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Rough Standard Neutrosophic Sets: an Application on standard Neutrosophic Information Systems

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Abstract: A rough fuzzy set is the result of approximation of a fuzzy set with respect to a crisp approximation space. It is mathematical tool for the knowledge discovery in the fuzzy information systems. In this paper, we introduce the concepts of rough standard neutrosophic sets, standard neutrosophic information system and give the knowledge discovery on standard neutrosophic information system based on rough standard neutrosophic sets.

Keywords: rough set, standard neutrosophic set, rough standard neutrosophic set, standard neutrosophic information systems

1. INTRODUCTION

Rough set theory was introduced by Pawlak in 1980s [1]. It becomes a usefully mathematical tool for data mining, especially for redundant and uncertain data. At first, the establishment of the rough set theory is based on equivalence relation. The set of equivalence classes of the universal set, obtained by an equivalence relation, is the basis for the construction of upper and lower approximation of the subset of universal set.

Fuzzy set theory was introduced by Zadeh since 1965 [2]. Immediately, it became a useful method to study in the problems of imprecision and uncertainty. Since, a lot of new theories treating imprecision and uncertainty have been introduced. For instance, Intuitionistic fuzzy sets were introduced in1986, by K. Atanassov [3], which is a generalization of the notion of a fuzzy set. When fuzzy set give the degree of membership of an element in a given set, Intuitionistic fuzzy set give a degree of membership and a degree of non-membership of an element in a given set. In 1999 [14], Sarandache gave the concept of neutrosophic set which generalized fuzzy set and intuitionistic fuzzy set. This new concept is difficult to apply in the real appliction. It is a set in which each proposition is estimated to have a degree of truth (T), adegree of indeterminacy (I) and a degree of falsity (F). Over time, the subclass of neutrosophic sets was proposed. They are also more advantageous in the practical application. Wang et al. [15] proposed interval neutrosophic sets and some operators of them. Wang et al. [16] proposed a single valued neutrosophic set as an instance of the neutrosophic set accompanied with various set theoretic operators and properties. Ye [17] defined the concept of simplified neutrosophic sets, It is a set where each element of the universe has a degree of truth, indeterminacy and falsity respectively and which lies between [0, 1] and some operational laws for simplified neutrosophic sets and to propose two aggregation operators, including a simplified neutrosophic weighted arithmetic average operator and a simplified neutrosophic weighted geometric average operator. In 2013, Cuong and Kreinovich introduced the concept of picture fuzzy set [4], in which a given set were to be in with three

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memberships: a degree of positive membership, a degree of negative membership, and a degree of neutral membership of an element in this set. After that, Son given the application of the picture fuzzy set in the clustering problem [5]. We also regard picture fuzzy set as standard neutrosophic set. In addition, combining rough set and fuzzy set has also many interesting results. The approximation of rough (or fuzzy) sets in fuzzy approximation space give us the fuzzy rough set [6, 7, 8]; and the approximation of fuzzy sets in crisp approximation space give us the rough fuzzy set [6, 7]. Wu et al, [8] present a general framework for the study of fuzzy rough sets in both constructive and axiomatic approaches. By the same, Wu and Xu were investigated the fuzzy topological structures on the rough fuzzy sets [9], in which both constructive and axiomatic approaches are used. In 2012, Xu and Wu were also investigated the rough intuitionistic fuzzy set and the intuitionistic fuzzy topologies in crisp approximation spaces [10]. In 2015, Thao et al. introduces the rough picture fuzzy set is the result of approximation of a picture fuzzy set with respect to a crisp approximation space [12].

In this paper, we introduce the concept of standard neutrosophic information system, study the knowledge discovery of standard neutrosophic information system based on rough standard neutrosophic sets. The remaining part of this paper is organized as following: we recall basic notions of rough set, standard neutrosophic set and rough standard neutrosophic set on the crisp approximation space, respectively, in section 2 and section 3. In section 4, we introduce the basic concepts of standard neutrosophic information system. Finally, we investigate the knowledge discovery of standard neutrosophic information system and the knowledge reduction and extension of the standard neutrosophic information system in section 5 and section 6, respectively.

