nu_A(x * (y * z)), \nu_A(x * y)\}$
$\lambda_A(0) \leq \lambda_A(x)$, $\lambda_A(x * z) \leq max\{\lambda_A(x * (y * z)), \lambda_A(x * y)\}$ $\forall x, y, z \in X$.
Now $\mu_A^c(0) = 1 - \mu_A(0) \leq 1 - \mu_A(x) = \mu_A^c(x)$
$\nu_A^c(0) = 1 - \nu_A(0) \geq 1 - \nu_A(x) = \nu_A^c(x)$
$\lambda_A^c(0) = 1 - \lambda_A(0) \geq 1 - \lambda_A(x) = \lambda_A^c(x)$ and

$$\begin{aligned}
\mu_A^c(x * z) &= 1 - \mu_A(x * z) \\
&\leq 1 - \min\{\mu_A(x * (y * z)), \mu_A(x * y)\} \\
&= \max\{1 - \mu_A(x * (y * z)), 1 - \mu_A(x * y)\} \\
&= \max\{\mu_A^c(x * (y * z)), \mu_A^c(x * y)\}
\end{aligned}$$

$$\begin{aligned}
\nu_A^c(x * z) &= 1 - \nu_A(x * z) \\
&\geq 1 - \max\{\nu_A(x * (y * z)), \nu_A(x * y)\} \\
&= \min\{1 - \nu_A(x * (y * z)), 1 - \nu_A(x * y)\} \\
&= \min\{\nu_A^c(x * (y * z)), \nu_A^c(x * y)\}
\end{aligned}$$

$$\begin{aligned}
\lambda_A^c(x * z) &= 1 - \lambda_A(x * z) \\
&\geq 1 - \max\{\lambda_A(x * (y * z)), \lambda_A(x * y)\} \\
&= \min\{1 - \lambda_A(x * (y * z)), 1 - \lambda_A(x * y)\} \\
&= \min\{\lambda_A^c(x * (y * z)), \lambda_A^c(x * y)\}.
\end{aligned}$$

Hence, $B = \{\langle x, \lambda_A^c(x), \nu_A(x), \mu_A^c(x) | x \in X\rangle\}$ is a PN-implicative UP-filter of X.

Conversely, suppose that B $= \{\langle x, \lambda_A^c(x), \nu_A(x), \mu_A^c(x) | x \in X\rangle\}$ is a PN-implicative UP filter of X then for any $x, y, z \in X$,

$$\begin{aligned}
\mu_A^c(0) &\leq \mu_A^c(x) \\
1 - \mu_A(0) &\leq 1 - \mu_A(x) \Rightarrow \mu_A(0) \geq \mu_A(x). \\
\mu_A^c(x * z) &\leq \max\{\mu_A^c(x * (y * z)), \mu_A^c(x * y)\} \\
1 - \mu_A(x * z) &\leq \max\{1 - \mu_A(x * (y * z)), 1 - \mu_A(x * y)\} \\
1 - \mu_A(x * z) &\leq 1 - \min\{\mu_A(x * (y * z)), \mu_A(x * y)\} \\
\mu_A(x * z) &\geq \min\{\mu_A(x * (y * z)), \mu_A(x * y)\}
\end{aligned}$$

$$\lambda^c_A 0 \geq \lambda^c_A(x)$$
$$1-\lambda_A(0) \geq 1-\lambda_A(x) \Rightarrow \lambda_A(0) \leq \lambda_A(x).$$
$$\lambda^c_A(x*z) \geq \min\{\lambda^c_A(x*(y*z)), \lambda^c_A(x*y)\}$$
$$1-\lambda_A(x*z) \geq \min\{1-\lambda_A(x*(y*z)), 1-\lambda_A(x*y)\}$$
$$1-\lambda_A(x*z) \geq 1-\max\{\lambda_A(x*(y*z)), \lambda_A(x*y)\}$$
$$\lambda_A(x*z) \leq \max\{\lambda_A(x*(y*z)), \lambda_A(x*y)\}$$

