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Applications of Soft Intersection Sets in Hypernear Rings

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Abstract: In this paper, we introduce soft intersection hypernear ring and shows how a soft set effects on a hypernear ring structure by means of intersection and insertion of sets. Further, we explore some properties using hypernear ring theoretic concepts for soft sets. Moreover, we have defined the cross product of two soft intersection hypernear rings. We proved that the cross product of two soft intersection hypernear rings is a soft intersection hypernear ring and the cross product of two soft intersection hyperideals is a soft intersection hyperideal.
Keywords: Hypernear rings, Soft intersection sets, Soft intersection hyperideals.

1 Introduction

Molodtsov introduced the concept of soft set theory for dealing uncertainty. His classical paper [14] has been used by many authors to generalize some of the basic notions of algebra. Cagman and Aktas [3] proposed the concept of soft algebraic structure. They introduced soft group theory and define soft group which is analogous to the fuzzy sets. Cagman et al. [5] gave a new approach to define soft group definition called soft intersection group. This approach depends on the insertion and intersection of sets. Many authors studied different aspects of soft set theory for instance, Adeel et al. [1], Gulistan et al. [10], Khan et al. [11], Sezgin et al. [16] and Yaqoob et al. [18]. Marty [13] introduced the notion of algebraic hyperstructures as a natural extension of classical algebraic structures. Numerous applications of hyperstructures was presented by Corsini and Leoreanu [6].

Hypernearrings is the generalization of the the concept of near-rings [15], which was introduced by Dasic [7]. In the hyperoperation $+$ is defined on the set R instead of the operation $+$ in the near-ring, which is a map from $R \times R$ to $P^*(R)$, where $P^*(R)$ is the set of all the non-empty subsets of R. Yamak [17] et al. defined fuzzy hyperideals in hypernear-rings and Zhan [19] defined fuzzy hyperideals in hypernear-rings with $t-$norms.

1.1 *Hypernear Ring*

Definition 1.1. [6]-[8] Let $\mathbf{N}$ be a non-empty set and let $\wp^*(\mathbf{N})$ be the set of all non-empty subsets of $\mathbf{N}$. A hyperoperation on $\mathbf{N}$ is a map $o : \mathbf{N} \times \mathbf{N} \to \wp^*(\mathbf{N})$ and $(\mathbf{N}, o)$ is called a hypergroupoid.

Definition 1.2. [7] An algebraic structure $(\mathbf{N}, +, \cdot)$ is said to be a hypernear ring if it satisfies the following axioms:
(1) $(\mathbf{N}, +)$ is a hypergroup.
(2) $(\mathbf{N}, \cdot)$ is a semigroup having a bilaterally absorbing element 0, i.e., $u \cdot 0 = 0 \cdot u = 0$ for all $u \in \mathbf{N}$.
(3) The multiplication is distributive with respect to the hyperoperation $+$ on the left side, i.e., $u \cdot (v + w)$ = $u \cdot v + u \cdot w$ for all $u, v, w \in \mathbf{N}$.

Example 1.1. [12] Let $\mathbf{N}$ = $\{0, a, b, c\}$ with a hyperoperation $'+'$ and a binary operation $'\cdot'$ as follows:

$+$	0	a	b	c
0	{0}	{a}	{b}	{c}
a	{a}	{0, a}	{b}	{c}
b	{b}	{b}	{0, a, c}	{b, c}
c	{c}	{c}	{b,c}	{0, a, b}

$\cdot$	0	a	b	c
0	0	a	b	c
a	0	a	b	c
b	0	a	b	c
c	0	a	b	c

Then $(\mathbf{N}, +, \cdot)$ is a hypernear ring.

Example 1.2. [17] Let $\mathbf{N}$ = $\{0, 1, 2\}$ with a hyperoperation $'+'$ and a binary operation $'\cdot'$ as follows:

$+$	0	1	2
0	$\{0\}$	$\{1\}$	$\{2\}$
1	$\{1\}$	$\{0\}$	$\{2\}$
2	$\{2\}$	$\{2\}$	$\{0,1\}$

$\cdot$	0	1	2
0	0	0	0
1	0	0	0
2	0	0	0

Then $(\mathbf{N}, +, \cdot)$ is a hypernear ring.

Definition 1.3. [9] A subset A of $\mathbf{N}$ is said to be normal if it is subhypergroup and for all $u \in \mathbf{N}$, we have $u + A - u \subseteq A$.

Definition 1.4. [9] A subset A is said to be a hyperideal of the hypergroup $(\mathbf{N}, +)$ if A is normal subhypergroup and $(u + A) \cdot v - u \cdot v \cup w \cdot A \subseteq A$ for all $u, v, w \in \mathbf{N}$.

Note that for all

$$u, v \in R, \text{ we have } -(-u) = u,\ 0 = -0,\ 0 \text{ is unique, and } -(u + v) = -v - u.$$

1.2 Soft Sets

Definition 1.5. [4]-[14] Let E be a set of parameters such that $A \subseteq E$ and $\mathcal{U}$ be a set of initial universe. Then a soft set $\mathcal{F}_A$ over $\mathcal{U}$ is a parameterized family of subsets of the set $\mathcal{U}$ which is defined by $\mathcal{F}_A : E \to P(\mathcal{U})$ and represented by the set of ordered pairs

$$\mathcal{F}_A = \{(u,\ \mathcal{F}_A(u))\ :\ u \in E,\ \mathcal{F}_A(u) \in P(\mathcal{U})\} \text{ and } \mathcal{F}_A(u) = \emptyset \text{ if } x \notin A.$$

Here $\mathcal{F}_A$ is also called an approximate function.

Definition 1.6. [4] Let $\mathcal{F}_A$ and $\mathcal{F}_B$ be two soft sets. Then, $\mathcal{F}_A$ is called a soft subset of $\mathcal{F}_B$ and denoted by $\mathcal{F}_A \sqsubseteq \mathcal{F}_B$, if $\mathcal{F}_A(u) \subseteq \mathcal{F}_B(u)$ for all $u \in E$.