II. BASIC NOTIONS OF SN SET AND ROUGH SET

In this paper, we denote be a nonempty set called the universe of discourse. The class of all subsets of will be denoted by and the class of all fuzzy subsets of will be denoted by

Definition 1. [4]. A standard neutrosophic set (SN - set) on the universe is an object of the form

where $\mu_A(x), \eta_A(x), \gamma_A(x) \in [0,1]$ is called the "degree of positive membership, the degree of neutral membership, the degree of negative membership of x in A", and $\mu_A(x), \eta_A(x), \gamma_A(x) \le 1$.

The family of all standard neutrosophic set in U is denoted by PFS(U). The complement of a picture fuzzy set A is $\sim A = \{(x, \gamma_A(x), \eta_A(x), \mu_A(x)) | x \in U$.

The operators on PFS(U) was introduced [4].

Definition 2. (Lattice $(D^*, \le_*)$. Let $D^* = \{(x_1, x_2, x_3) \in [0,1]^3 : x_1 + x_2 + x_3 < 1\}$. We define a relation $\le_{D^*}$ on D^* as follows: $\forall x = (x_1, x_2, x_3)$, $y = (y_1, y_2, y_3) \in D^*$ then $x \le_{D^*} y$ iff (or $(x_1 < y_1, x_3 \ge y_3)$ or $(x_1 = y_1, x_3 > y_3)$ or $(x_1 = y_1, x_3 = y_3, x_2 \le y_2)$ and $x = y \Leftrightarrow (x_1 = y_1) \wedge (x_2 = y_2) \wedge (x_3 = y_3)$. We have $(D^*, \le_*)$ is a lattice with $0_{D^*} = (0,0,1)$, $1_{D^*} = (1,0,0)$.

Definition 3.

(i) Negative of $x = (x_1, x_2, x_3) \in D^*$ is $\overline{x} = (x_3, x_2, x_1)$

(ii) $\forall x = (x_1, x_2, x_3)$, $y = (y_1, y_2, y_3) \in D^*$ we have

$$x \wedge y = (x_1 \wedge y_1, x_2 \vee y_2, x_3 \wedge y_3)$$

$$x \vee y = (x_1 \vee y_1, x_2 \wedge y_2, x_3 \vee y_3)$$

We have some properties of those operators.

Lemma 1.

a) For all $x = (x_1, x_2, x_3)$, $y = (y_1, y_2, y_3) \in D^*$ we have $\overline{x \wedge y} = \bar{x} \vee \bar{y}$ and $\overline{x \vee y} = \bar{x} \wedge \bar{y}$

b) For all $x, y, u, v \in D^*$ and $x \le_{D^*} u, y \le_{D^*} v$ we have $x \wedge y \le_{D^*} u \wedge v$ and $x \vee y \le_{D^*} u \vee v$.

Now, we mention the level sets of the SN-sets. Where $(\alpha, \beta, \theta) \in D^*$, we define:

- (α, β, θ) −level cut set of the SN- set $A = \{(x, \mu_A(x), \eta_A(x), \gamma_A(x)) | x \in U\}$ as follows:

$$A_\theta^{\alpha,\beta} = \{x \in U | (\mu_A(x), \eta_A(x), \gamma_A(x)) \ge (\alpha, \beta, \theta)\}$$

- strong (α, β, θ) −level cut set of the SN- set A as follows:

$$A_{\theta+}^{\alpha+,\beta+} = \{x \in U | (\mu_A(x), \eta_A(x), \gamma_A(x)) \ge (\alpha, \beta, \theta)\}$$

- (α, β, θ) −level cut set of the SN- set A as

$$A_\theta^{\alpha^+,\beta} = \{x \in U | \mu_A(x) > \alpha, \gamma_A(x) \le \theta\}$$