Hence, $A = \{\langle x, \mu_A(x), \nu_A(x), \lambda_A(x) | x \in X\rangle\}$ is a PN implicative UP filter of X. □

Corollary 3.1 *A PNS $A = \{\langle x, \mu_A(x), \nu_A(x), \lambda_A(x) | x \in X\rangle\}$ is PN implicative UP-filter iff the pythagorean fuzzy sets $< \mu_A(x), \lambda_A(x) >$, $< \nu^c_A(x), \nu_A >$ and $< \lambda^c_A(x), \mu^c_A >$ are Pythagorean implicative UP-filter of X.*

Proof: In the above theorem, if the indeterminacy membership is absent, the structure reduces to a Pythagorean fuzzy set, and the proof follows in a manner similar to the preceding theorem. □

Definition 3.5 Let μ, ν and λ be fuzzy sets in a nonempty set X. For $r, s, t \in [0, 1]$, the set $\ddot{\mathcal{U}}(\mu; t) = \{x \in X \mid \mu(x) \geq t\}$ and $\ddot{\mathcal{U}}^+(\mu;\ t) = \{x \in X \mid \mu(x) > t\}$ are called the upper t-level subset and the upper t-strong level subset of μ, respectively. The sets $\ddot{\mathcal{L}}(\nu;\ s) = \{x \in X \mid \nu(x) \leq s\}$ and $\ddot{\mathcal{L}}^-(\nu;\ s) = \{x \in X \mid \nu(x) < s\}$ are called the lower s-level subset and the lower s-strong level subset of ν, respectively. The set $\ddot{\mathcal{L}}(\lambda : r) = \{x \in X | \lambda(x) \leq r\}$ and $\ddot{\mathcal{L}}^-(\lambda : r) = \{x \in X | \lambda(x) < r\}$ are called a lower r-level subset and a lower r-strongly level subset of λ respectively. The set $C(\mu, \nu, \lambda : t, s, r) = \cup(\mu : t) \cap L(\nu : s) \cap L(\lambda : s)$ is called the (t, s, r) cut of μ, ν and λ.

Theorem 3.5 *A PNS $A = \{\langle x, \mu_A(x), \nu_A(x), \lambda_A(x) | x \in X\rangle\}$ is a PN implicative UP-filter of $X = (X, *, 0)$ iff the non empty sets $\ddot{\mathcal{U}}(\mu_A : t)$, $\ddot{\mathcal{L}}(\nu_A : s)$ and $\ddot{\mathcal{L}}(\lambda_A : r)$, are implicative UP-filters of X for each $t, s, r \in [0, 1]$.*

Proof: Suppose that the PNS set $A = \{\langle x, \mu_A(x), \nu_A(x), \lambda_A(x) | x \in X\rangle\}$ is a PN implicative UP filter of X, let $s, t, r \in [0, 1]$ be such that $\ddot{\mathcal{U}}(\mu_A;\ t)$, $\ddot{\mathcal{L}}(\nu_A;\ s)$ and $\ddot{\mathcal{L}}(\lambda_A;\ s)$ are nonempty subsets of X. Then there exist $x \in \ddot{\mathcal{U}}(\mu_A;\ t)$, $y \in \ddot{\mathcal{L}}(\nu_A;\ s)$ and $z \in \ddot{\mathcal{L}}(\lambda_A;\ r)$. Then $\mu_A(x) \geq t$, $\nu_A(x) \leq s$ and $\lambda_A(x) \leq r$. By assumption, we have $\mu_A(0) \geq \mu_A(x) \geq t$, $\nu_A(0) \leq \nu_A(y) \leq s$ and $\lambda_A(0) \leq \lambda_A(z) \leq r$, so $0 \in \ddot{\mathcal{U}}(\mu_A;\ t)$, $0 \in \ddot{\mathcal{L}}(\nu_A;\ s)$ and $0 \in \ddot{\mathcal{L}}(\lambda_A;\ r)$. Let $x, y, z \in X$ be such that $x*(y*z) \in \ddot{\mathcal{U}}(\mu_A;\ t)$ and $x*z \in \ddot{\mathcal{U}}(\mu_A;\ t)$. Then $\mu_A(x*(y*z)) \geq t$ and $\mu_A(x*y) \geq t$. Thus, $\mu_A(x*z) \geq \min\{\mu_A(x*(y*z)),\ \mu_A(x*y)\} \geq t$. So $x*z \in \ddot{\mathcal{U}}(\mu_A;\ t)$. Hence, $\ddot{\mathcal{U}}(\mu_A;\ t)$ is a implicative UP filter of X.