Definition 1.7. [4] Let $\mathcal{F}_A$ and $\mathcal{F}_B$ be two soft sets. Then, $\mathcal{F}_A \widetilde{\bigcup} \mathcal{F}_B$, is defined as $\mathcal{F}_A \widetilde{\bigcup} \mathcal{F}_B = \mathcal{F}_{A \widetilde{\cup} B}$, where $\mathcal{F}_{A \widetilde{\cup} B} = \mathcal{F}_A(u) \bigcup \mathcal{F}_B(u)$ and $\mathcal{F}_A \widetilde{\bigcap} \mathcal{F}_B$, is defined as $\mathcal{F}_A \widetilde{\bigcap} \mathcal{F}_B = \mathcal{F}_{A \widetilde{\cap} B}$, where $\mathcal{F}_{A \widetilde{\cap} B} = \mathcal{F}_A(u) \bigcap \mathcal{F}_B(u)$ for all $u \in E$.

2 Soft Intersection Hypernear Rings

In this section, we introduce soft intersection hypernear ring (briefly, S.I. hypernear ring). Then, we define S.I. hyperideal of a hypernear ring and investigated their related properties using soft set operations.

Definition 2.1. A non-null soft set $\mathcal{F}_{\mathbf{N}}$ is said to be an soft intersection(briefly, S.I.) hypernear ring of $\mathbf{N}$ over $\mathcal{U}$ if it satisfies the following conditions:

(1) $\bigcap\limits_{\vartheta \in u + v} \mathcal{F}_{\mathbf{N}}(\vartheta) \supseteq \mathcal{F}_{\mathbf{N}}(u) \cap \mathcal{F}_{\mathbf{N}}(v)$;
(2) $\mathcal{F}_{\mathbf{N}}(-u) = \mathcal{F}_{\mathbf{N}}(u)$;
(3) $\mathcal{F}_{\mathbf{N}}(u \cdot v) \supseteq \mathcal{F}_{\mathbf{N}}(v), \forall\, u, v \in \mathbf{N}$.

Example 2.1. Consider a hypernear ring $\{\mathbf{N}, +, \cdot\}$ from the Example 1.1. Let $\mathcal{U} = \{x, y, z, w\}$. Define a soft set $\mathcal{F}_{\mathbf{N}} : \mathbf{N} \longrightarrow P(\mathcal{U})$ by

$$\mathcal{F}_{\mathbf{N}}(0) = \{x, y, z, w\},\ \mathcal{F}_{\mathbf{N}}(a) = \{x, y, z\} \text{ and } \mathcal{F}_{\mathbf{N}}(b) = \{x, y\}$$
$$\mathcal{F}_{\mathbf{N}}(c) = \{x, y\}.$$

Then we can verify that $\mathcal{F}_{\mathbf{N}}$ is an S.I. hypernear ring of $\mathbf{N}$ over $\mathcal{U}$.

Lemma 2.1. Let $\mathcal{F}_{\mathbf{N}}$ be an S.I. hypernear ring of $\mathbf{N}$ over $\mathcal{U}$. Then $\mathcal{F}_{\mathbf{N}}(0) \supseteq \mathcal{F}_{\mathbf{N}}(u)$ for all $u \in \mathbf{N}$.

Proof: Proof is straightforward. □

Theorem 1. *Let $\mathbf{N}$ be a hypernear ring and $\mathcal{F}_{\mathbf{N}}$ be a soft set over $\mathcal{U}$. Then, $\mathcal{F}_{\mathbf{N}}$ is an S.I. hypernear ring over $\mathcal{U}$ if and only if*

(1) $\bigcap\limits_{\vartheta \in (u - v)} \mathcal{F}_{\mathbf{N}}(\vartheta) \supseteq \mathcal{F}_{\mathbf{N}}(u) \cap \mathcal{F}_{\mathbf{N}}(v)$
(2) $\mathcal{F}_{\mathbf{N}}(u \cdot v) \supseteq \mathcal{F}_{\mathbf{N}}(u) \cap \mathcal{F}_{\mathbf{N}}(v), \forall\, u, v \in \mathbf{N}$.

Proof: Let $\mathcal{F}_{\mathbf{N}}$ be an S.I. hypernear ring over $\mathcal{U}$. Then $\mathcal{F}_{\mathbf{N}}(u \cdot v) \supseteq \mathcal{F}_{\mathbf{N}}(u) \cap \mathcal{F}_{\mathbf{N}}(v)$ and

$$\begin{aligned} \bigcap_{\vartheta \in (u - v)} \mathcal{F}_{\mathbf{N}}(\vartheta) &\supseteq \mathcal{F}_{\mathbf{N}}(u) \cap \mathcal{F}_{\mathbf{N}}(-v) \\ &= \mathcal{F}_{\mathbf{N}}(u) \cap \mathcal{F}_{\mathbf{N}}(v) \end{aligned}$$

$\forall\, u, v \in \mathbf{N}$. □

Lemma 2.2. Let $\mathbf{N}$ be a hypernear ring. If $\mathcal{F}_{\mathbf{N}}$ is an S.I. hypernear ring over $\mathcal{U}$. Then, $\mathcal{F}_{\mathbf{N}}(-v) \supseteq \mathcal{F}_{\mathbf{N}}(v)$ for any $v \in \mathbf{N}$.

Proof: Let $\mathcal{F}_{\mathbf{N}}$ be an S.I. hypernear ring over $\mathcal{U}$. Then, we have

$$\begin{aligned} \mathcal{F}_{\mathbf{N}}(-v) &\supseteq \bigcap_{\vartheta \in (0-v)} \mathcal{F}_{\mathbf{N}}(\vartheta) \\ &\supseteq \mathcal{F}_{\mathbf{N}}(0) \cap \mathcal{F}_{\mathbf{N}}(v) \\ &= \mathcal{F}_{\mathbf{N}}(v). \end{aligned}$$

Hence, $\mathcal{F}_{\mathbf{N}}(-v) \supseteq \mathcal{F}_{\mathbf{N}}(v)$. □

Theorem 2. *Let $\mathbf{N}$ be a hypernear ring and $\mathcal{F}_{\mathbf{N}}$ an S.I. hypernear ring over $\mathcal{U}$. If $\bigcap_{\vartheta \in (u+v)} \mathcal{F}_{\mathbf{N}}(\vartheta) = \mathcal{F}_{\mathbf{N}}(0)$ for any $u, v \in \mathbf{N}$. Then $\mathcal{F}_{\mathbf{N}}(u) = \mathcal{F}_{\mathbf{N}}(v)$.*