- $(\alpha, \beta, \theta^+)$ − level cut set of the SN-set A as

$$A_{\theta^+}^{\alpha^+,\beta} = \{x \in U | \mu_A(x) \ge \alpha, \gamma_A(x) < \theta\}$$

- (α^+, θ^+) − level cut set of the SN- set A as

$$A = \{(x, \mu_A(x), \eta_A(x), \gamma_A(x)) | x \in U\}$$

$$A_{\theta^+}^{\alpha^+} = \{x \in U | \mu_A(x) > \alpha, \gamma_A(x) < \theta\}$$

- $\alpha-$ level cut set of the SN- set A as

$$A^\alpha = \{x \in U | \mu_A(x) \geq \alpha\}$$

- the strong $\alpha-$ level cut set of the SN- set A as

$$A^\alpha = \{x \in U | \mu_A(x) > \alpha\}$$

- $\theta-$ level low cut set of the degree of negative membership of x in A as $A_\theta = \{x \in U | \gamma_A \leq \theta\}$
- strong $\theta-$ level low cut set of the degree of negative membership of x in A as

$$A_\theta = \{x \in U | \gamma_A < \theta\}$$

Definition 4.[6]. Let (U, R) be a crisp approximation space. For each crisp set $A \subset U$, we define the upper and lower approximations of A (w.r.t) (U, R) denoted by $\overline{R}(A)$ and $\underline{R}(A)$, respectively, are defined as follows $\overline{R}(A) = \{x \in U : R_s(x) \cap A \neq \emptyset$, $\underline{R}(A) = \{x \in U : R_s(x) \subseteq A$ where $R_s(x) = \{y \in U | (x, y) \in R\}$.

III. ROUGH STANDARD NEUTROSOPHIC SET

A rough SN- set is the approximation of a SN-set w. r. t a crisp approximation space. Here, we consider the upper and lower approximations of a SN-set in the crisp approximation spaces together with their membership functions, respectively.

Definition 5. Let (U, R) be a crisp approximation space. For each $A \in PF(U)$, the upper and lower approximations of A (w.r.t) (U, R) denoted by $\overline{R}(A)$ and $\underline{R}(A)$, respectively, are defined as follows:

$$\overline{R}(A) = \{(x, \mu_{\overline{R}(A)}(x), \eta_{\overline{R}(A)}(x), \gamma_{\overline{R}(A)}(x)) | x \in U\}$$

$$\underline{R}(A) = \{(x, \mu_{\underline{R}(A)}(x), \eta_{\underline{R}(A)}(x), \gamma_{\underline{R}(A)}(x) | x \in U\}$$

where $\mu_{\overline{R}(A)}(x) = \vee_{y \in R_s(x)} \mu_A(y)$, $\eta_{\overline{R}(A)}(x) = \wedge_{y \in R_s(x)} \eta_A(y)$, $\theta_{\overline{R}(A)}(x) = \wedge_{y \in R_s(x)} \theta_A(y)$

and $\mu_{\underline{R}(A)}(x) = \wedge_{y \in R_s(x)} \mu_A(y)$, $\eta_{\underline{R}(A)}(x) = \wedge_{y \in R_s(x)} \eta_A(y)$, $\theta_{\underline{R}(A)}(x) = \vee_{y \in R_s(x)} \theta_A(y)$.

Some basic properties of rough SN-set approximation operators represent in [12].

IV. THE STANDARD NEUTROSOPHIC INFORMATION SYSTEMS

In this section, we introduce a new concept: standard neutrosophic information system (SNIS).

Let (U, A, F) be a classical information system. Here U is the (nonempty) set of objects, i.e., $U = \{u_1, u_2, \dots, u_{10}\}$, $A = \{a_1, a_2, \dots, a_m\}$ is the attribute set, and F is the relation set of U and A, i.e., $F = \{f_j : U \to V_j, j = 1,2, \dots, m\}$ where V_j is the domain of the attribute $a_j, j = 1,2, \dots, m$.

