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A Study of Intuitionistic Fuzzy Associative Filter in Lattice Implication Algebra

J. Revathi[1,*], *D. Kalamani*[2], *C. Duraisamy*[1] *and K. Arun Prakash*[1]

[1] Department of Mathematics,Kongu Engineering College, Perundurai-638060
[2] Department of Mathematics, Bharathiar University Post Graduate Extension Centre, Erode,Tamil Nadu, India.

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Abstract: In discrete mathematics, automated reasoning is quite useful for real-time applications involving autonomous vehicles and robots. A Lattice Implication Algebra (LIA) assumes implication values in a general complete mathematical lattice toward enhancing the representation of ambiguity in reasoning. Since real numbers stem from real-world measurements, the present study sets a ground for real-world applications of LIA. The aforementioned lattice of intervals follows a capacity to optimize LIA reasoning. In this paper, the notion of intuitionistic fuzzy associative filter in lattice implication algebra is introduced. The equivalent conditions for an intuitionistic fuzzy filter to become an intuitionistic fuzzy associative filter are explained. In addition, the relations among intuitionistic fuzzy associative filter, intuitionistic fuzzy fantastic filter and intuitionistic fuzzy positive implicative filter are elaborated..

Keywords: Lattice implication algebra, associative filter, fuzzy associative filter, intuitionistic fuzzy associative filter.

1 Introduction

Fuzzy sets were introduced by Zadeh [8] in 1965 to represent data and information possessing nonstatistical uncertainities. In 1986, on the basis of fuzzy set theory, Atanassov [1] proposed the intuitionistic fuzzy set characterized by a membership function and nonmembership function. Research behind the logical system depends mainly on lattice implication algebra proposed by Xu [6] in 1993. Following this Xu [6] have introduced and investigated the properties of filters in lattice implication algebra.In [3], Jun has introduced the notion of a fantastic filter in a lattice implication algebra and has given some results. Additionaly, Zhan Jianming [7] has fuzzified the concept of fantastic filters of lattice implication algebras and has given the relations among fuzzy filter, fuzzy positive implicative filter and fuzzy fantastic filter. The present study mainly focus on the properties of intuitionistic fuzzy associative filters in lattice implication algebra and equivalent conditions for a intuitionistic fuzzy filter to be an intuitionistic fuzzy associative filter. This paper is structured as follows. Section 2 reproduces some basic definitions and results in lattice implication algebra. In section 3, the intuitionistic fuzzy associative filter is introduced, some of its properties and comparisons with existing filters are given. The relation with some of the filters is shown in figure. The last section throws light of conclusion and future work that can extended from this present work.

2 Preliminary

Definition 2.1.[6] Let $(L,\vee,\wedge,\prime,\rightarrow,0,1)$ be a bounded lattice with order-reversing involution "$\prime$", 1 and 0 are the greatest and least element of L respectively, $\rightarrow: L\times L\rightarrow L$ be a mapping. $(L,\vee,\wedge,\prime,\rightarrow,0,1)$ is called a lattice implication algebra if the following conditions hold for any $x,y,z\in L$.
(I1) $x\rightarrow(y\rightarrow z)=y\rightarrow(x\rightarrow z)$
(I2) $x\rightarrow x=1$
(I3)$x\rightarrow y=y\prime\rightarrow x\prime$
(I4) If $x\rightarrow y=y\rightarrow x=1$ then $x=y$
(I5) $(x\rightarrow y)\rightarrow y=(y\rightarrow x)\rightarrow x$
(L1) $(x\vee y)\rightarrow z=(x\rightarrow z)\wedge(y\rightarrow z)$
(L2)$(x\wedge y)\rightarrow z=(x\rightarrow z)\vee(y\rightarrow z)$
A partial ordering "$\leq$" can be defined on a lattice implication algebra L by $x\leq y$ if and only if $x\rightarrow y=1$.
Theorem 2.2.[6] In a lattice implication algebra L, for the accompanying hold:

* Corresponding author e-mail: revathifuzzy@gmail.com

(1) $0 \to x = 1, 1 \to x = x$ and $x \to 1 = 1$
(2)$x\prime = x \to 0$
(3) $x \to y \leq (y \to z) \to (x \to z)$
(4) $x \vee y = (x \to y) \to y$
(5) $x \leq y$ implies $y \to z \leq x \to z$ and $z \to x \leq z \to y$
(6) $x \leq (x \to y) \to y$.