Now, let $x, y, z \in X$ be such that $x*(y*z) \in \ddot{\mathcal{L}}(\nu_A;\ s)$ and $x*z \in \ddot{\mathcal{L}}(\nu_A;\ s)$. Then $\nu_A(x*(y*z)) \leq s$ and $\nu_A(x*y) \leq s$. Thus, $\nu_A(x*z) \leq \max\{\nu_A(x*(y*z)),\ \nu_A(x*y)\} \leq s$. So $x*z \in \ddot{\mathcal{L}}(\nu_A;\ s)$. Hence, $\ddot{\mathcal{L}}(\nu_A;\ s)$ is a implicative UP filter of X.

Finally let $x, y, z \in X$ be such that $x*(y*z) \in \ddot{\mathcal{L}}(\lambda_A;\ r)$ and $x*z \in \ddot{\mathcal{L}}(\lambda_A;\ r)$. Then $\lambda_A(x*(y*z)) \leq r$ and $\lambda_A(x*y) \leq r$. Thus, $\lambda_A(x*z) \leq \max\{\lambda_A(x*(y*z)),\ \lambda_A(x*y)\} \leq r$. So $x*z \in \ddot{\mathcal{L}}(\lambda_A;\ r)$. Hence, $\ddot{\mathcal{L}}(\lambda_A;\ r)$ is a PN implicative UP filter of X.

Conversely, suppose that $\ddot{\mathcal{U}}(\mu_A; t)$, $\ddot{\mathcal{L}}(\nu_A; s)$ and $\ddot{\mathcal{L}}(\lambda_A; r)$ are PN implicative UP filter of X for each $t, s, r \in [0, 1]$ such that $\ddot{\mathcal{U}}(\mu_A; t) \neq ptyset$, $\ddot{\mathcal{L}}(\nu_A; s) \neq ptyset$ and $\ddot{\mathcal{L}}(\lambda_A; t) \neq ptyset$. Let $x \in X$. Then we have $x \in \ddot{\mathcal{U}}(\mu_A; \mu_A(x))$, $x \in \ddot{\mathcal{L}}(\nu_A; \nu_A(x))$ and $x \in \ddot{\mathcal{L}}(\lambda_A; \lambda_A(x))$.

By assumption, we have $\ddot{\mathcal{U}}(\mu_A; \mu_A(x))$, $\ddot{\mathcal{L}}(\nu_A; \nu_A(x))$ and $\ddot{\mathcal{L}}(\lambda_A; \lambda_A(x))$ are implicative UP filter of X. Thus, $0 \in \ddot{\mathcal{U}}(\mu_A; \mu_A(x))$ and, $0 \in \ddot{\mathcal{L}}(\nu_A; \nu_A(x))$ and $0 \in \ddot{\mathcal{L}}(\lambda_A; \lambda_A(x))$ which imply $\mu_A(0) \geq \mu_A(x)$, $\nu_A(0) \leq \nu_A(x)$ and $\lambda_A(0) \leq \lambda_A(x)$.

