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FUZZY DOT SUBALGEBRA AND FUZZY DOT *I**-IDEAL OF *I**-ALGEBRA

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Abstract: In this paper a new type of i*-algebra has been defined. Also, fuzzy dot subalgebra and fuzzy dot i*-ideal of i*-algebra introduced and its properties are derived.

Keywords: *i**-algebra, *i**-ideal, fuzzy dot subalgebra**,** fuzzy dot *i**-ideal.

1. Introduction

According to Zadeh [8] is introduced to the idea of fuzzy sets (Fs). Since then, a variety of algebraic structures, such as semigroups, groups, rings, modules, vector spaces, and topologies, have been studied using these concepts. Fs were introduced by Xi [7] in 1991 and were later used to the BCK -algebras suggested by Imai and Iséki [2,3].

In this paper, we describe the concept of a fuzzy dot subalgebra of an i*-algebra as an extension of a fuzzy subalgebra of an i*-algebra. Following that, we'll examine at some of the essential properties of fuzzy dot subalgebras. We also examine the concept of fuzzy dot i*-algebraic ideals before delving into several essential properties associated with these ideals. In section 2 describe the basic preliminaries and Fuzzy dot subalgebra (FDs) of *i**-algebra discussed in section 3. In section 4 proved some theorem and definition with example of Fuzzy dot *i**-ideal of *i**-algebra. Finally Conclusion given in the last section.

2. Preliminaries

2.1 Definition: *Cartesian product of fuzzy sets*
Let ψ and ϑ be the Fs in a set Θ. The Cartesian product (C_p) $\psi\times\vartheta$: $\Theta\times\Theta\to[0, 1]$ is defined by $(\psi\times\vartheta)(\theta, y) = \psi(\theta)\cdot\vartheta(y)$, for all $\theta, y \in \Theta$.

2.2 Example
Define a fuzzy set ψ in $\Theta = \{0, 1, 2\}$ by $\psi(0) = 0.1$, $\psi(1)=0.2$, $\psi(2)=0.5$. Define a fuzzy set ϑ in Θ by $\vartheta(0)= 1$, $\vartheta(1)=0.5$, $\vartheta(2)=0.2$.
Then the Cartesian product $\psi\times\vartheta$: $\Theta\times\Theta\to[0, 1]$ is defined as $(\psi\times\vartheta)(0,1) = \psi(0)\cdot\vartheta(1) = (0.1).(0.5) = 0.05$. Similarly we can get values for other elements in $\Theta\times\Theta$.

2.3 Definition: *Union of fuzzy subsets*
For any fuzzy subsets(FSs) ϑ and γ of a set Θ, we define $(\vartheta \cup \gamma)(\theta) = ma\theta\{\vartheta(\theta), \gamma(\theta)\}$ for all $\theta \in \Theta$.

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2.4 Example

Let Fs, ϑ in Θ = {0, 1, 2} by ϑ (0) = 0. 1, ϑ (1) = 0.2, ϑ (2) = 0.5.
Let Fs, γ in Θ by γ (0) = 1, γ(1) = 0.5, γ(2) = 0.2.

$$\Rightarrow (\vartheta \cup \gamma)(0) = \text{ma}\theta\{\vartheta(0), \gamma(0)\} = \text{ma}\theta\{0.1, 1\} = 1.$$

Similarly we can definitely for other elements in Θ.

3. **Fuzzy dot subalgebra (FDs) of *i**-algebra**

3.1 Definition: *i*-algebra*

A *i**-algebra is an algebra (Θ,∗,0) of type (2,0) satisfying the following conditions.

(i) $\theta*\theta = 1, \theta \neq 0 \in \Theta$

(ii) $0* \theta = 0, \theta \neq 0 \in \Theta$

(iii) $\theta * y = 1$ and $y * \theta = 1$

$\Rightarrow \theta = y$ for all $\theta \neq 0, y \neq 0 \in \Theta$.