Definition 2.3.[1] An Intuitionistic Fuzzy Set (IFS) A of a non-empty set X is an object having the form $A = \{x, \mu_A(x), \nu_A(x)/x \in X\}$ where the function $\mu_A(x) : X \to [0,1]$ denotes the degree of membership and $\nu_A(x) : X \to [0,1]$ denotes the degree of non-membership respectively,and $0 \leq \mu_A(x) + \nu_A(x) \leq 1$ for any $x \in X$.

Definition 2.4.[5] A subset F of a lattice implication algebra L is called a filter of L if it satisfies for all $x, y \in L$
(i) $1 \in F$
(ii) $x \in F$ and $x \to y \in F$ imply $y \in F$.

Definition 2.5.[5] A fuzzy set μ in a lattice implication algebra L is called a fuzzy filter of L if it satisfies
(i) $\mu(1) \geq \mu(x)$ for all $x \in L$,
(ii) $\mu(y) \geq min\{\mu(x), \mu(x \to y)\}$ for all $x, y \in L$.

Definition 2.6.[3] A non empty subset F of a lattice implication algebra L is called a fantastic filter of L if it satisfies
(i) $1 \in F$,
(ii) $z \to (y \to x)$ and $z \in F$ imply $((x \to y) \to y) \to x \in F$, for all $x, y \in L$.

Definition 2.7.[8] A fuzzy set μ in L is called a fuzzy fantastic filter of L if it satisfies
(i) $\mu(1) \geq \mu(x)$ for all $x \in L$,
(ii) $\mu(((x \to y) \to y) \to x) \geq min\{\mu(z \to (y \to x)), \mu(z)\}$ for all $x, y, z \in L$.

Definition 2.8.[2] Let A be an IFS of L and L be a lattice implication algebra.If A satisfies the following
(i) For any $x \in L, \mu_A(1) \geq \mu_A(x)$ and $\nu_A(1) \leq \nu_A(x)$
(ii) For any $x, y \in L, \mu_A(y) \geq min\{\mu_A(x \to y), \mu_A(x)\}$
(iii) For any $x, y \in L, \nu_A(y) \leq max\{\nu_A(x \to y), \nu_A(x)\}$
then A is called intuitionistic fuzzy filter of L.

Definition 2.9.[4] An IFS A of L is called an intuitionistic fuzzy fantastic filter of L if it satisfies the following conditions:
(i) For any $x \in L, \mu_A(1) \geq \mu_A(x)$ and $\nu_A(1) \leq \nu_A(x)$
(ii) For any $x, y, z \in L, \mu_A(((x \to y) \to y) \to x) \geq min\{\mu_A(z \to (y \to x)), \mu_A(z)\}$
(iii) For any $x, y, z \in L, \nu_A(((x \to y) \to y) \to x) \leq max\{\nu_A(z \to (y \to x)), \nu_A(z)\}$.

Definition 2.10.[4] An IFS A of L is called an intuitionistic fuzzy positive implicative filter of L if it satisfies
(i) $\mu_A(1) \geq \mu_A(x)$ and $\nu_A(1) \leq \nu_A(x)$ for all $x \in L$,
(ii) $\mu_A(y) \geq min\{\mu_A(x \to ((y \to z) \to y), \mu_A(x))\}$ for all $x, y, z \in L$
(iii) $\nu_A(y) \leq max\{\nu_A(x \to ((y \to z) \to y), \nu_A(x))\}$ for all $x, y, z \in L$.
Definition 2.11.[4] Every intuitionistic fuzzy positive implicative filter of L is an intuitionistic fuzzy fantastic filter.

3 Intuitionistic fuzzy associative filter in lattice implication algebra

The concept of intuitionistic fuzzy associative filter is introduced in a lattice implication algebra. The equal conditions for an intuitionistic fuzzy filter to be an intuitionistic fuzzy associative filter are introduced.
Definition 3.1. Let x be a fixed componenet of a lattice implication algebra L . An IFS A of L is called an intuitionistic fuzzy associative filter of L with respect to x such that,
(i) $\mu_A(1) \geq \mu_A(x)$ and $\nu_A(1) \leq \nu_A(x)$
(ii) $\mu_A(z) \geq min\{\mu_A(x \to (y \to z)), \mu_A(x \to y)\}$
(iii) $\nu_A(z) \leq max\{\nu_A(x \to (y \to z)), \nu_A(x \to y)\}$ for all $y, z \in L$.
An intuitionistic fuzzy associative filter of L with respect to all $x \neq 0$ is called an intuitionistic fuzzy associative filter of L. Obviously, an intuitionistic fuzzy associative filter with respect to 0 is constant.