Proof: Suppose that $\mathcal{F}_{\mathbf{N}}$ is an S.I. hypernear ring over $\mathcal{U}$ and $\bigcap_{\vartheta \in (u+v)} \mathcal{F}_{\mathbf{N}}(\vartheta) = \mathcal{F}_{\mathbf{N}}(0)$ for any $u, v \in \mathbf{N}$. Then, we have

$$\begin{aligned} \mathcal{F}_{\mathbf{N}}(u) &\supseteq \bigcap_{\vartheta \in (0+u)} \mathcal{F}_{\mathbf{N}}(\vartheta) \\ &\supseteq \bigcap_{\vartheta \in (u+v-v)} \mathcal{F}_{\mathbf{N}}(\vartheta) \\ &= \bigcap_{\vartheta \in ((u+v)-v)} \mathcal{F}_{\mathbf{N}}(\vartheta) \\ &\supseteq \bigcap_{\vartheta \in (u+v)} \mathcal{F}_{\mathbf{N}}(\vartheta) \cap \mathcal{F}_{\mathbf{N}}(v) \\ &= \mathcal{F}_{\mathbf{N}}(0) \cap \mathcal{F}_{\mathbf{N}}(v) \\ &= \mathcal{F}_{\mathbf{N}}(v) \end{aligned}$$

and

$$\begin{aligned} \mathcal{F}_{\mathbf{N}}(v) &\supseteq \bigcap_{\vartheta \in (0+v)} \mathcal{F}_{\mathbf{N}}(\vartheta) \\ &\supseteq \bigcap_{\vartheta \in ((-u+u)+v)} \mathcal{F}_{\mathbf{N}}(\vartheta) \\ &= \bigcap_{\vartheta \in (-u+(u+v)} \mathcal{F}_{\mathbf{N}}(\vartheta) \\ &\supseteq \mathcal{F}_{\mathbf{N}}(-u) \cap \bigcap_{\vartheta \in (u+v)} \mathcal{F}_{\mathbf{N}}(\vartheta) \\ &= \mathcal{F}_{\mathbf{N}}(-u) \cap \mathcal{F}_{\mathbf{N}}(0) \\ &= \mathcal{F}_{\mathbf{N}}(-u) \\ &= \mathcal{F}_{\mathbf{N}}(u). \end{aligned}$$

Therefore, $\mathcal{F}_{\mathbf{N}}(u) = \mathcal{F}_{\mathbf{N}}(v)$. □

Corollary 1. *Let $\mathbf{N}$ be a hypernear ring and $\mathcal{F}_{\mathbf{N}}$ an S.I. hypernear ring over $\mathcal{U}$. If $\bigcap_{\vartheta \in (u-v)} \mathcal{F}_{\mathbf{N}}(\vartheta) = \mathcal{F}_{\mathbf{N}}(0)$ for any $u, v \in \mathbf{N}$. Then $\mathcal{F}_{\mathbf{N}}(u) = \mathcal{F}_{\mathbf{N}}(v)$.*

Theorem 3. *Let $\mathbf{N}$ be a hypernear ring and $\mathcal{F}_{\mathbf{N}}$ an S.I. hypernear ring over $\mathcal{U}$. Then for $u \in \mathbf{N}$*

$$\mathcal{F}_{\mathbf{N}}(u) = \mathcal{F}_{\mathbf{N}}(0) \text{ if and only if } \bigcap_{\vartheta \in (u+v)} \mathcal{F}_{\mathbf{N}}(\vartheta) = \bigcap_{\vartheta \in (v+u)} \mathcal{F}_{\mathbf{N}}(\vartheta) = \mathcal{F}_{\mathbf{N}}(v) \ \forall\, v \in \mathbf{N}.$$

Proof: Assume $\bigcap_{\vartheta \in (u+v)} \mathcal{F}_{\mathbf{N}}(\vartheta) = \bigcap_{\vartheta \in (v+u)} \mathcal{F}_{\mathbf{N}}(\vartheta) = \mathcal{F}_{\mathbf{N}}(v)\ \forall\, v \in \mathbf{N}$. By putting $v = 0$, we have $\bigcap_{\vartheta \in (u+0)} \mathcal{F}_{\mathbf{N}}(\vartheta) = \mathcal{F}_{\mathbf{N}}(0)$. It implies $\mathcal{F}_{\mathbf{N}}(u) = \mathcal{F}_{\mathbf{N}}(0)$.

Conversely, suppose that $\mathcal{F}_{\mathbf{N}}(u) = \mathcal{F}_{\mathbf{N}}(0)$. By Lemma 2.1, we have $\mathcal{F}_{\mathbf{N}}(0) \supseteq \mathcal{F}_{\mathbf{N}}(u) \supseteq \mathcal{F}_{\mathbf{N}}(v)\ \forall\, v \in \mathbf{N}$. Thus, we have

$$\begin{aligned} \bigcap_{\vartheta \in u\,+\,v} \mathcal{F}_{\mathbf{N}}(\vartheta) &\supseteq \mathcal{F}_{\mathbf{N}}(u) \cap \mathcal{F}_{\mathbf{N}}(v) \\ &\supseteq \mathcal{F}_{\mathbf{N}}(v)\ \forall\, v \in \mathbf{N}. \end{aligned} \tag{1}$$

Now

$$\begin{aligned}
\mathcal{F}_{\mathbf{N}}(v) &= \bigcap_{\vartheta \in 0\,+\,v} \mathcal{F}_{\mathbf{N}}(\vartheta) \\
&\supseteq \bigcap_{\vartheta \in (-u+u)\,+\,v} \mathcal{F}_{\mathbf{N}}(\vartheta) \\
&= \bigcap_{\vartheta \in -u\,+\,(u\,+\,v)} \mathcal{F}_{\mathbf{N}}(\vartheta) \\
&\supseteq \mathcal{F}_{\mathbf{N}}(-u) \cap \bigcap_{\vartheta \in u\,+\,v} \mathcal{F}_{\mathbf{N}}(\vartheta) \\
&\supseteq \mathcal{F}_{\mathbf{N}}(u) \cap \bigcap_{\vartheta \in u\,+\,v} \mathcal{F}_{\mathbf{N}}(\vartheta). \qquad (2)
\end{aligned}$$