3.2 Example

Let Θ = {0, a, b,}. Consider the following Cayley table

*	0	a	b
0	1	0	0
a	0	1	0
b	0	1	1

***Table 1:* the system (Θ,*,0) is a *i**-algebra**

Clearly this table shows that, the system (Θ,*,0) is a *i**-algebra.

3.3 Definition: *Subalgebra of I*-algebra*

Let S be a nonempty subset of a *i**-algebra Θ. Then S is called a subalgebra of Θ if θ∗y∈S, for all θ,y∈ S.

3.4 Example

Consider a *i**-algebra Θ= {0, 1, 2} having the following Cayley table.

*	0	1	2
0	1	0	0
1	0	1	2
2	0	1	1

Table 2: S={0,1} is a subalgebra of a *i-algebra**

Clearly the table 2 shows that S= {0, 1} is a subalgebra of a *i**-algebra.

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3.5 Definition: *fuzzy dot sub algebra of a i*algebra*

A fuzzy subset ϑ of Θ is called fuzzy dot sub algebra of a *i**-algebra Θ if $\vartheta(\theta * y) \leq \vartheta(\theta)\cdot\vartheta(y)$for all θ, y, $\theta = y \neq 1 \in \Theta$.

3.6 Example

Consider a *i**-algebra Θ={0,1,2}having the following Cayley table:

*	0	1	2
0	1	0	0
1	0	1	1
2	0	0	1

Define a fuzzy set ϑ in Θ by ϑ(0)=1, ϑ(1)=0.2, ϑ(2)=1. It is easy to verify that ϑ is a fuzzy dot subalgebra of a *i**-algebra.

3.7 Theorem

If ϑ is a fuzzy dot subalgebra of a *i**-algebra Θ, then we have $\vartheta(1) \leq (\vartheta(\theta))^2$ for all $\theta \neq 1 \in \Theta$.

Proof

For every $\theta \neq 1 \in \Theta$,

we have, $\vartheta(1) = \vartheta(\theta * \theta) \leq \vartheta(\theta)\cdot\vartheta(\theta) = (\vartheta(\theta))^2$

This completing the Proof:

3.8 Theorem

If ϑ and γ are fuzzy dot subalgebra of a *i**-algebra Θ, then so is ϑ∪γ.

Proof

Let $\theta, y \in \Theta$.

$$
\begin{aligned}
\text{Then } (\vartheta \cup \gamma)(\theta * y) &= \text{ma}\theta\{\vartheta(\theta * y), \gamma(\theta * y)\} \\
&\leq \text{ma}\theta\{\vartheta(\theta)\cdot\vartheta(y), \gamma(\theta)\cdot\gamma(y)\} \\
&\leq (\text{ma}\theta\{\vartheta(\theta), \gamma(\theta)\}) \cdot (\text{ma}\theta\{\vartheta(y), \gamma(y)\}) \\
&= ((\vartheta \cup \gamma)(\theta)) \cdot ((\vartheta \cup \gamma)(y)).
\end{aligned}
$$

Hence ϑ∪γ is a fuzzy dot subalgebra of a i*-algebra Θ.

3.9 Theorem

If ψ and ϑ are fuzzy dot subalgebras of a i*-algebra Θ, then $\psi \times \vartheta$ is a fuzzy dot subalgebra of Θ×Θ.

Proof

For any $\theta_1, \theta_2, y_1, y_2 \in \Theta$,

$$
\begin{aligned}
(\psi\times\vartheta)((\theta_1, y_1)*(\theta_2, y_2)) &= (\psi\times\vartheta)(\theta_1 * \theta_2, y_1 * y_2) \\
&= \psi(\theta_1 * \theta_2)\cdot \vartheta(y_1 * y_2) \\
&\leq ((\psi(\theta_1)\cdot\psi(\theta_2)) \cdot ((\vartheta(y_1)\cdot\vartheta(y_2)) \\
&= ((\psi(\theta_1)\cdot\vartheta(y_1)) \cdot (\psi(\theta_2)\cdot\vartheta(y_2)) \\
&= (\psi\times\vartheta)(\theta_1, y_1) \cdot (\psi\times\vartheta)(\theta_2, y_2),
\end{aligned}
$$

This completing the Proof:

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3.10 Definition: *strongest fuzzy ϕ-relation on i*-algebra*

The strongest fuzzy ϕ-relation on *i**-algebra Θ is the fuzzy subset ϑ_ϕ of Θ×Θ given by $\vartheta_\phi(\theta, y) = \phi(\theta) \cdot \phi(y)$ for all θ, y Θ .

