

# $\theta$ -Euclidean k-Fuzzy Ideals of Semirings

D.R Prince Williams

**Abstract**— In this paper, we introduce the notion  $\theta$ -Euclidean k-fuzzy ideal in semirings and to study the properties of the image and pre image of a  $\theta$ -Euclidean k-fuzzy ideal in a semirings under epimorphism.

**Keywords**—semiring, fuzzy ideal, k-fuzzy ideal,  $\theta$ -Euclidean L-fuzzy ideal,  $\theta$ -Euclidean fuzzy k-ideal,  $\theta$ -Euclidean k-fuzzy ideal.

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## I. INTRODUCTION

L.A. Zadeh [1] introduced the notion of a fuzzy subset  $\mu$  of a set  $X$  as a function from  $X$  into the closed unit interval  $[0,1]$ . The concept of fuzzy subgroups was introduced by A. Rosenfeld [2]. W.J. Liu [3] introduced and studied fuzzy ideals of rings. T.K. Dutta and B.K. Biswas [4] studied fuzzy ideals, fuzzy prime ideals of semirings and they defined fuzzy k-ideal and fuzzy prime k-ideals of semirings and characterized fuzzy prime k-ideals of semirings of non-negative integers and determined all its prime k-ideals. S.I. Baik and H.S Kim [6] studied more about the fuzzy k-ideals in semirings and investigated their properties. Y.B. Jun *et.al* [5] extended the concept of L-fuzzy ideal of rings to semirings. Ayten Koç, Erol Balkanay [7, 8] introduced a concept of  $\theta$ -Euclidean L-fuzzy ideals,  $\theta$ -Euclidean level subset in rings and studied the properties of ideals  $\theta$ -Euclidean L-fuzzy ideals,  $\theta$ -Euclidean level subset in rings. C.B Kim *et al* [10] introduce the k-fuzzy ideal of semirings and studied the properties of the image and pre image of a k-fuzzy ideal in semirings. C.B Kim [9] studied some isomorphism theorems and fuzzy k-ideals in k-semirings.

The purpose of this paper is to introduce  $\theta$ -Euclidean k-fuzzy ideals in semirings and to study the properties of the image and pre image of a  $\theta$ -Euclidean k-fuzzy ideal in a semiring under epimorphism. Also we prove the structural theorem for a  $\theta$ -Euclidean k-fuzzy ideal.

## II. PRELIMINARIES

An algebra  $(S; +, \cdot)$  is said to be a semiring if  $(S; +)$  and  $(S; \cdot)$  are semigroup satisfying  $a(b+c) = ab+ac$  and  $(b+c)a = ba+ca$ , for all  $a, b, c \in S$ . A semiring  $S$  may have an identity 1, defined by  $1.a = a = a.1$  and a zero 0, defined by  $0+a = a = a+0$  and  $a.0 = 0 = 0.a$  for all  $a \in S$ . A non-empty subset  $I$  of  $S$  is said to be left (*resp.*, right) ideal if  $x, y \in I$  and  $r \in S$  imply that  $x+y \in I$  and  $rx \in I$  (*resp.*,  $xr \in I$ ). If  $I$  is both left and right ideal of  $S$ , we say  $I$  is a two-sided ideal, or simply ideal, of  $S$ . A left ideal  $I$  of a semiring  $S$  is said to be a left k-ideal if  $a \in I$  and  $x \in S$  and if  $a+x \in I$  or  $x+a \in I$  then  $x \in I$ . Right k-ideal is defined dually, and two-sided k-ideal or simply a k-ideal is both a left and a right k-ideal.

**Definition 2.1** [10]: Let  $K$  and  $S$  be any sets and let  $f: K \rightarrow S$  be a function. A fuzzy subset  $\mu$  of  $K$  is called  $f$ -invariant if  $f(x) = f(y)$  implies  $\mu(x) = \mu(y)$ , where  $x, y \in K$ .