As $\mathcal{F}_{\mathbf{N}}(u) \supseteq \mathcal{F}_{\mathbf{N}}(v)\ \forall\, v \in \mathbf{N}$. It implies that $\mathcal{F}_{\mathbf{N}}(u) \supseteq \mathcal{F}_{\mathbf{N}}(\vartheta)\ \forall\, \vartheta \in u\,+\,v$. Therefore, $\mathcal{F}_{\mathbf{N}}(u) \supseteq \bigcap_{\vartheta \in u\,+\,v} \mathcal{F}_{\mathbf{N}}(\vartheta)$. Hence, from (2)

$$\mathcal{F}_{\mathbf{N}}(v) \supseteq \bigcap_{\vartheta \in u\,+\,v} \mathcal{F}_{\mathbf{N}}(\vartheta). \qquad (3)$$

Now from (1) and (3), we have

$$\mathcal{F}_{\mathbf{N}}(v) = \bigcap_{\vartheta \in u\,+\,v} \mathcal{F}_{\mathbf{N}}(\vartheta). \qquad (4)$$

Also, we have

$$\begin{aligned}
\bigcap_{\vartheta \in v\,+\,u} \mathcal{F}_{\mathbf{N}}(\vartheta) &= \bigcap_{\vartheta \in (v\,+\,u)\,+\,0} \mathcal{F}_{\mathbf{N}}(\vartheta) \\
&\supseteq \bigcap_{\vartheta \in (v\,+\,u)\,+\,(v-v)} \mathcal{F}_{\mathbf{N}}(\vartheta) \\
&= \bigcap_{\vartheta \in (v\,+\,(u\,+\,v))\,-\,v} \mathcal{F}_{\mathbf{N}}(\vartheta) \\
&\supseteq \mathcal{F}_{\mathbf{N}}(v) \cap \bigcap_{\vartheta \in u\,+\,v} \mathcal{F}_{\mathbf{N}}(\vartheta) \cap \mathcal{F}_{\mathbf{N}}(v) \\
&= \mathcal{F}_{\mathbf{N}}(v) \cap \bigcap_{\vartheta \in u\,+\,v} \mathcal{F}_{\mathbf{N}}(\vartheta) \\
&= \mathcal{F}_{\mathbf{N}}(v).
\end{aligned}$$

and

$$\begin{aligned}
\mathcal{F}_{\mathbf{N}}(v) &= \bigcap_{\vartheta \in v\,+\,0} \mathcal{F}_{\mathbf{N}}(\vartheta) \\
&= \bigcap_{\vartheta \in v\,+\,(u\,-\,u)} \mathcal{F}_{\mathbf{N}}(\vartheta) \\
&= \bigcap_{\vartheta \in (v\,+\,u)\,-\,u} \mathcal{F}_{\mathbf{N}}(\vartheta) \\
&\supseteq \bigcap_{\vartheta \in v\,+\,u} \mathcal{F}_{\mathbf{N}}(\vartheta) \cap \mathcal{F}_{\mathbf{N}}(u) \\
&= \bigcap_{\vartheta \in v\,+\,u} \mathcal{F}_{\mathbf{N}}(\vartheta).
\end{aligned}$$

Therefore,

$$\mathcal{F}_{\mathbf{N}}(v) = \bigcap_{\vartheta \in v\,+\,u} \mathcal{F}_{\mathbf{N}}(\vartheta). \qquad (5)$$

From (4) and (5), we have $\bigcap_{\vartheta \in u\,+\,v} \mathcal{F}_{\mathbf{N}}(\vartheta) = \bigcap_{\vartheta \in v\,+\,u} \mathcal{F}_{\mathbf{N}}(\vartheta) = \mathcal{F}_{\mathbf{N}}(v)\ \forall\, v \in \mathbf{N}$. $\square$

Definition 2.2. Let $\mathbf{N}$ be a hypernear ring and $\mathcal{F}_{\mathbf{N}}$ an S.I. hypernear ring of $\mathbf{N}$ over $\mathcal{U}$. Then $\mathcal{F}_{\mathbf{N}}$ is called an S.I. hyperideal of $\mathbf{N}$ over $\mathcal{U}$ if it satisfies the following conditions:

(1) $\bigcap_{\vartheta \in u\,+\,v\,-\,u} \mathcal{F}_{\mathbf{N}}(\vartheta) \supseteq \mathcal{F}_{\mathbf{N}}(v)$,
(2) $\mathcal{F}_{\mathbf{N}}(uv) \supseteq \mathcal{F}_{\mathbf{N}}(u)$, and
(3) $\bigcap_{\vartheta \in (u\cdot(v\,+\,w)\,-\,u\cdot v)} \mathcal{F}_{\mathbf{N}}(\vartheta) \supseteq \mathcal{F}_{\mathbf{N}}(w),\ \forall\, u, v, w \in \mathbf{N}$.

If $\mathcal{F}_{\mathbf{N}}$ is an S.I. hypernear ring of $\mathbf{N}$ over $\mathcal{U}$ such that $\mathcal{F}_{\mathbf{N}}$ satisfied the condition (1) and (2), then $\mathcal{F}_{\mathbf{N}}$ is called an S.I. right hyperideal of $\mathbf{N}$ over $\mathcal{U}$ and if $\mathcal{F}_{\mathbf{N}}$ satisfied the condition (1) and (3), then $\mathcal{F}_{\mathbf{N}}$ is called an S.I. left hyperideal of $\mathbf{N}$ over $\mathcal{U}$

Example 2.2. Consider a hypernear ring $\{\mathbf{N}, +, \cdot\}$ from the Example 1.2. Let $\mathcal{U} = \{x, y, z\}$. Define a soft set $\mathcal{F}_{\mathbf{N}} : \mathbf{N} \longrightarrow P(\mathcal{U})$ by

$$\mathcal{F}_{\mathbf{N}}(0) = \{x, y, z\}, \mathcal{F}_{\mathbf{N}}(1) = \{x, y\} \text{ and } \mathcal{F}_{\mathbf{N}}(2) = \{x, y\}.$$

Then we can verify that $\mathcal{F}_{\mathbf{N}}$ is an S.I. hyperideal of $\mathbf{N}$ over $\mathcal{U}$.