3.11 Definition: *fuzzy ϕ-product relation*

A fuzzy relation ϑ on *i**-algebra Θ is called a fuzzy ϕ-product relation if $\vartheta(\theta, y) \le \phi(\theta) \cdot \phi(y)$ for all θ, y ∈ Θ.

3.12 Definition: *left fuzzy relation*

A fuzzy relation ϑ on *i**-algebra Θ is called a left fuzzy relation on ϕ if $\vartheta(\theta, y) = \phi(\theta)$ for all θ, y ∈ Θ. Note that a left fuzzy relation on ϕ is a fuzzy ϕ-product relation.

3.13 Theorem

Let ϑ_ϕ be the strongest fuzzy ϕ-relation on *i**-algebra Θ, where ϕ is a fuzzy subset of a *i**-algebra Θ. If ϕ is a fuzzy dot subalgebra of a *i**algebra Θ, then ϑ_ϕ is a fuzzy dot subalgebra of Θ× Θ.

Proof

Suppose that ϕ is fuzzy dot subalgebra of Θ.

For any $\theta_1, \theta_2, y_1, y_2 \in \Theta$, we have,

$$\vartheta_\phi((\theta_1, y_1) * (\theta_2, y_2)) = \vartheta_\phi(\theta_1 * \theta_2, y_1 * y_2)$$
$$= \phi(\theta_1 * \theta_2) \cdot \phi(y_1 \quad y_2)$$
$$\le (\phi(\theta_1) \cdot \phi(\theta_2)) \cdot (\phi(y_1) \cdot \phi(y_2))$$
$$= (\phi(\theta_1) \cdot \phi(y_1)) \cdot (\phi(\theta_2) \cdot \phi(y_2))$$
$$= \vartheta_\phi(\theta_1, y_1) \cdot \vartheta_\phi(\theta_2, y_2),$$

so ϑ_ϕ is a fuzzy dot subalgebra of Θ×Θ.

3.14 Theorem

Let ϑ be a left fuzzy relation on a fuzzy subset ϕ of a *i**-algebra Θ. If ϑ is a fuzzy dot subalgebra of Θ × Θ, then ϕ is a fuzzy dot subalgebra of a *i**-algebra Θ.

Proof

Suppose that a left fuzzy relation ϑ on ϕ is fuzzy dot subalgebra of Θ× Θ.

Then $\phi(\theta_1 * \theta_2) = \vartheta(\theta_1 * \theta_2, y_1 * y_2)$

$$= \vartheta((\theta_1, y_1) * (\theta_2, y_2))$$
$$\le \vartheta(\theta_1, y_1) \cdot \vartheta(\theta_2, y_2)$$
$$= \phi(\theta_1) \cdot \phi(\theta_2) \text{ for all } \theta_1, \theta_2, y_1, y_2 \in \Theta.$$

Hence ϕ *is* a fuzzy dot subalgebra of a *i**-algebra Θ.

4. Fuzzy dot *i**-ideal of *i**-algebra

4.1 Definition: *i*-ideal of i*-algebra*

Let Θ be a i*-algebra and I be a subset of Θ, then I is called *i**-ideal of Θ if it satisfies the following conditions.

(i) 1 ∈I
(ii) θ*y ∈ I and y∈ I ⇒θ∈ I

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(iii) θ∈I, y∈ Θ
⇒θ∗y∈I .