Example 3.2. Let $L = \{0, a_1, b_1, c_1, d_1, 1\}$ be a poset . Define a uniary operation "$\prime$ " , and a binary operation "$\to$" on L, and define $\vee$ and $\wedge$ operations on L as follow: $x \vee y = (x \to y) \to y$ and $x \wedge y = ((x\prime \to y\prime) \to y\prime)\prime$ respectively for all $x, y \in L$.
L is a lattice implication algebra defined as follows. An

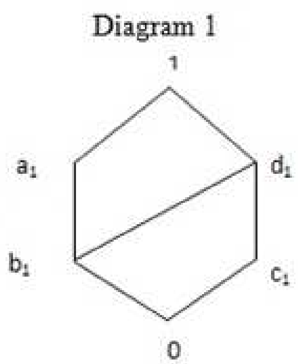


Table 1: Operator order reversing involution in L

x	$x\prime$
0	1
a_1	d_1
b_1	c_1
c_1	b_1
d_1	a_1
1	0

Table 2: Operator $\rightarrow$ in L

$\rightarrow$	0	a_1	b_1	c_1	d_1	1
0	1	1	1	1	1	1
a_1	d_1	1	a_1	c_1	c_1	1
b_1	c_1	1	1	c_1	c_1	1
c_1	b_1	a_1	b_1	1	a_1	1
d_1	a_1	1	a_1	1	1	1
1	0	a_1	b_1	c_1	d_1	1

IFS A in L defined by

$$\mu_A(x) = \begin{cases} 0.8, & x \in \{1, a_1, b_1\} \\ 0.7, & x \in \{0, c_1, d_1\} \end{cases}$$

$$\nu_A(x) = \begin{cases} 0.6, & x \in \{0, c_1, d_1\} \\ 0.3, & x \in \{1, a_1, b_1\} \end{cases}$$

for all $x \in L$. Then A is an intuitionistic fuzzy associative filter of L as for a_1 and b_1 yet not regarding c_1 and d_1.

Proposition 3.3. An IFS A of L is an intuitionistic fuzzy associative filter of a lattice implication algebra L with respect to $x \in L$,then $\mu_A(x) = \mu_A(1)$ and $\nu_A(x) = \nu_A(1)$.

Proof. If x=0,1 it is trivial.Let x be assumed as neither 0 nor 1. Then

$$\begin{aligned} \mu_A(x) &\geq \min\{\mu_A(x \rightarrow (1 \rightarrow x)), \mu_A(x \rightarrow 1)\} \\ &= \min\{\mu_A(x \rightarrow x), \mu_A(1)\} \\ &= \min\{\mu_A(1), \mu_A(1)\}. \end{aligned}$$

By the definition and

$\mu_A(x) \geq \mu_A(1)$, $\mu_A(x) = \mu_A(1)$

Also

$$\begin{aligned} \nu_A(x) &\leq max\{\nu_A(x \rightarrow (1 \rightarrow x)), \nu_A(x \rightarrow 1)\} \\ &= max\{\nu_A(x \rightarrow x), \nu_A(1)\} \\ &= max\{\nu_A(1), \nu_A(1)\}. \end{aligned}$$

By the definition and $\nu_A(x) \leq \nu_A(1)$,$\nu_A(x) = \nu_A(1)$.

Theorem 3.4. Every intuitionistic fuzzy associative filter of lattice implication algebra L with respect to 1 is an intuitionistic fuzzy filter.

Proof. Consider A be an intuitionistic fuzzy associative filter of L with respect to 1.Then
$\mu_A(z) \geq min\{\mu_A(1 \rightarrow (y \rightarrow z)), \mu_A(1 \rightarrow y)\}$
$= min\{\mu_A(y \rightarrow z), \mu_A(y)\}$
Therefore $\mu_A(z) \geq min\{\mu_A(y \rightarrow z), \mu_A(y)\}$
$\nu_A(z) \leq max\{\nu_A(1 \rightarrow (y \rightarrow z)), \nu_A(1 \rightarrow y)\}$
$= max\{\nu_A(y \rightarrow z), \nu_A(y)\}$
Therefore $\nu_A(z) \leq max\{\nu_A(y \rightarrow z), \nu_A(y)\}$
Hence,A is an intuitionistic fuzzy filter of L.