We call (U, A, F, D, G) an information system or decision table, where (U, A, F) is the classical information system, A is the condition attribute set and D is the decision attribute set, i.e., $D = \{d_1, d_2, \dots, d_p\}$ and G is the relation set of U and D, i.e., $G = \{g_j : U \to V'_j, j = 1,2, \dots, m\}$ where V'_j is the domain of the attribute $d_j, j = 1,2, \dots, p$.

Let (U, A, F, D, G) be the information system. For $B \subset A \cup D$, we define a relation, denoted $R_B = IND(B)$, as follows, $\forall x, y \in U$: $R_B = \{(x, y) \in U^2 : f_j(x) = f_j(y), \forall j \in \{j : a_j \in B\}$.

The equivalence class of $x \in U$ based on R_B is $[x]_B = \{y \in U : yR_Bx\}$.

Here, we consider $R_A = IND(A)$, $R_D = IND(D)$. If $R_A \subseteq R_D$, i.e., for any $[x]_A, x \in U$ there exists $[x]_D$ such that $[x]_A \subseteq [x]_D$, then the information system is called a consistent information system, other called an inconsistent information system.

Let (U, A, F, D, G) be the information system, where (U, A, F) be a classical information system. If $D = \{D_k \mid k = 1, 2, \dots, q\}$, where D_k is a fuzzy subset of U, then (U, A, F, D, G) be the fuzzy information system. If $D = \{D_k \mid k = 1, 2, \dots, q\}$ where D_k is an intutionistic fuzzy subset of U, then (U, A, F, D, G) be an intuitionistic fuzzy information system.

Definition 6. Let (U, A, F, D, G) be the information system or decision table, where (U, A, F) be a classical information system. If $D = \{D_k | k = 1,2, \dots, p\}$ where D_k is a SN- subset of U and G is the relation set of U and D, then (U, A, F, D, G) is called a SN information system.

Example 1. The following table 2 gives a SN information system, where the objects set $\underline{RP}_A(D_2)(x) = (0.15, 0.05, 0.6)$ condition attribute set is $A = \{a_1, a_2, a_3\}$ and the decision attribute set is $D = \{D_1, D_2, D_3\}$, where $D_k | k = 1,2, \dots, p$ is the SN subsets of U.

Table 1: *A SN- information system*

U	a_1	a_2	a_2	D_1	D_3	D_4
u_1	3	2	1	(0.2,0.3,0.5)	(0.15,0.6,0.2)	(0.4,0.05,0.5)
u_2	1	3	2	(0.3,0.1,0.5)	(0.3,0.3,0.3)	(0.35,0.1,0.4)
u_3	3	2	1	(0.6,0,0.4)	(0.3,0.05,0.6)	(0.1,0.45,0.4)
u_4	3	3	1	(0.15,0.1,0.7)	(0.1,0.05,0.8)	(0.2,0.4,0.3)
u_5	2	2	4	(0.05,0.2,0.7)	(0.2,0.4,0.3)	(0.05,0.4,0.5)
u_6	2	3	4	(0.1,0.3,0.5)	(0.2,0.3,0.4)	(1,0,0)
u_7	1	3	2	(0.25,0.3,0.4)	(1,0,0)	(0.3,0.3,0.4)
u_8	2	2	4	(0.1,0.6,0.2)	(0.25,0.3,0.4)	(0.4,0,0.6)
u_9	3	2	1	(0.45,0.1,0.45)	(0.25,0.4,0.3)	(0.2,0.5,0.3)
u_{10}	1	3	2	(0.05,0.05,0.9)	(0.4,0.2,0.3)	(0.05,0.7,0.2)

V. THE KNOWLEDGE DISCOVERY IN THE SNIS

In this section, we will give some results about the knowledge discovery for a SNIS by using the basic theory of rough standard neutrosophic set in section 3. Throughout this paper, let (U, A, F, D, G) be the standard neutrosophic information system and $B \subseteq A$ we denote $\underline{RP}_B(D_j)$ is the lower rough standard neutrosophic approximation of $D_j \in PFS(U)$ on approximation space (U, R_B).