4.2 Example:
Consider a *i**-algebra Θ ={0,1,2, 3} having the following Cayley table:

*	0	1	2	3
0	0	0	0	0
1	1	1	2	0
2	2	1	1	0
3	1	0	0	1

Table 4: I = {0, 1, 2} is i*-ideal of i*-algebra

Clearly this table shows that I = {0, 1, 2} is *i**-ideal of *i**-algebra.

4.3 Definition: *fuzzy i*-ideal i*-algebras*

A fuzzy subset μ of Θ is called a fuzzy *i**-ideal of Θ if it satisfies the following conditions for all θ,y∈ Θ:

(i) $\vartheta(1) \leq \vartheta(\theta)$
(ii) $\vartheta(\theta) \leq$ maθ$\{\vartheta(\theta*y), \vartheta(y)\}$
(iii) $\vartheta(\theta*y) \leq$maθ $\{\vartheta(\theta), \vartheta(y)\}$

4.4 Example

For the table 3, Define a fuzzy set ϑ in Θ by ϑ(0)=0.6, ϑ(1)=0.5, ϑ(2)=0.8, ϑ(3)=0.9. Then it is easy to verify that ϑ is a fuzzy i*-ideal algebra of i*-algebra Θ.

4.5 Definition: *Fuzzy Dot i*-ideals of i*-algebras*

A fuzzy subset μ of Θ is called a fuzzy dot *i**-ideal of Θ if it satisfies the following conditions for all θ, y, θ = y ≠ 1∈ Θ.

(i) $\vartheta(1) \leq \vartheta(\theta)$
(ii) $\vartheta(\theta) \leq \vartheta(\theta*y) \bullet \vartheta(y)$
(iii) $\vartheta(\theta*y) \leq \vartheta(\theta) \bullet \vartheta(y)$

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4.6 Example

Let Θ = {0, 1, a, b}. Consider the following Cayley table.

*	0	a	b	1
0	0	0	0	0
a	a	1	0	a
b	b	0	1	b
1	1	0	0	1

Table 5: (Θ,*, 0) is a i*-algebra. I = {0, a, 1} is a i*-ideal

Clearly this table shows that, the system (Θ,*, 0) is a *i**-algebra. I = {0, a, 1} is a *i**-ideal.

Define a fuzzy set ϑ in Θ by ϑ(0)=1, ϑ(1)=0.5, ϑ(a)=ϑ(b)=1. Then it is easy to verify that ϑ is a fuzzy dot subalgebra of a *i**-algebra. Also it is fuzzy dot *i**-ideal of *i**-algebra Θ.

4.7 Theorem

Every fuzzy dot *i**-ideal of a *i**-algebra Θ is a fuzzy dot subalgebra of Θ.

Proof

By the definition of fuzzy dot *i**-ideal of a *i**-algebra Θ, it is clearly true that every fuzzy dot *i**-ideal of a *i**-algebra Θ is a fuzzy dot subalgebra of Θ.

4.8 Remark

The converse of Proposition is not true.

4.9 Theorem

If ϑ and γ are fuzzy dot *i**-ideals of a *i**-algebra Θ, then so is ϑ ∪ γ.

Proof

Let θ, y ∈ Θ.

(I) Then $(\vartheta \cup \gamma)(1) = ma\theta\{\vartheta(1), \gamma(1)\}$

$$\leq ma\theta\ \{\ \vartheta(\theta), \gamma(\theta)\}$$
$$= (\vartheta \cup \gamma)(\theta).$$

(ii) Also, $(\vartheta \cup \gamma)(\theta) = ma\theta\{\vartheta(\theta), \gamma(\theta)\}$

$$\leq ma\theta\ \{\vartheta(\theta * y) \cdot \vartheta(y), \gamma(\theta * y) \cdot \gamma(y)\}$$
$$\leq (ma\theta\ \{\vartheta(\theta * y), \gamma(\theta * y)\}) \cdot (ma\theta\{\vartheta(\theta), \gamma(\theta)\})$$
$$= ((\vartheta \cup \gamma)(\theta * y)) \cdot ((\vartheta \cup \gamma)(\theta)).$$

(iii) And, $(\vartheta \cup \gamma)(\theta * y) = ma\theta\ \{\vartheta(\theta * y), \gamma(\theta * y)\}$

$$\leq ma\theta\ \{\vartheta(\theta) \cdot \vartheta(y), \gamma(\theta) \cdot \gamma(y)\}$$
$$\leq (ma\theta\ \{\vartheta(\theta), \gamma(\theta)\}) \cdot (ma\theta\{\vartheta(y), \gamma(y)\})$$

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$= ((\vartheta \cup \gamma)(\theta)) \cdot ((\vartheta \cup \gamma)(y))$.