Table 3: Operator order reversing involution in L

x	$x\prime$
0	1
a_2	c_2
b_2	b_2
c_2	a_2
1	0

Table 4: Operator $\rightarrow$ in L

$\rightarrow$	0	a_2	b_2	c_2	1
0	1	1	1	1	1
a_2	c_2	1	1	1	1
b_2	b_2	c_2	1	1	1
c_2	a_2	b_2	c_2	1	1
1	0	a_2	b_2	c_2	1

Corollary 3.5. Each intuitionistic fuzzy associative filter of lattice implication algebra is an intuitionistic fuzzy filter. The opposite of the above corollary may not be true, as shown by the following example.

Example 3.6. Let $L = \{0, a_2, b_2, c_2, 1\}$. The partial order relation can be defined on L as $0 < a_2 < b_2 < c_2 < 1$, and $x \wedge y = min\{x, y\}$,$x \vee y = max\{x, y\}$,for all $x, y \in L$ and ”$\prime$ ” and ” $\rightarrow$” as follows the Table 3 and Table 4: Then $(L, \wedge, \vee, \prime, \rightarrow)$ is a lattice implication algebra. An intuitionistic fuzzy set A can be defined in L by

$$\mu_A(x) = \begin{cases} 0.8, & x \in \{1\} \\ 0.7, & Otherwise \end{cases}$$

$$\nu_A(x) = \begin{cases} 0.2, & x \in \{1\} \\ 0.3, & x \in \{a_2, c_2, 0\} \\ 0.4, & x \in \{b_2\} \end{cases}$$

Hence A is an intuitionistic fuzzy filter, but not an intuitionistic fuzzy associative filter of L with respect to a_2,for $c_2 \in L, \mu_A(c_2) \neq \min\{\mu_A(1), \mu_A(1)\}$ and $\nu_A(c_2) \neq \max\{\nu_A(1), \nu_A(1)\}$.

Theorem 3.7. Let A be an intuitionistic fuzzy filter of a lattice implication algebra L . Then A is an intuitionistic fuzzy associative filter of if and only if it satisfies

$$\begin{aligned} &\mu_A((x \rightarrow y) \rightarrow z)) \geq \mu_A(x \rightarrow (y \rightarrow z)), \\ &\nu_A((x \rightarrow y) \rightarrow z)) \leq \nu_A(x \rightarrow (y \rightarrow z)) forall\ x, y, z \in L. \end{aligned} \quad (1)$$

Proof. Let A satisfy $\mu_A((x \rightarrow y) \rightarrow z)) \geq \mu_A(x \rightarrow (y \rightarrow z))$,

$\nu_A((x \to y) \to z)) \leq \nu_A(x \to (y \to z))$ for all $x,y,z \in L$
Hence
$\mu_A(z) \geq min\{\mu_A(x \to y) \to z), \mu_A(x \to y)\}$
$\geq min\{\mu_A(x \to (y \to z), \mu_A(x \to y)$
and $\nu_A(z) \leq max\{\nu_A(x \to y) \to z), \nu_A(x \to y)\}$
$\leq max\{\nu_A(x \to (y \to z), \nu_A(x \to y)$ for all $x,y,z \in L$
Therefore, A is an intuitionistic fuzzy associative filter of L .
Conversely A can be assumed as an intuitionistic fuzzy associative filter of L and $x,y,z \in L$.The following can be considered.
$x \to ((y \to z) \to ((x \to y) \to z)) = (y \to z) \to (x \to ((x \to y) \to z))$
$=(y \to z) \to ((x \to y) \to (x \to z))$
$=(x \to y) \to ((y \to z) \to (x \to z))$
$=1 \in F$
Further $\mu_A((x \to y) \to z) \geq min\{\mu_A(x \to ((y \to z) \to ((x \to y) \to z))), \mu_A(x \to (y \to z))\}$
$=\min\{\mu_A(1), \mu_A(x \to (y \to z)\}$
$=\mu_A(x \to (y \to z)\}$
Therefore $\mu_A((x \to y) \to z) \geq \mu_A(x \to (y \to z)\}$
$\nu_A((x \to y) \to z) \leq max\{\nu_A(x \to ((y \to z) \to ((x \to y) \to z))), \nu_A(x \to (y \to z))\}$
$=\max\{\nu_A(1), \nu_A(x \to (y \to z)\}$
$=\nu_A(x \to (y \to z)\}$
Therefore $\nu_A((x \to y) \to z) \leq \nu_A(x \to (y \to z))$
Another comparable condition for an intuitionistic fuzzy filter to be an intuitionistic fuzzy associative filter is given in the following theorem .