**Definition 2.2** [2]: A fuzzy subset  $\mu$  of a semiring  $S$  is said to be fuzzy left (*resp.*, right) ideal of  $S$  if

$$(i) \mu(x+y) \geq \min\{\mu(x), \mu(y)\} \text{ and}$$

$$(ii) \mu(xy) \geq \mu(y) \text{ (resp., } \mu(xy) \geq \mu(x))$$

for all  $x, y \in S$ . If  $\mu$  is a fuzzy ideal of  $S$  if it is both fuzzy left and a fuzzy right ideal of  $S$ .

**Definition 2.3** [10]: A fuzzy ideal  $\mu$  of a semiring  $S$  is said to be a k-fuzzy ideal of  $S$   $\mu(x+y) = \mu(0)$  and  $\mu(y) = \mu(0)$  imply  $\mu(x) = \mu(0)$ , for all  $x, y \in S$ .

**Definition 2.4** [8]: Let  $\theta: S \rightarrow [0,1]$  and  $\mu: S \rightarrow [0,1]$  be a fuzzy subsets of  $S$ . For any,  $0 \neq y \in S$  the set

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$$\mu_{\theta_y} = \left\{ x \in S \mid \text{there exists } q, r \in S \text{ such that } x = yq + r \right. \\ \left. \text{where either } r = 0 \text{ or else } \mu(r) \geq \max \{ \mu(y), \theta(y) \} \right\}$$

is called a  $\theta$ -Euclidean level subset of  $\mu$ .

## II. $\theta$ -EUCLIDEAN K-FUZZY IDEALS

**Definition 3.1:** Let  $S$  be a semiring and let  $\theta : S \rightarrow [0, 1]$  be a non-constant fuzzy subset of  $S$ . A fuzzy ideal  $\mu : S \rightarrow [0, 1]$  is called a  $\theta$ -Euclidean  $k$ -fuzzy ideal if  $\mu$  satisfies the following axioms

(i)  $\mu(x + y) = \mu(0)$  and  $\mu(y) = \mu(0)$  imply  $\mu(x) = \mu(0)$ , for all  $x, y$  in  $R$ .

(ii) For any  $x, y \in R$  with  $y \neq 0$ , there exists elements  $q, r \in R$  such that  $x = yq + r$ , where either  $r = 0$  or else  $\max \{ \mu(r), \theta(r) \} \geq \max \{ \mu(y), \theta(y) \}$ .

**Example 3.2:** Let  $S$  be the set of Natural Numbers including zero and  $\mu : S \rightarrow [0, 1]$  be a fuzzy subset defined by

$$\mu(a) = \begin{cases} 1 & \text{if } a = 0, \\ \frac{1}{3} & \text{if } a \text{ is non-zero even,} \\ 0 & \text{if } a \text{ is odd.} \end{cases}$$

Let  $\theta : S \rightarrow [0, 1]$  be a fuzzy subset defined by

$$\theta(a) = \begin{cases} 0 & \text{if } a = 0, \\ \frac{1}{3} & \text{if } a = 3, 5, 7, \dots \\ \frac{1}{|a|} & \text{otherwise.} \end{cases}$$

Clearly  $\mu$  is a  $k$ -fuzzy ideal of  $S$ , also  $\mu$  is a  $\theta$ -Euclidean  $k$ -fuzzy ideal of  $S$ .

**Example 3.3:** Let  $S$  be the set of Natural Numbers including zero and  $\mu : S \rightarrow [0, 1]$  be a fuzzy set defined by

$$\mu(a) = \begin{cases} 1 & \text{if } a = 0, \\ \frac{1}{3} & \text{if } a \text{ is non-zero even,} \\ 0 & \text{if } a \text{ is odd.} \end{cases}$$

Let  $\theta_1 : S \rightarrow [0, 1]$  be a fuzzy subset defined by

$$\theta_1(a) = \begin{cases} 0 & \text{if } a = 0 \\ \frac{1}{|a|} & \text{otherwise.} \end{cases}$$

So  $\mu$  is a  $k$ -fuzzy ideal but  $\mu$  is not a  $\theta_1$ -Euclidean  $k$ -fuzzy ideal of  $S$ .