Hence $\vartheta \cup \gamma$ is a fuzzy dot i*-ideal of a i*-algebra Θ.

4.10 Theorem

If ψ and ϑ are fuzzy dot i*-ideal of a d-algebra Θ, then $\psi \times \vartheta$ is a fuzzy dot i*-ideal of $\Theta \times \Theta$.

Proof

Let $\theta, y \in \Theta$.

(i) $(\psi \times \vartheta)(1,1) = \psi(1) \bullet \vartheta(1) \leq \psi(\theta) \bullet \vartheta(y)$

For any $\theta, \theta_1, y, y_1 \in \Theta$, we have

(ii) $(\psi \times \vartheta)(\theta,y) = \psi(\theta) \bullet \vartheta(y)$
$\leq (\psi(\theta*\theta_1) \bullet \psi(\theta_1)) \bullet (\vartheta(y*y_1) \bullet \vartheta(y_1))$
$= (\psi(\theta*\theta_1) \bullet \vartheta(y*y_1)) \bullet (\psi(y_1) \bullet \vartheta(y_1))$
$= (\psi \times \vartheta)(\theta, y) \bullet (\psi \times \vartheta)(\theta_1,y_1)$
$= (\psi \times \vartheta)((\theta,y) *(\theta_1,y_1)) \bullet (\psi \times \vartheta)(\theta_1,y_1)$

(iii) $(\psi \times \vartheta)((\theta,y)*(\theta_1,y_1)) = (\psi \times \vartheta)((\theta*\theta_1),(y,y_1))$
$= \psi(\theta*\theta_1) \bullet \vartheta(y*y_1)$
$\leq ((\psi(\theta) \bullet \psi(\theta_1)) \bullet (\vartheta(y) \bullet \vartheta(y_1))$
$= (\psi(\theta) \bullet \vartheta(y)) \bullet (\psi(\theta_1) \bullet \vartheta(y_1))$
$= (\psi \times \vartheta)(\theta,y) * (\psi \times \vartheta)(\theta_1,y_1)$

Hence $\psi \times \vartheta$ is a fuzzy dot d-ideal of $\Theta \times \Theta$.

4.11 Theorem

Let ϕ be a fuzzy subset of a i*-algebra Θ and ϕ_ϑ be the strongest fuzzy ϕ-relation on i*-algebra Θ. Then ϕ is a fuzzy dot i*-ideal of Θ if and only if ϕ_ϑ is a fuzzy dot i*-ideal of $\Theta \times \Theta$.

Proof

Assume that ϕ is a fuzzy dot d-ideal of Θ.

For any $\theta, y \in \Theta$ we have $\vartheta_\phi (1, 1) = \phi(1) \cdot \phi(1)$
$\leq \phi(\theta) \cdot \phi(y)$
$= \vartheta_\phi (\theta, y)$.

Let $\theta, \theta', y, y' \in \Theta$.