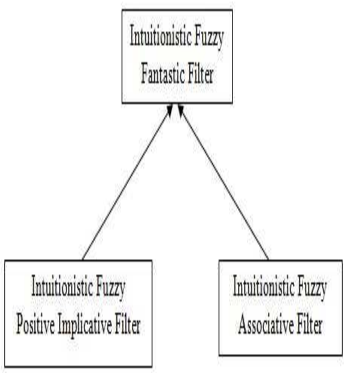
Theorem 3.8. Let A be an intuitionistic fuzzy filter of lattice implication algebra L . Then A is an intuitionistic fuzzy associative filter of L if and only if it satisfies,

$$\mu_A(y) \geq \mu_A(x \to (x \to y), \nu_A(y) \leq \nu_A(x \to (x \to y) \quad forall\ x,y \in L. \tag{2}$$

Proof. Let A be an intuitionistic fuzzy filter of a lattice implication algebra L.
To prove that A is an intuitionistic fuzzy associative filter of L, it is enough to prove that (1) and (2) are equivalent.
setting x=y in (1)
$\mu_A((y \to y) \to z)) \geq \mu_A(y \to (y \to z))$,
$\mu_A(1 \to z) \geq \mu_A(y \to (y \to z))$,
$\mu_A(z) \geq \mu_A(y \to (y \to z))$,
and
$\nu_A((y \to y) \to z)) \leq \nu_A(y \to (y \to z))$,
$\nu_A((1 \to z) \leq \nu_A(y \to (y \to z))$,
$\nu_A(z) \leq \nu_A(y \to (y \to z))$,
Hence, (1)$\Rightarrow$ (2)
Conversely (2) can be assumed to be satisfied.The following can be considered
$(x \to (y \to z)) \to (x \to (x \to ((x \to y) \to z))) = 1 \to ((x \to (y \to z)) \to (x \to (x \to ((x \to y) \to z))))$
$= ((y \to z) \to (x \to (x \to y) \to z)) \to ((x \to (y \to z)) \to (x \to (x \to (x \to ((x \to y) \to z))))$
$= (x \to (y \to z)) \to ((y \to z) \to (x \to (x \to y) \to z)))) \to (x \to (x \to ((x \to y) \to z)))$
$\geq (x \to (y \to z)) \to (x \to (y \to z))$
$=1$
As $(x \to (y \to z)) \to (x \to (x \to ((x \to y) \to z))) \in F$
Let $\mu_A((x \to y) \to z) \geq \{\mu_A(x \to ((x \to y) \to z)))\}$
$\geq min\{\mu_A(x \to (y \to z)) \to (x \to (x \to ((x \to y) \to z))), \mu_A(x \to (y \to z))\}$
$=min\{\mu_A(1), \mu_A(x \to (y \to z))\}$
$=\mu_A(x \to (y \to z)))$
$\mu_A((x \to y) \to z) \geq \mu_A(x \to (y \to z)))$
Similarly $\nu_A((x \to y) \to z) \leq \nu_A(x \to (y \to z)))$
Hence (2)$\Rightarrow$ (1) ,as (1) and (2) are equivalent by theorem 2.7, A is an intuitionistic fuzzy associative filter.

Theorem 3.9. Every intuitionistic fuzzy associative filter of lattice implication algebra is an intuitionistic fuzzy fantastic filter.

Proof. Let A be an intuitionistic fuzzy associative filter of L . By Corollary 3.5, A is an intuitionistic fuzzy filter of L.
$(y \to x) \to (x \to (x \to ((x \to y) \to y) \to x)) = (y \to x) \to (x \to (((x \to y) \to y) \to (x \to x))$
$= (y \to x) \to (x \to ((x \to y) \to y) \to 1)$
$=(y \to x) \to (x \to 1)$
$=(y \to x) \to 1$
$=1$
which implies that
$(y \to x) \to (x \to (x \to ((x \to y) \to y) \to x)) \in F$
Therefore,$\mu_A(((x \to y) \to y) \to x) \geq \mu_A(x \to (x \to (((x \to y) \to y) \to x))$
$=min\{\mu_A((y \to x) \to (x \to (x \to (x \to y) \to y) \to x)), \mu_A(y \to x)\}$
$=min\{\mu_A(1), \mu_A(y \to x)\}$
$=\mu_A(y \to x)$
Therefore $\mu_A(((x \to y) \to y) \to x) \geq \mu_A(y \to x)$
Similarly $\nu_A(((x \to y) \to y) \to x) \leq \nu_A(y \to x)$
Hence A is an intuitionistic fuzzy fantastic filter of L.
The following implication gives the relation among intuitionistic fuzzy fantastic filter, intuitionistic fuzzy positive implicative filter and intuitionistic fuzzy associative filter.