Theorem 4. *If $\mathcal{G}_{\mathbf{N}}$, $\mathcal{K}_{\mathbf{N}}$ are two S.I. hypernear rings over $\mathcal{U}$. Then $\mathcal{G}_{\mathbf{N}}\tilde{\bigcap}\mathcal{K}_{\mathbf{N}}$ is an S.I. hypernear ring over $\mathcal{U}$.*

Proof: Let $x, y \in \mathbf{N}$. Then,

$$\begin{aligned}
\bigcap_{\vartheta\in u-v} (\mathcal{G}_{\mathbf{N}}\tilde{\bigcap}\mathcal{K}_{\mathbf{N}})(\vartheta) &= \bigcap_{\vartheta\in u-v} \left[\mathcal{G}_{\mathbf{N}}(\vartheta) \cap \mathcal{K}_{\mathbf{N}}(\vartheta)\right] \\
&= \bigcap_{\vartheta\in u-v} \mathcal{G}_{\mathbf{N}}(\vartheta) \cap \bigcap_{\vartheta\in u-v} \mathcal{K}_{\mathbf{N}}(\vartheta) \\
&\supseteq \left[\mathcal{G}_{\mathbf{N}}(u) \cap \mathcal{G}_{\mathbf{N}}(v)\right] \cap \left[\mathcal{K}_{\mathbf{N}}(u) \cap \mathcal{K}_{\mathbf{N}}(v)\right] \\
&= \left[\mathcal{G}_{\mathbf{N}}(u) \cap \mathcal{K}_{\mathbf{N}}(u)\right] \cap \left[\mathcal{G}_{\mathbf{N}}(v) \cap \mathcal{K}_{\mathbf{N}}(v)\right] \\
&= \left[(\mathcal{G}_{\mathbf{N}}\tilde{\bigcap}\mathcal{K}_{\mathbf{N}})(u)\right] \cap \left[(\mathcal{G}_{\mathbf{N}}\tilde{\bigcap}\mathcal{K}_{\mathbf{N}})(v)\right]
\end{aligned}$$

and

$$\begin{aligned}
(\mathcal{G}_{\mathbf{N}}\tilde{\bigcap}\mathcal{K}_{\mathbf{N}})(uv) &= \mathcal{G}_{\mathbf{N}}(uv) \cap \mathcal{K}_{\mathbf{N}}(uv) \\
&\supseteq \left[\mathcal{G}_{\mathbf{N}}(u) \cap \mathcal{G}_{\mathbf{N}}(v)\right] \cap \left[\mathcal{K}_{\mathbf{N}}(u) \cap \mathcal{K}_{\mathbf{N}}(v)\right] \\
&= \left[\mathcal{G}_{\mathbf{N}}(u) \cap \mathcal{K}_{\mathbf{N}}(u)\right] \cap \left[\mathcal{G}_{\mathbf{N}}(u) \cap \mathcal{K}_{\mathbf{N}}(v)\right] \\
&= \left[(\mathcal{G}_{\mathbf{N}}\tilde{\bigcap}\mathcal{K}_{\mathbf{N}})(u)\right] \cap \left[(\mathcal{G}_{\mathbf{N}}\tilde{\bigcap}\mathcal{K}_{\mathbf{N}})(v)\right].
\end{aligned}$$

Therefore, $\mathcal{G}_{\mathbf{N}}\tilde{\bigcap}\mathcal{K}_{\mathbf{N}}$ is an S.I. hypernear ring over $\mathcal{U}$. □

Theorem 5. *If $\mathcal{G}_{\mathbf{N}}$ and $\mathcal{K}_{\mathbf{N}}$ are S.I. hyperideals of $\mathbf{N}$ over $\mathcal{U}$. Then $\mathcal{G}_{\mathbf{N}}\tilde{\bigcap}\mathcal{K}_{\mathbf{N}}$ is an S.I. hyperideal of $\mathbf{N}$ over $\mathcal{U}$.*

Proof: Proof is straightforward. □

Theorem 6. *If $\mathcal{F}_{\mathbf{N}}$ is an S.I. hyperideal of $\mathbf{N}$ over $\mathcal{U}$, then $\mathbf{N}_F = \{u \in \mathbf{N} : \mathcal{F}_{\mathbf{N}}(u) = \mathcal{F}_{\mathbf{N}}(0)\}$ is an hyperideal of $\mathbf{N}$.*

Proof: $\mathbf{N}_F$ is non-empty, since $0 \in \mathbf{N}_F$. Now, we claim that $\mathbf{N}_F$ is an hyperideal of $\mathbf{N}$. To prove our claim, we have to show that

1. $\mathbf{N}_F$ is a sub-hypergroup of $\mathbf{N}$,
2. $n + u - n \subseteq \mathbf{N}_F$,
3. $u \cdot n \in \mathbf{N}_F$ and
4. $n \cdot (s + u) - n \cdot s \subseteq \mathbf{N}_F$.

Suppose that $u, v \in \mathbf{N}_F$, then $\mathcal{F}_{\mathbf{N}}(u) = \mathcal{F}_{\mathbf{N}}(v) = \mathcal{F}_{\mathbf{N}}(0)$. By Lemma 2.1, $\mathcal{F}_{\mathbf{N}}(0) \supseteq \bigcap_{\vartheta\in u-v} \mathcal{F}_{\mathbf{N}}(\vartheta), \mathcal{F}_{\mathbf{N}}(0) \supseteq \bigcap_{\vartheta\in n+u-n} \mathcal{F}_{\mathbf{N}}(\vartheta)$, $\mathcal{F}_{\mathbf{N}}(0) \supseteq \mathcal{F}_{\mathbf{N}}(u \cdot n)$ and $\mathcal{F}_{\mathbf{N}}(0) \supseteq \bigcap_{\vartheta\in(n\cdot(s+u)-n\cdot s)} \mathcal{F}_{\mathbf{N}}(\vartheta)$ for all $u, v \in \mathbf{N}_F$ and $n, s \in \mathbf{N}$. As $\mathcal{F}_{\mathbf{N}}$ is an S.I. hyperideal of $\mathbf{N}$ over $\mathcal{U}$, thus for all $u, v \in \mathbf{N}_F$ and $n, s \in \mathbf{N}$, (1). $\bigcap_{\vartheta\in u-v} \mathcal{F}_{\mathbf{N}}(\vartheta) \supseteq \mathcal{F}_{\mathbf{N}}(u) \cap \mathcal{F}_{\mathbf{N}}(v) = \mathcal{F}_{\mathbf{N}}(0)$, (2). $\bigcap_{\vartheta\in n+u-n} \mathcal{F}_{\mathbf{N}}(\vartheta) \supseteq \mathcal{F}_{\mathbf{N}}(u) = \mathcal{F}_{\mathbf{N}}(0)$, (3). $\mathcal{F}_{\mathbf{N}}(u \cdot n) \supseteq \mathcal{F}_{\mathbf{N}}(n) = \mathcal{F}_{\mathbf{N}}(0)$ and (4). $\bigcap_{\vartheta\in(n\cdot(s+u)-n\cdot s)} \mathcal{F}_{\mathbf{N}}(\vartheta) \supseteq \mathcal{F}_{\mathbf{N}}(u) = \mathcal{F}_{\mathbf{N}}(0)$. Therefore,