**Theorem 3.4:** Let  $A$  be a non empty subset of  $S$ . Let  $\mu$  be a fuzzy subset of a semiring  $S$  such that  $\mu$  is into  $\{0, 1\}$ , so that  $\mu$  is the characteristic function of  $A$ . Then  $\mu$  is a  $\theta$ -Euclidean  $k$ -fuzzy ideal of a semiring  $S$  then  $A$  is a left ideal of  $S$ .

**Proof:** The proof is easy and straight forward.  $\square$

**Theorem 3.5:** Let  $\mu$  be a  $\theta$ -Euclidean  $k$ -fuzzy ideal of a semiring  $S$ . Then for  $0 \neq y \in S$ , (i)  $\mu_{\theta_y}$  is an ideal of  $S$

(ii)  $\theta_{\mu_y}$  is an ideal of  $S$ . and (iii)  $\mu_t$  is a  $\theta$ -Euclidean  $k$ -fuzzy ideal of  $S$ , for  $t \in [0, 1]$ .

**Proof:** The proof is similar to [8, Theorem 3.3].  $\square$

**Theorem 3.6:** Let  $\mu$  be a fuzzy ideal of a semiring  $S$ . If  $\mu_{\theta_y}$  and  $\theta_{\mu_y}$  is the Euclidean level set of  $\mu$  and  $\theta$  respectively. Then  $\mu$  is a  $\theta$ -Euclidean  $k$ -fuzzy ideal of a semiring  $S$ .

**Proof:** Suppose  $\mu$  is fuzzy ideal of semiring  $S$ . For  $x, y \in S$ , if  $\mu(x + y) = \mu(0)$  and  $\mu(y) = \mu(0)$ , then  $\mu(x + y) \geq \min \{ \mu(x), \mu(y) \}$ , since  $\mu$  is fuzzy ideal of  $S$ .

$$\mu(0) \geq \min \{ \mu(x), \mu(0) \}$$

$$\mu(x) = \mu(0).$$

Thus  $\mu$  is a  $k$ -fuzzy ideal of semiring  $S$ .

We have  $\mu_{\theta_y}$  and  $\theta_{\mu_y}$  is the Euclidean level set of  $\mu$  and  $\theta$  respectively. Then, for  $x, y \in S$ , with  $0 \neq y$ , there exists  $q, r \in S$  such that  $x = yq + r$  where either  $r = 0$  or else  $\mu(r) \geq \max \{ \mu(y), \theta(y) \}$  and  $\theta(r) \geq \max \{ \mu(y), \theta(y) \}$ .

Thus  $\max \{ \mu(r), \theta(r) \} \geq \max \{ \mu(y), \theta(y) \}$ .

Hence  $\mu$  is a  $\theta$ -Euclidean  $k$ -fuzzy ideal of a semiring  $S$ .  $\square$

**Definition 3.7** ([10]): Let  $f : S \rightarrow S'$  be a homomorphism of semirings. Let  $\mu$  be a fuzzy subset of  $S'$ . We define a fuzzy subset  $f^{-1}\mu$  of  $S$  by  $f^{-1}\mu(x) = \mu(f(x))$ , for all  $x \in S$

**Theorem 3.7:** Let  $f : S \rightarrow S'$  be an epimorphism of semirings and  $\mu$  be a fuzzy ideal of  $S'$ . Then  $\mu$  is a  $\theta$ -Euclidean  $k$ -fuzzy ideal of  $S'$  if and only if  $f^{-1}(\mu)$

is a  $f^{-1}(\theta)$ -Euclidean  $k$ -fuzzy ideal of fuzzy ideal of  $S$ .