The converse implications of the above relation are not true as shown by the following example.

Example 3.10. Consider $L = \{0, a_3, b_3, 1\}$ be a set with partial ordering. An unary operation ”$\prime$ ” and a binary

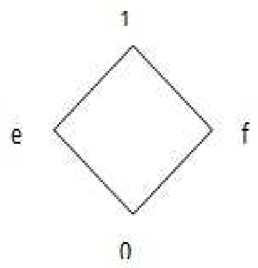
Table 5: Operator order reversing involution in L

x	$x\prime$
0	1
e	f
f	e
1	0

Table 6: Operator $\rightarrow$ in L

$\rightarrow$	0	e	f	1
0	1	1	1	1
e	f	1	1	1
f	e	f	1	1
1	0	e	f	1

operation " $\rightarrow$ " on L can be defined as follow:



$\vee$ and $\wedge$ operation can be defined on L as follow:
$x \vee y = (x \rightarrow y) \rightarrow y, x \wedge y = ((x\prime \rightarrow y\prime) \rightarrow y\prime)\prime$
At that point L is a lattice implication algebra. Characterize an intuitionistic fuzzy set A can be defined in L by

$$\mu_A(x) = \begin{cases} 0.7, & x \in \{0, e, f\} \\ 0.8, & x \in \{1\} \end{cases} \quad \nu_A(x) = \begin{cases} 0.3, & x \in \{0, e, f\} \\ 0.1, & x \in \{1\} \end{cases}$$

Obviously, A is an intuitionistic fuzzy fantastic filter, but not an intuitionistic fuzzy associative filter as for $e, f, 0 \in A, \mu_A(0) \neq \min\{\mu_A(1), \mu_A(1)\}$ and $\nu_A(0) \neq \max\{\nu_A(1), \nu_A(1)\}$.Similarly it is not an intuitionistic fuzzy positive implicative filter as $\mu_A(f) \neq \min\{\mu_A(1), \mu_A(1)\}$ and $\nu_A(f) \neq \max\{\nu_A(1), \nu_A(1)\}$.

4 Conclusion

In this paper, the concept of intuitionistic fuzzy associative filter in lattice implication algebra is introduced. The properties and equivalent conditions of intuitionistic fuzzy associative filters are discussed. The relations between intuitionistic fuzzy associative filter, intuitionistic fuzzy fantastic filter and intuitionistic fuzzy positive implicative filter are shown. The present study would serve as a foundation for further study of the structure of minimal filters and enrich corresponding many-valued logical system. Future studies can include theoretical extensions driven by practical applications. In particular, on the one hand, regarding theory, extensions can be made in the mathematical lattice of fuzzy numbers based on interval a-cuts. On the other hand, regarding practical applications,machine intelligence might be pursed; in mobile/humanoid robot applications, planning by reasoning that accommodates uncertainty can be done.

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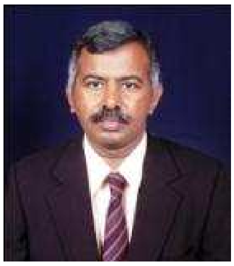
J.Revathi is Assistant Professor of Department of Mathematics at Kongu Engineering College ,Erode,Tamilnadu, India. She has 10 years of teaching experience and she has published research articles in reputed international journals.

D.Kalamani is Associate Professor of Department of Mathematics at Bharathiar University Post Graduate Extension centre,Erode,Tamilnadu, India. She has 20 years of teaching experience and she has published 30 papers in National and International journals.



C.Duraisamy is Professor and Dean , School of Science and Humanities, Kongu Engineering College ,Erode,Tamilnadu, India.He has 25 years of teaching experience and he has published 40 papers in National and International journals.

K.Arun Prakash received his Ph.D. (2013) in Mathematics from Bharathiyar University in the field of Intuitionistic Fuzzy Topology. He is currently working as an Assistant Professor in the department of Mathematics, Kongu Engineering College, Perundurai, Erode, Tamilnadu, India. His main fields of interest are Intuitionistic fuzzy topology, Intuitionistic fuzzy optimization, Intuitionistic fuzzy lattice structures in algebras and Intuitionistic fuzzy decision making. He has published 25 papers in reputed international journals.