Then $\vartheta_\phi ((\theta, \theta') * (y, y')) \cdot \vartheta_\phi (y, y') = \vartheta_\phi(\theta * y, \theta' * y') \cdot \vartheta_\phi(y, y')$
$= (\phi(\theta * y) \cdot \phi(\theta' * y')) \cdot (\phi(y) \cdot \phi(y'))$
$= (\phi(\theta * y) \cdot \phi(y)) \cdot (\phi(\theta' * y') \cdot \phi(y'))$
$\geq \phi(\theta) \cdot \phi(\theta')$
$= \vartheta_\phi (\theta, \theta')$.

and, $\vartheta_\phi (\theta, \theta') \cdot \vartheta_\phi (y, y') = (\phi(\theta) \cdot \phi(\theta')) \cdot (\phi(y) \cdot \phi(y'))$
$= (\phi(\theta) \cdot \phi(y)) \cdot (\phi(\theta') \cdot \phi(y'))$
$\geq \phi(\theta * y) \cdot \phi(\theta' * y')$
$= \vartheta_\phi (\theta * y, \theta' * y')$
$= \vartheta_\phi ((\theta, \theta') * (y, y'))$.

Thus ϑ_ϕ is a fuzzy dot i*-ideal of $\Theta \times \Theta$.

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Conversely suppose that ϑ_ϕ is a fuzzy dot i*-ideal of Θ×Θ.

$$(\phi(1))^2 = \phi(1)\cdot\phi(1) = \vartheta_\phi(1,1) \le \vartheta_\phi(\theta, \theta)$$
$$= \vartheta(\theta)\cdot\vartheta(\theta) = (\vartheta(\theta))^2$$

and so $\phi(1) \le \phi(\theta)$ for all $\theta \in \Theta$. Also we have

$$(\phi(\theta))^2 = \vartheta_\phi(\theta, \theta)$$
$$\le \vartheta_\phi((\theta, \theta) * (y, y)) \cdot \vartheta_\phi(y,y)$$
$$= \vartheta_\phi((\theta*y),(\theta*y)) \cdot \vartheta_\phi(y,y)$$
$$= \phi((\theta*y) \cdot \phi(y))^2$$

which implies that $\phi(\theta) \le \phi(\theta * y) \cdot \phi(y)$ for all $\theta, y \in \Theta$. Also we have

$$(\phi(\theta*y))^2 = \vartheta_\phi(\theta*y, \theta*y)$$
$$= \vartheta_\phi((\theta, \theta) * (y, y))$$
$$\le \vartheta_\phi(\theta, \theta) \cdot \vartheta_\phi(y, y)$$
$$= (\phi(\theta) \cdot \phi(y))^2.$$

So $\phi(\theta * y) \le \phi(\theta)\cdot\phi(y)$ for all $\theta, y \in \Theta$. Therefore ϕ is a fuzzy dot i*-ideal of Θ.

4.12 Theorem

Let ϑ be a left fuzzy relation on a fuzzy subset ϕ of a i*-algebra Θ. If ϑ is a fuzzy dot d-ideal of Θ× Θ, then ϕ is a fuzzy dot i*-ideal of a i*-algebra Θ.

Proof

Suppose that a left fuzzy relation ϑ on ϕ is a fuzzy dot i*-ideal of Θ× Θ.

Then $\phi(1) = \vartheta(1,z)$, $\forall z \in \Theta$.

By putting $z=1$

$$\phi(1) = \vartheta(1,1) \le \vartheta(\theta, y) = \phi(\theta), \text{ for all } \theta \in \Theta.$$

For any $\theta,\theta',y,y' \in \Theta$

$$\phi(\theta) = \vartheta(\theta, y) \le \vartheta((\theta, y)*(\theta', y')) . \vartheta(\theta', y')$$
$$= \vartheta((\theta*\theta'),(y*y')).\vartheta(\theta', y')$$
$$= \phi(\theta*\theta').\phi(\theta').$$

Also, $\phi(\theta*\theta') = \vartheta(\theta*\theta', y*y')$

$$= \vartheta((\theta, y) *(\theta', y'))$$
$$\le \vartheta(\theta, y) . \vartheta(\theta', y')$$
$$= \phi(\theta).\phi(\theta').$$

Thus ϕ is a fuzzy dot i*-ideal of a i*-algebra Θ.

5. Conclusion

In this paper a new type of i*-algebra has been defined. Also fuzzy dot subalgebra and fuzzy dot i*-ideal of i*-algebra introduced and its properties are derived successfully. The study is still going on for the further innovative results in this i*-algebra.

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