**Proof:** Suppose  $\mu$  is a  $\theta$ -Euclidean  $k$ -fuzzy ideal of  $S'$ .

(i) For all  $x, y \in S'$

$$\begin{aligned} f^{-1}\mu(x+y) &= \mu(f(x+y)) = \mu(f(x) + f(y)) \\ &\geq \min\{\mu(f(x)), \mu(f(y))\} \\ &= \min\{f^{-1}\mu(x), f^{-1}\mu(y)\} \end{aligned}$$

(ii) For all  $x, y \in S'$

$$\begin{aligned} f^{-1}\mu(xy) &= \mu(f(xy)) = \mu(f(x)f(y)) \\ &\geq \max\{\mu(f(x)), \mu(f(y))\} \\ &= \max\{f^{-1}\mu(x), f^{-1}\mu(y)\} \end{aligned}$$

(iii) For all  $x, y \in S'$ , if  $f^{-1}\mu(x+y) = f^{-1}\mu(0)$

and  $f^{-1}\mu(y) = f^{-1}\mu(0)$  then

$$\begin{aligned} f^{-1}\mu(x) &= \mu(f(x)) = \mu(x) = \mu(0) \\ &= \mu(f(0)) = f^{-1}\mu(0). \end{aligned}$$

iv) We have  $\mu$  is a  $\theta$ -Euclidean  $k$ -fuzzy ideal of  $S'$ , then for

any  $x, y \in S$ , then  $f(x), f(y) \in S'$  there exists elements

$f(q), f(r) \in S'$  such that  $f(x) = f(y)f(q) + f(r)$  where either  $f(r) = 0$  or else

$$\max\{\mu(f(y)), \theta(f(y))\} \geq \max\{\mu(f(r)), \theta(f(r))\}.$$

That is  $f(x) = f(yq) + f(r)$  where either  $f(r) = 0$  or

else  $\max\{f^{-1}\mu(y), f^{-1}\theta(y)\} \geq \max\{f^{-1}\mu(r), f^{-1}\theta(r)\}.$

Thus  $f(x) = f(yq + r)$  where either  $f(r) = 0$  or else

$$\max\{f^{-1}\mu(y), f^{-1}\theta(y)\} \geq \max\{f^{-1}\mu(r), f^{-1}\theta(r)\}.$$

Hence for any  $x, y \in S$  there exists elements  $q, r \in S$  such

that  $x = yq + r$  where either  $r = 0$  or else

$$\max\{f^{-1}\mu(y), f^{-1}\theta(y)\} \geq \max\{f^{-1}\mu(r), f^{-1}\theta(r)\}.$$

Conversely, suppose  $f^{-1}(\mu)$  is a  $\theta$ -Euclidean  $k$ -fuzzy ideal of  $S$ .

(i) For any  $x, y \in S$  then  $a = f(x), b = f(y) \in S'$ .

$$\begin{aligned} \mu(a+b) &= \mu(f(x) + f(y)) = \mu(f(x+y)) \\ &= f^{-1}\mu(x+y) \\ &\geq \min\{f^{-1}\mu(x), f^{-1}\mu(y)\} \\ &= \min\{\mu(f(x)), \mu(f(y))\} \\ &= \max\{\mu(a), \mu(b)\}. \end{aligned}$$

(ii) For any  $x, y \in S$  then  $a = f(x), b = f(y) \in S'$ .

$$\begin{aligned} \mu(ab) &= \mu(f(x)f(y)) = \mu(f(xy)) = f^{-1}\mu(xy) \\ &\geq \max\{f^{-1}\mu(x), f^{-1}\mu(y)\} \\ &= \max\{\mu(f(x)), \mu(f(y))\} \\ &= \max\{\mu(a), \mu(b)\}. \end{aligned}$$