Suppose that there exist $x, y, z \in X$ such that $\mu_A(x*z) < \min\{\mu_A(x*(y*z)), \mu_A(x*y)\}$. Choose $t_0 = \frac{1}{2}[\mu_A(x*z) + \min\{\mu_A(x*(y*z)), \mu_A(x*y)\}]$. Thus, $t_0 \in [0, 1]$ and $\mu_A(x*z) < t_0 < \min\{\mu_A(x*(y*z)), \mu_A(x*y)\}$. It implies that $x*z \notin \ddot{\mathcal{U}}(\mu_A; t_0)$ but $x*(y*z)$, $x*y \in \ddot{\mathcal{U}}(\mu_A; t_0)$. Thus, $\ddot{\mathcal{U}}(\mu_A; t_0)$ is not an implicative UP filter of X, which is a contradiction, Hence $\mu_A(x*z) \geq \min\{\mu_A(x*(y*z)), \mu_A(x*y)\}$ for all $x, y, z \in X$.

Similarly, there exist $a, b, c \in X$ such that $\nu_A(a * c) > \max\{\nu_A(a * (b * c)), \nu_A(a * b)\}$. Choose $s_0 = \frac{1}{2}[\nu_A(a*c) + \max\{\nu_A(a*(b*c)), \nu_A(a*b)\}]$. Thus, $s_0 \in [0, 1]$ and $\max\{\nu_A(a*(b*c)), \nu_A(a*b)\} < s_0 < \nu_A(a*c)$. It implies that $a*c \notin \ddot{\mathcal{L}}(\nu_A : s_0)$ but $a*(b*c)$, $a*b \in \ddot{\mathcal{L}}(\nu_A : s_0)$. Thus, $\ddot{\mathcal{L}}(\nu_A : s_0)$ is not an implicative UP filter of X, which is a contradiction. Therefore, $\nu_A(a*c) \leq \max\{\nu_A(a*(b*c)), \nu_A(a*b)\}$ for all $a, b, c \in X$.

Similarly, there exist $l, m, n \in X$ such that $\lambda_A(l * m) > \max\{\lambda_A(l * (m * n)), \lambda_A(l * m)\}$. Choose $r_0 = \frac{1}{2}[\lambda_A(l*n) + \max\{\lambda_A(l*(m*n)), \lambda_A(l*m)\}]$. Thus, $r_0 \in [0, 1]$ and $\max\{\lambda_A(l*(m*n)), \lambda_A(l*m)\} < r_0 < \lambda_A(l*n)$. It implies that $l*n \notin \ddot{\mathcal{L}}(\lambda_A : r_0)$ but $l*(m*n)$, $l*m \in \ddot{\mathcal{L}}(\lambda_A : r_0)$. Thus, $\ddot{\mathcal{L}}(\lambda_A : r_0)$ is not an implicative UP filter of X, which is a contradiction. Therefore, $\lambda_A(l*n) \leq \max\{\lambda_A(l*(m*n)), \lambda_A(l*m)\}$ for all $l, m, n \in X$. Therefore, $A = \{\langle x, \mu_A(x), \nu_A(x), \lambda_A(x) | x \in X\rangle\}$ is a PN implicative UP filter of X. □

Corollary 3.2 *A PNS $A = \{\langle x, \mu_A(x), \nu_A(x), \lambda_A(x) | x \in X\rangle\}$ is a PN implicative of UP-filter of X iff for all $t, s, r \in [0, 1]$, the $\ddot{\mathcal{C}}(\mu_A, \nu_A, \lambda_A; t, s, r)$ is either empty or an implicative UP-filter.*

Proof: Let $A = \{\langle x, \mu_A(x), \nu_A(x), \lambda_A(x) | x \in X\rangle\}$ is a PN implicative UP-filter of X for all $t, s, r \in [0, 1]$, then from Theorem 3.5 $\ddot{\mathcal{U}}(\omega_F; t)$, $\ddot{\mathcal{L}}(\nu_A : s)$ and $\ddot{\mathcal{L}}(\lambda_A : r)$ are either empty or implicative UP filters of X. Since, intersection of UP-filter is UP-filter. Hence $\ddot{\mathcal{C}}(\mu_A, \nu_A, \lambda_A; t, s, r)$ is either empty or an implicative UP-filter.