1. $\bigcap_{\vartheta\in u-v} \mathcal{F}_{\mathbf{N}}(\vartheta) = \mathcal{F}_{\mathbf{N}}(0)$,
2. $\bigcap_{\vartheta\in n+u-n} \mathcal{F}_{\mathbf{N}}(\vartheta) = \mathcal{F}_{\mathbf{N}}(0)$,
3. $\mathcal{F}_{\mathbf{N}}(u \cdot n) = \mathcal{F}_{\mathbf{N}}(0)$ and
4. $\bigcap_{\vartheta\in(n\cdot(s+u)-n\cdot s)} \mathcal{F}_{\mathbf{N}}(\vartheta) = \mathcal{F}_{\mathbf{N}}(0)$.

Hence, $\mathbf{N}_F$ is an hyperideal of $\mathbf{N}$. □

Definition 2.3. Let $\mathbf{N}$ be hypernear ring and $\mathcal{F}_{\mathbf{N}}$ a soft set of $\mathbf{N}$ over $\mathcal{U}$. Then the set $U(\mathcal{F}_{\mathbf{N}}, \delta) = \{u \in \mathbf{N} : \mathcal{F}_{\mathbf{N}}(u) \supseteq \delta\}$, where $\delta \subseteq \mathcal{U}$, is called upper δ-inclusion of $\mathcal{F}_{\mathbf{N}}$.

Theorem 7. *Let $\mathbf{N}$ be hypernear ring and $\mathcal{F}_{\mathbf{N}}$ a soft set of $\mathbf{N}$ over $\mathcal{U}$, and δ be a subset of $\mathcal{U}$ such that $\emptyset \subseteq \delta \subseteq \mathcal{F}_{\mathbf{N}}(0)$. $\mathcal{F}_{\mathbf{N}}$ is an S.I. hyperideal of $\mathbf{N}$ over $\mathcal{U}$, then $U(\mathcal{F}_{\mathbf{N}}, \delta)$ is a hyperideal of $\mathbf{N}$.*

Proof: As $\mathcal{F}_{\mathbf{N}}(0) \supseteq \delta$, then $0 \in U(\mathcal{F}_{\mathbf{N}}, \delta)$ and $\emptyset \neq U(\mathcal{F}_{\mathbf{N}}, \delta) \subseteq \mathbf{N}$. If $u, v \in U(\mathcal{F}_{\mathbf{N}}, \delta)$, then $\mathcal{F}_{\mathbf{N}}(u) \supseteq \delta$ and $\mathcal{F}_{\mathbf{N}}(v) \supseteq \delta$. We have to prove that (1) $u - v \subseteq U(\mathcal{F}_{\mathbf{N}}, \delta)$, (2) $n + u - n \subseteq U(\mathcal{F}_{\mathbf{N}}, \delta)$, (3) $u \cdot n \in U(\mathcal{F}_{\mathbf{N}}, \delta)$ and (4) $n \cdot (s + u) - n \cdot s \subseteq U(\mathcal{F}_{\mathbf{N}}, \delta)$ for all $u, v \in U(\mathcal{F}_{\mathbf{N}}, \delta)$, $n, s \in N$. Now, $\mathcal{F}_{\mathbf{N}}$ is an S.I. hyperideal of $\mathbf{N}$ over $\mathcal{U}$, so (1) $\bigcap_{\vartheta\in u-v} \mathcal{F}_{\mathbf{N}}(\vartheta) \supseteq \mathcal{F}_{\mathbf{N}}(u) \cap \mathcal{F}_{\mathbf{N}}(v) \supseteq \delta \cap \delta$, (2) $\bigcap_{\vartheta\in n+u-n} \mathcal{F}_{\mathbf{N}}(\vartheta) \supseteq \mathcal{F}_{\mathbf{N}}(u) \supseteq \delta$, (3) $\mathcal{F}_{\mathbf{N}}(u \cdot n) \supseteq \mathcal{F}_{\mathbf{N}}(n) \supseteq \delta$ and (4) $\bigcap_{\vartheta\in(n\cdot(s+u)-n\cdot s)} \mathcal{F}_{\mathbf{N}}(\vartheta) \supseteq \mathcal{F}_{\mathbf{N}}(u) \supseteq \delta$. Hence, $U(\mathcal{F}_{\mathbf{N}}, \delta)$ is a hyperideal of $\mathbf{N}$. □

Theorem 8. *Let $(\mathbf{M}, +_1, \cdot_1)$ and $(\mathbf{N}, +_2, \cdot_2)$ be two hypernear rings. Then the product $\mathbf{M} \times \mathbf{N}$ is a hypernear ring, where for all (u_1, v_1) and (u_2, v_2) belonging to $\mathbf{M} \times \mathbf{N}$, hyperoperation $\bigoplus$ and operation $\bigodot$ are defined as*

(1) $(u_1, v_1) \bigoplus (u_2, v_2) = \{(u, v) : u \in u_1 +_1 u_2, v \in v_1 +_2 v_2\}$,
(2) $(u_1, v_1) \bigodot (u_2, v_2) = (u_1 \cdot_1 u_2, v_1 \cdot_2 v_2)$.