(iii) For any  $x, y \in S$  then  $a = f(x), b = f(y) \in S'$ , if  $\mu(a+b) = \mu(0)$  and  $\mu(b) = \mu(0)$  imply

$$\mu(a) = \mu(f(x)) = f^{-1}\mu(x) = f^{-1}\mu(0) = \mu(f(0)) = \mu(0)$$

(iv) For any  $x, y, q, r \in S$  then

$$a = f(x), b = f(y), c = f(q), d = f(r) \in S'.$$

We have  $f^{-1}(\mu)$  is a  $\theta$ -Euclidean  $k$ -fuzzy ideal of fuzzy ideal of  $S$ , then there exists  $q, r \in S$  such that  $x = yq + r$  either  $r = 0$  or else

$$\max\{f^{-1}\mu(y), f^{-1}\theta(y)\} \geq \max\{f^{-1}\mu(r), f^{-1}\theta(r)\}.$$

That is  $f(x) = f(yq + r)$  either  $f(r) = 0$  or else

$$\max\{\mu(f(y)), \theta(f(y))\} \geq \max\{\mu(f(r)), \theta(f(r))\}.$$

that is  $f(x) = f(y)f(q) + f(r)$  either  $f(r) = 0$  or else

$$\max\{\mu(f(y)), \theta(f(y))\} \geq \max\{\mu(f(r)), \theta(f(r))\}.$$

Thus there exists  $c, d \in S'$  such that  $a = bc + d$  either

$$r = 0 \text{ or else } \max\{\mu(c), \theta(c)\} \geq \max\{\mu(d), \theta(d)\}. \quad \square$$

**Definition 3.8:** Let  $f: S \rightarrow S'$  be an homomorphism of the semirings. Let  $\mu$  be a fuzzy subset of  $S$ . we define a fuzzy subset  $f(\mu)$  of  $S'$  by

$$f(\mu)(y) = \begin{cases} \sup\{\mu(t) \mid t \in S, f(t) = y\} & \text{if } f^{-1}(y) \neq \emptyset \\ 0 & \text{if } f^{-1}(y) = \emptyset \end{cases}$$

**Theorem 3.9:** Let  $f: S \rightarrow S'$  epimorphism of semirings. Let  $\mu$  be a  $f$ -invariant  $\theta$ -Euclidean  $k$ -fuzzy ideal of  $S$ . Then  $f(\mu)$  is  $f(\theta)$ -Euclidean  $k$ -fuzzy ideal of  $S'$ .

**Proof:** Suppose  $x, y \in S'$  such that  $x = f(a), y = f(b)$ , for all  $a, b \in S$ . Then  $x + y = f(a) + f(b) = f(a+b)$  and  $xy = f(a)f(b) = f(ab)$ . Since  $\mu$  is  $f$ -invariant

Thus

$$\begin{aligned} (i) \quad f(\mu)(x+y) &= f(\mu)f(a+b) \\ &= \sup\{\mu(t) \mid t \in S, f(t) = f(a+b)\} \end{aligned}$$

$$\begin{aligned}
&= \sup \{ \mu(t) \mid t \in S, \mu(t) = \mu(a+b) \} \\
&= \mu(a+b) \\
&\geq \min \{ \mu(a), \mu(b) \},
\end{aligned}$$

since  $\mu$  is a  $k$ -fuzzy ideal of  $S$ .

$$\begin{aligned}
&= \min \{ \mu(f^{-1}(x)), \mu(f^{-1}(y)) \} \\
&= \min \{ f(\mu)(x), f(\mu)(y) \}.
\end{aligned}$$

$$\begin{aligned}
(ii) \quad f(\mu)(xy) &= f(\mu)f(ab) = \mu(ab) \\
&\geq \max \{ \mu(a), \mu(b) \},
\end{aligned}$$

since  $\mu$  is a  $k$ -fuzzy ideal of  $S$ .

$$\begin{aligned}
&= \max \{ \mu(f^{-1}(x)), \mu(f^{-1}(y)) \} \\
&= \max \{ f(\mu)(x), f(\mu)(y) \}.
\end{aligned}$$

$$\begin{aligned}
(iii) \quad \text{If } f(\mu)(x+y) &= f(\mu)(0) \text{ and } \\
f(\mu)(y) &= f(\mu)(0) \text{ imply that} \\
f(\mu)(x) &= f(\mu)(f(a)) = \mu(a) \\
&= \mu(0) = \mu(f^{-1}(0)) = f(\mu)(0).
\end{aligned}$$