Conversely, assume that the set $\ddot{\mathcal{C}}(\mu_A, \nu_A, \lambda_A; t, s, r)$ is either empty or an implicative UP-filter of X for all $s, t, r \in [0, 1]$. Let $t \in [0, 1]$ be such that $\ddot{\mathcal{U}}(\mu_A : t) \neq ptyset$. Then, $ptyset \neq \ddot{\mathcal{U}}(\mu_A : t) = \ddot{\mathcal{U}}(\mu_A : t) \cap X = \ddot{\mathcal{U}}(\mu_A : t) \cap \ddot{\mathcal{L}}(\nu_A : 1) \cap \ddot{\mathcal{L}}(\lambda_A : 1) = \ddot{\mathcal{U}}(\mu_A, \nu_A, \lambda_A : t, 1, 1)$. By assumption, we have $\ddot{\mathcal{U}}(\mu_A; t) = \ddot{\mathcal{C}}(\mu_A, \nu_A, \lambda_A; t, 1, 1)$ is an implicative UP filter of X. Let $s \in [0, 1]$ be such that $\ddot{\mathcal{L}}(\nu_A; s) \neq ptyset$. Then $ptyset \neq \ddot{\mathcal{L}}(\nu_A; s) = X \cap \ddot{\mathcal{L}}(\nu_A; s) = \ddot{\mathcal{U}}(\mu_A; 0) \cap \ddot{\mathcal{L}}(\nu_A; s) \cap \ddot{\mathcal{L}}(\lambda_A; 1) = \ddot{\mathcal{C}}(\mu_A, \nu_A, \lambda_A : 0, s, 1)$. By assumption, $\ddot{\mathcal{L}}(\nu_A; s) = \ddot{\mathcal{C}}(\mu_A, \nu_A, \lambda_A; 0, s, 1)$ is an implicative UP filter of X.

Let assume $r \in [0, 1]$ be such that $\ddot{\mathcal{L}}(\lambda_A; r) \neq ptyset$. Then $ptyset \neq \ddot{\mathcal{L}}(\lambda_A; r) = X \cap \ddot{\mathcal{L}}(\lambda_A : r) = \ddot{\mathcal{U}}(\mu_A; 0) \cap \ddot{\mathcal{L}}(\nu_A; 1) \cap \ddot{\mathcal{L}}(\lambda_A; r) = \ddot{\mathcal{C}}(\mu_A, \nu_A, \lambda_A : 0, 1, r)$. By assumption, $\ddot{\mathcal{L}}(\lambda_A; r) = \ddot{\mathcal{C}}(\mu_A, \nu_A\lambda_A : 0, 1, r)$ is an implicative UP-filter of X. Hence by Theorem 3.5, $A = \{\langle x, \mu_A(x), \nu_A(x), \lambda_A(x) | x \in X\rangle\}$ is an PN implicative UP-filter of X. □

Theorem 3.6 *If a PNS $A = \{\langle x, \mu_A(x), \nu_A(x), \lambda_A(x) | x \in X\rangle\}$ is a PN implicative UP-filter of X, then for all $s, t, r \in [0, 1]$, the sets $\ddot{\mathcal{U}}^+(\mu_A; t)$, $\ddot{\mathcal{L}}^+(\nu_A; s)$ and $\ddot{\mathcal{L}}(\lambda_A; r)$ are either empty or implicative UP-filters of X.*

Proof: Suppose that an PNS $A = \{\langle x, \mu_A(x), \nu_A(x), \lambda_A(x) | x \in X\rangle\}$ is PN implicative UP-filter of X. Let $s, t, r \in [0, 1]$ be such that $\ddot{\mathcal{U}}^+(\mu_A; t)$, $\ddot{\mathcal{L}}^-(\nu_A; s)$ and $\ddot{\mathcal{L}}^-(\lambda_A; r)$ are nonempty subsets of X. Then there exist $x \in \ddot{\mathcal{U}}^+(\mu_A; t)$, $y \in \ddot{\mathcal{L}}^-(\nu_A; s)$ and $z \in \ddot{\mathcal{L}}^-(\lambda_A; r)$ with $\mu_A(x) > t$, $\nu_A(x) < s$ and $\lambda_A(x) < r$. By assumption, we have $\mu_A(0) \geq \mu_A(x) > t$, $\nu_A(0) \leq \nu_A(y) < s$ and $\lambda_A(0) \leq \lambda_A(z) < r$, so $0 \in \ddot{\mathcal{U}}^+(\mu_A; t)$, $0 \in \ddot{\mathcal{L}}^-(\nu_A : s)$ and $0 \in \ddot{\mathcal{L}}^-(\lambda_A; r)$.