Proof: Proof is straightforward. □

Definition 2.4. Let $\mathbf{N}$, $\mathbf{M}$ be two hypernear rings and $\mathcal{G}_{\mathbf{N}}$ an S.I. hypernear ring of $\mathbf{N}$ over $\mathcal{U}$, $\mathcal{K}_{\mathbf{M}}$ an S.I. hypernear rings of $\mathbf{M}$ over $\mathcal{U}$. Then the cross product of $\mathcal{G}_{\mathbf{N}}$ and $\mathcal{K}_{\mathbf{M}}$ is defined as $\mathcal{F}_{\mathbf{N}\times\mathbf{M}} = \mathcal{G}_{\mathbf{N}} \times \mathcal{K}_{\mathbf{M}}$, where $\mathcal{F}_{\mathbf{N}\times\mathbf{M}}(u, v) = \mathcal{G}_{\mathbf{N}}(u) \times \mathcal{K}_{\mathbf{M}}(v)$ for all $(u, v) \in \mathbf{N} \times \mathbf{M}$.

Theorem 9. *If $\mathcal{G}_{\mathbf{N}}$ is an S.I. hypernear ring of $\mathbf{N}$ over $\mathcal{U}$ and $\mathcal{K}_{\mathbf{M}}$ is an S.I. hypernear ring of $\mathbf{M}$ over $\mathcal{U}$. Then the cross product $\mathcal{F}_{\mathbf{N}\times\mathbf{M}}$ is an S.I. hypernear ring of $\mathbf{N} \times \mathbf{M}$ over $\mathcal{U} \times \mathcal{U}$.*

Proof: Let $(u_1, v_1), (u_2, v_2) \in \mathbf{N} \times \mathbf{M}$. Then

$$\begin{aligned}
\bigcap_{(\vartheta_1,\vartheta_2)\in(u_1,v_1) \ominus (u_2,v_2)} \mathcal{F}_{\mathbf{N}\times\mathbf{M}}(\vartheta_1, \vartheta_2) &= \bigcap_{(\vartheta_1,\vartheta_2)\in(u_1 -_1 u_2) \times (v_1 -_2 v_2)} \mathcal{F}_{\mathbf{N}\times\mathbf{M}}(\vartheta_1, \vartheta_2) \\
&= \bigcap_{\vartheta_1\in(u_1 -_1 u_2),\vartheta_2\in(v_1 -_2 v_2)} \mathcal{G}_{\mathbf{N}}(\vartheta_1) \times \mathcal{K}_{\mathbf{M}}(\vartheta_2) \\
&= \bigcap_{\vartheta_1\in(u_1 -_1 u_2)} \mathcal{G}_{\mathbf{N}}(\vartheta_1) \times \bigcap_{\vartheta_2\in(v_1 -_2 v_2)} \mathcal{K}_{\mathbf{M}}(\vartheta_2) \\
&\supseteq \big[\mathcal{G}_{\mathbf{N}}(u_1) \cap \mathcal{G}_{\mathbf{N}}(u_2)\big] \times \big[\mathcal{K}_{\mathbf{M}}(v_1) \cap \mathcal{K}_{\mathbf{M}}(v_2)\big] \\
&= \big[\mathcal{G}_{\mathbf{N}}(u_1) \times \mathcal{K}_{\mathbf{M}}(v_1)\big] \cap \big[\mathcal{G}_{\mathbf{N}}(u_2) \times \mathcal{K}_{\mathbf{M}}(v_2)\big] \\
&= \mathcal{F}_{\mathbf{N}\times\mathbf{M}}(u_1, v_1) \cap \mathcal{F}_{\mathbf{N}\times\mathbf{M}}(u_2, v_2).
\end{aligned}$$

and

$$\begin{aligned}
\mathcal{F}_{\mathbf{N}\times\mathbf{M}}((u_1, v_1) \bigodot (u_2, v_2)) &= \mathcal{F}_{\mathbf{N}\times\mathbf{M}}(u_1 \cdot_1 u_2, v_1 \cdot_2 v_2) \\
&= \mathcal{G}_{\mathbf{N}}(u_1 \cdot_1 u_2) \times \mathcal{K}_{\mathbf{M}}(v_1 \cdot_2 v_2) \\
&\supseteq \big[\mathcal{G}_{\mathbf{N}}(u_1) \cap \mathcal{G}_{\mathbf{N}}(u_2)\big] \times \big[\mathcal{K}_{\mathbf{M}}(v_1) \cap \mathcal{K}_{\mathbf{M}}(v_2)\big] \\
&= \big[\mathcal{G}_{\mathbf{N}}(u_1) \times \mathcal{K}_{\mathbf{M}}(v_1)\big] \cap \big[\mathcal{G}_{\mathbf{N}}(u_2) \times \mathcal{K}_{\mathbf{M}}(v_2)\big] \\
&= \mathcal{F}_{\mathbf{N}\times\mathbf{M}}(u_1, v_1) \cap \mathcal{F}_{\mathbf{N}\times\mathbf{M}}(u_2, v_2).
\end{aligned}$$

Therefore, $\mathcal{F}_{\mathbf{N}\times\mathbf{M}}$ is an S.I. hypernear ring of $\mathbf{N} \times \mathbf{M}$ over $\mathcal{U} \times \mathcal{U}$. □

Definition 2.5. Let $\mathbf{N}$, $\mathbf{M}$ be two hypernear rings. Let $\mathcal{G}_{\mathbf{N}}$ be an S.I. hyperideal of $\mathbf{N}$ over $\mathcal{U}$ and $\mathcal{K}_{\mathbf{M}}$ an S.I. hyperideal of $\mathbf{M}$ over $\mathcal{U}$. Then the cross product of $\mathcal{G}_{\mathbf{N}}$ and $\mathcal{K}_{\mathbf{M}}$ is defined as $\mathcal{F}_{\mathbf{N}\times\mathbf{M}} = \mathcal{G}_{\mathbf{N}} \times \mathcal{K}_{\mathbf{M}}$, where $\mathcal{F}_{\mathbf{N}\times\mathbf{M}}(u, v) = \mathcal{G}_{\mathbf{N}}(u) \times \mathcal{K}_{\mathbf{M}}(v)$ for all $(u, v) \in \mathbf{N} \times \mathbf{M}$.