(iv) We have  $\mu$  is  $f$ -invariant  $\theta$ -Euclidean  $k$ -fuzzy ideal of  $S$ . If  $a, b, c, d \in S$  then  $x = f(a)$ ,  $y = f(b)$ ,  $q = f(c)$ ,  $r = f(d)$ , for all  $x, y, q, r \in S'$ . Then for any  $a, b \in S$  there exists elements  $c, d \in S$ , such that  $a = bc + d$ , where either  $d = 0$  or else

$$\max \{ \mu(b), \theta(b) \} \geq \max \{ \mu(d), \theta(d) \}.$$

That is,  $f(a) = f(bc + d)$ ,

$$\text{thus } f(a) = f(b)f(c) + f(d),$$

Thus  $x = yq + r$ . Let  $d = 0$ .

Then  $f(d) = f(0) = 0$ . We get  $r = 0$ .

Finally, we have

$$\max \{ \mu(b), \theta(b) \} \geq \max \{ \mu(d), \theta(d) \},$$

Since  $\mu$  is  $f$ -invariant.

$$\begin{aligned}
f(\mu)(y) &= f(\mu)f(b) = \sup \{ \mu(t) \mid t \in R, f(t) = f(b) \} \\
&= \sup \{ \mu(t) \mid t \in R, \mu(t) = \mu(b) \} \\
&= \mu(b)
\end{aligned}$$

so that  $\max \{ \mu(b), \theta(b) \} \geq \max \{ \mu(d), \theta(d) \}$  then

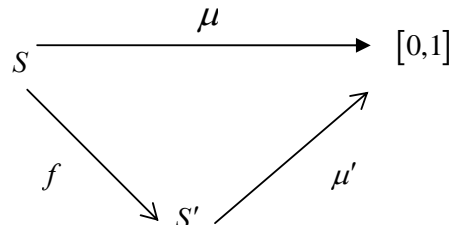
$$\max \{ f(\mu)(y), f(\theta)(y) \} \geq \max \{ f(\mu)(r), f(\theta)(r) \}.$$

Hence  $f(\mu)$  is a  $f(\theta)$ -Euclidean  $k$ -fuzzy ideal of  $S'$ .

**Theorem 3.10:** Let  $f: S \rightarrow S'$  be an isomorphism of the semirings and  $\mu': S' \rightarrow [0,1]$  be a  $\theta$ -Euclidean  $k$ -fuzzy ideal of  $S'$ . Then  $\mu' \circ f: S \rightarrow [0,1]$  is a  $(\theta' \circ f)$ -Euclidean

$k$ -fuzzy ideal of  $S$ . Here, we mean that  $(\mu' \circ f)(x) = \mu'[f(x)]$ .

**Proof:** Let  $\mu = \mu' \circ f, \theta = \theta' \circ f$  and also  $a, b \in S$  and  $\mu'$  is an  $\theta$ -Euclidean  $k$ -fuzzy ideal of  $S'$ .



It was proved that  $\mu$  is a fuzzy ideal of  $S$  [5] and  $\mu$  is a  $\theta$ -Euclidean fuzzy ideal of  $S$  [7].

If  $\mu(a+b) = \mu(0)$  and  $\mu(b) = \mu(0)$ , then

$$\begin{aligned}
\mu(a) &= \mu' \circ f(a) = \mu'(f(a)) = \mu'(0). \text{ Since } \mu' \text{ is an} \\
&\theta\text{-Euclidean } k\text{-fuzzy ideal of } S'. \\
&= \mu'(f(0)) \\
&= \mu' \circ f(0) \\
&= \mu(0)
\end{aligned}$$

Hence  $\mu' \circ f: S \rightarrow [0,1]$  is a  $(\theta' \circ f)$ -Euclidean  $k$ -fuzzy ideal of  $S$ .  $\square$

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