Let $x, y, z \in X$ be such that $x*(y*z)$, $x*y \in \ddot{\mathcal{U}}^+(\mu_A; t)$. Then $\mu_A(x*(y*z)) > t$ and $\mu_A(x*y) > t$. Thus, $\mu_A(x * z) \geq \min\{\mu_A(x * (y * z)), \mu_A(x * y)\} > t$, so $x * z \in \ddot{\mathcal{U}}^+(\mu_A; t)$. Hence, $\ddot{\mathcal{U}}^+(\mu_A; t)$ is an implicative UP-filter of X. Let $a, b, c \in X$ be such that $a * (b * c)$, $a * b \in \ddot{\mathcal{L}}^-(\nu_A; s)$. Then $\nu_A(x * (y * z)) < s$ and $\nu_A(x * y) < s$. Thus, $\nu_A(x * z) \leq \max\{\nu_A(x * (y * z)), \nu_A(x * y)\} < s$, so $x * z \in \ddot{\mathcal{L}}^-(\nu_A; s)$. Hence, $\ddot{\mathcal{L}}^-(\nu_A; s)$ is an implicative UP-filter of X. Finally let $l, m, n \in X$ be such that $l*(m, n), l*m \in \ddot{\mathcal{L}}^-(\lambda_A; r)$, Then $\lambda_A(l * (m * n)) < r$, $\lambda_A(l * m) < r$. Thus, $\lambda_A(l * n) \leq \max\{\lambda_A(l * (m * n)), \lambda_A(l * m)\} < r$, so $l * n \in \ddot{\mathcal{L}}^-(\lambda_A; r)$. Hence $\ddot{\mathcal{L}}^-(\lambda_A; r)$ is an implicative UP-filter of X. □

4. Conclusion

In this paper, we have introduced the concept of $PNIUPF$'s of UP-algebras and provided some properties of $PNIUPF$'s and together studied the relation of $PNIUPF$'s and $PNUPF$'s in UP-algebras.

We will further extend PN comparative UP- filters in UP-algebras and study properties of PN comparative UP-filters in UP-algebras. In the near future, we will broaden the scope of the research covered in this work to include investigation into essential implicative UP-filters and t-essential Pythagorean neutrosophic implicative UP-filters.