Theorem 10. *If $\mathcal{G}_{\mathbf{N}}$ is an S.I. hyperideal of $\mathbf{N}$ over $\mathcal{U}$ and $\mathcal{K}_{\mathbf{M}}$ is an S.I. hyperideal of $\mathbf{M}$ over $\mathcal{U}$. Then the cross product $\mathcal{F}_{\mathbf{N}\times\mathbf{M}}$ is an S.I. hyperideal of $\mathbf{N} \times \mathbf{M}$ over $\mathcal{U} \times \mathcal{U}$.*

Proof: Let $\mathcal{G}_{\mathbf{N}}$ be an S.I. hyperideal of $\mathbf{N}$ over $\mathcal{U}$ and $\mathcal{K}_{\mathbf{M}}$ an S.I. hyperideal of $\mathbf{M}$ over $\mathcal{U}$. Then by Theorem 9, the cross product $\mathcal{F}_{\mathbf{N}\times\mathbf{M}}$ is an S.I. hypernear ring of $\mathbf{N} \times \mathbf{M}$ over $\mathcal{U} \times \mathcal{U}$. Now suppose (u_1, v_1), (u_2, v_2), $(x_3, y_3) \in \mathbf{N} \times \mathbf{M}$. Then

$$\begin{aligned}
&\bigcap_{(\vartheta_1,\vartheta_2)\in(u_1,v_1) \bigoplus (u_2,v_2) \ominus (u_1,v_1)} \mathcal{F}_{\mathbf{N}\times\mathbf{M}}(\vartheta_1, \vartheta_2) = \\
&\bigcap_{(\vartheta_1,\vartheta_2)\in(u_1 +_1 u_2 -_1 u_1) \times (v_1 +_2 v_2 -_2 v_1)} \mathcal{F}_{\mathbf{N}\times\mathbf{M}}(\vartheta_1, \vartheta_2) \\
&= \bigcap_{\vartheta_1\in(u_1 +_1 u_2 -_1 u_1),\vartheta_2\in(v_1 +_2 v_2 -_2 v_1)} \mathcal{G}_{\mathbf{N}}(\vartheta_1) \times \mathcal{K}_{\mathbf{M}}(\vartheta_2) \\
&= \bigcap_{\vartheta_1\in(u_1 +_1 u_2 -_1 u_1)} \mathcal{G}_{\mathbf{N}}(\vartheta_1) \times \bigcap_{\vartheta_2\in(v_1 +_2 v_2 -_2 v_1)} \mathcal{K}_{\mathbf{M}}(\vartheta_2) \\
&\supseteq \mathcal{G}_{\mathbf{N}}(u_2) \times \mathcal{K}_{\mathbf{M}}(v_2) \\
&= \mathcal{F}_{\mathbf{N}\times\mathbf{M}}(u_2, v_2),
\end{aligned}$$

$$\begin{aligned}
\mathcal{F}_{\mathbf{N}\times\mathbf{M}}((u_1, v_1) \bigodot (u_2, v_2)) &= \mathcal{F}_{\mathbf{N}\times\mathbf{M}}(u_1 \cdot_1 u_2, v_1 \cdot_2 v_2) \\
&= \mathcal{G}_{\mathbf{N}}(u_1 \cdot_1 u_2) \times \mathcal{K}_{\mathbf{M}}(v_1 \cdot_2 v_2) \\
&\supseteq \mathcal{G}_{\mathbf{N}}(u_1) \times \mathcal{K}_{\mathbf{M}}(v_1) \\
&= \mathcal{F}_{\mathbf{N}\times\mathbf{M}}(u_1, v_1).
\end{aligned}$$

and

$$\begin{aligned}
&\bigcap_{(\vartheta_1,\vartheta_2)\in((u_1,v_1) \bigodot ((u_2,v_2) \bigoplus (x_3,y_3)) \ominus (u_1,v_1) \bigodot (u_2,v_2))} \mathcal{F}_{\mathbf{N}\times\mathbf{M}}(\vartheta_1, \vartheta_2) = \\
&\bigcap_{(\vartheta_1,\vartheta_2)\in(u_1 \cdot_1 (u_2 +_1 x_3) -_1 u_1\cdot_1 u_2) \times (v_1 \cdot_2 (v_2 +_2 y_3) -_2 v_1\cdot_2 v_2)} \mathcal{F}_{\mathbf{N}\times\mathbf{M}}(\vartheta_1, \vartheta_2) \\
&= \bigcap_{\vartheta_1\in(u_1 \cdot_1 (u_2 +_1 x_3) -_1 u_1\cdot_1 u_2),\vartheta_2\in(v_1 \cdot_2 (v_2 +_2 y_3) -_2 v_1\cdot_2 v_2)} \mathcal{G}_{\mathbf{N}}(\vartheta_1) \times \mathcal{K}_{\mathbf{M}}(\vartheta_2) \\
&= \bigcap_{\vartheta_1\in(u_1 \cdot_1 (u_2 +_1 x_3) -_1 u_1\cdot_1 u_2)} \mathcal{G}_{\mathbf{N}}(\vartheta_1) \times \bigcap_{\vartheta_2\in(v_1 \cdot_2 (v_2 +_2 y_3) -_2 v_1\cdot_2 v_2)} \mathcal{K}_{\mathbf{M}}(\vartheta_2) \\
&\supseteq \mathcal{G}_{\mathbf{N}}(x_3) \times \mathcal{K}_{\mathbf{M}}(y_3) \\
&= \mathcal{F}_{\mathbf{N}\times\mathbf{M}}(x_3, y_3).
\end{aligned}$$

Hence, $\mathcal{F}_{\mathbf{N}\times\mathbf{M}}$ is an S.I. hyperideal of $\mathbf{N} \times \mathbf{M}$ over $\mathcal{U} \times \mathcal{U}$. □

Conclusion: In this paper, we have introduced soft intersection hypernear ring and defined some properties of hypernear ring theoretic concepts for soft sets. Moreover, we have introduced cross product of two soft intersection hypernear rings and proved that the cross product of two soft intersection hypernear rings is a soft intersection hypernear ring. Based on the results of this paper, some further work can be done on the hypernear ring using fuzzy set theory and soft set theory.

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