References

1. H. K. Abdullah and M. T. Shadhan, *Intuitionistic fuzzy pseudo ideals in Q-algebra*, J. Phys.: Conf. Ser., **1591** (2020), 012095.
2. M. A. Ansari, A. N. A. Koam and A. Haider, *Rough set theory applied to UP-algebras*, Ital. J. Pure Appl. Math., **42** (2019), 388-402.
3. M. A. Ansari, A. Haidar and A. N. A. Koam, *On a graph associated to UP-algebras*, Math. Comput. Appl., *23* (4) (2018).
4. M. A. Ansari, A. N. A. Koam and A. Haider, *On binary block codes associated to UP-algebras*, Ital. J. Pure Appl. Math., **47** (2022), 205-220.
5. K. T. Atanassov, *Intuitionistic fuzzy sets*, Fuzzy Sets Syst., **35** (1986), 87-96.
6. N. Dokkhamdang, A. Kesorn and A. Iampan, *Generalized fuzzy sets in UP-algebras*, Ann. Fuzzy Math. Inform., **16** (2) (2018), 171-190.
7. T. Gaketem and A. Iampan, *Essential UP-ideals and t-essential fuzzy UP-ideals of UP-algebras*, ICIC Express Letters, **15** (12) (2021), 1283-1289.
8. T. Gaketem, P. Khamrot and A. Iampan, *Essential UP-filters and t-essential fuzzy UP-filters of UP-algebras*, ICIC Express Letters, **16** (10) (2022), 1057-1062.
9. Q. P. Hu and X. Li, *On BCH-algebras*, Math. Seminar Notes (Kobe Univ.), **11**(2) (1983), 313-320.
10. Y. Imai and K. Iséki, *On axiom systems of propositional calculi*, Proc. of Japan Acad., **42** (1) (1966), 19-22.
11. A. Iampan, *A new branch of the logical algebra: UP-algebras*, J. Algebra Relat. Top., **5**(1) (2017), 35-54.
12. A. Iampan, *Introducing fully UP-semigroups, Discuss. Math., Gen. Algebra Appl.*, **38** (2) (2018), 297-306.
13. K. Iséki, *An algebra related with a propositional calculus*, Proc. of Japan Acad., **42** (1) (1966), 26-29.
14. Y. B. Jun and A. Iampan, *Comparative and allied UP-filters*, Lobachevskii J. Math., **40** (1) (2019), 60-66.
15. Y. B. Jun and A. Iampan, *Implicative UP-filters*, Afr. Mat., **30** (2019), 1093-1101.
16. B. Kesorn, K. Maimum, W. Ratbandan and A. Iampan, *Intuitionistic fuzzy sets in UP-algebra*, Ital. J. Pure Appl. Math., **34** (2015), 339-364.
17. P. Khamrot, T. Gaketem, P. Julatha, N. Chunsee, R Prasertpong and A. Iampan, *A note on intuitionstic fuzzy implicative UP-filters*, ICIC Express Letters Part B: Applications, **14** (4) (2023), 339-347.
18. C. Prabpayak and U. Leerawat, *On ideals and congruences in KU-algebras*, Sci. Magna., **5** (1) (2009), 54-57.
19. R. Radha, A. S. A. Mary, R. Prema and S. Broumi, *Neutrosophic Pythagorean sets with dependent neutrosophic Pythagorean components and its improved correlation coefficients*, Neutrosophic Sets Syst., **46** (1) (2021), 77-86.
20. A. Satirad, P. Mosrijai and A. Iampan, *Formulas for finding UP-algebras*, Int. J. Math. Comput. Sci., **14** (2) (2019), 403-409.
21. A. Satirad, P. Mosrijai and A. Iampan, *Generalized power UP-algebras*, Int. J. Math. Comput. Sci., **14** (1) (2019), 17-25.
22. J. Somjanta, N. Thuekaew, P. Kumpeangkeaw and A. Iampan, *Fuzzy sets in UP-algebras*, Ann. Fuzzy Math. Inform., **12** (2016), 739-756.
23. M. Songsaeng, K. P. Shum, R. Chinram and A. Iampan, *Neutrosophic implicative UP-filters, neutrosophic comparative UP-filters, and neutrosophic shift UP-filters of UP-algebras*, Neutrosophic Sets Syst., **47** (2021), 620-643.
24. N. Thongngam and A. Iampan, *A novel approach to intuitionistic fuzzy sets in UP-algebras*, Korean J. Math., **27** (4) (2019), 1077-1108.
25. L. A. Zadeh, *Fuzzy sets*, Inf. Control, **8** (3) (1965), 338-353.

M. Vasu,
Department of Mathematics, Government Arts College for Women, Sivagangai - 630 562, Tamil Nadu, India.
Department of Mathematics, Annamalai University, Annamalai Nagar - 608 002, India.
E-mail address: mvasu1974@gmail.com

and

T. Vigneshwaran,
Department of Mathematics, Government Arts and Science College,
Manalmedu, Mayiladuthurai - 609 202, Tamil Nadu, India.
Department of Mathematics, Annamalai University, Annamalai Nagar - 608 002, India.
E-mail address: juvis1713@gmail.com