Theorem 1. Let (U, A, F, D, G) be the standard neutrosophic information system and $B \subset A$. If for any $x \in U$: $\left(\mu_{D_i}(x), \eta_{D_i}(x), \gamma_{D_i}(x)\right) \geq (\alpha(x), \beta(x), \theta(x)) = \underline{RP_B}(D_i)(x) > \underline{RP_B}(D_j)(x), i \neq j$ then $[x]_B \cap (D)^{\theta(x),0}_{\alpha(x)} \neq \emptyset$ and $[x]_B \subset (D)^{\alpha(x)\beta(x)}_{\theta(x)}$ where $(\alpha(x), \beta(x), \theta(x)) \in D^*$.

Let (U, A, F, D, G) be the standard neutrosophic information system, R_A is the equivalence classes which induced by the condition attribute set A, and the universe is divided by R_A as following: $U/R_A = \{X_1, X_2 \ldots, X_k\}$. Then the approximation of SN decision denoted as, for all $i = 1, 2, \ldots, k$.

$$\underline{RP}_A(D(X_i)) = \left(\underline{RP}_A(D_1(X_i)), \underline{RP}_A(D_2(X_i)), \ldots, \underline{RP}_A(D_q(X_i))\right)$$

Example 2. We consider the SN information system in Table 1. The equivalent classes

$$U/R_A = \{X_1 = \{u_1, u_3, u_9\}, X_2 = \{u_2, u_7, u_{10}\},$$
$$X_3 = \{u_4\}, X_4 = \{u_5, u_8\}, X_5 = \{u_6\}\}$$

The approximation of the SN decision is as follows:

Table 2: *The approximation of the SN decision*

U/R_A	$\underline{RP}_A(D_1(X_i))$	$\underline{RP}_A(D_2(X_i))$	$\underline{RP}_A(D_3(X_i))$
X_1	(0.2,0,0.5)	(0.15,0.05,0.6)	(0.1,0.05,0.5)
X_2	(0.05,0.05,0.9)	(0.3,0.1,0.3)	(0.05,0.1,0.4)
X_3	(0.15, 0.1,0.7)	(0.1,0.05,0.8)	(0.2,0.4,0.3)
X_4	(0.05,0.2,0.7)	(0.2,0.3,0.4)	(0.05,0,0.6)
X_5	(0.1,0.3,0.5)	(0.2,0.3,0.4)	(1,0,0)

VI. THE KNOWLEDGE REDUCTION AND EXTENSION OF SNIS

Definition 7.

(i) Let (U, A, F) be the classical information system and $B \subset A$. B is called the SN reduction of the classical information system (U, A, F), if B is the minimum set which satisfies the following relations: for any $X \in PFS(U), x \in U$.

$$\underline{RP}_A(X) = \underline{RP}_B(X), \overline{RP}_A(X) = \overline{RP}_B(X)$$

(ii) B is called the SN lower approximation reduction of the classical information system (U, A, F), if B is the minimum set which satisfies the following relations: for any $X \in PFS(U), x \in U$ we have $\underline{RP_A}(X) = \underline{RP_B}(X)$.

(iii) B is called the standard neutrosophic upper approximation reduction of the classical information system (U, A, F), if B is the minimum set which satisfies the following relations: for any $X \in PFS(U), x \in U$ $\overline{RP_A}(X) = \overline{RP_B}(X)$.

Where $\underline{RP}_A(X), \underline{RP}_B(X), \overline{RP}_A(X), \overline{RP}_B(X)$ are SN-lower and SN- upper approximation sets of SN- set $X \in PFS(U)$ based on R_A, R_B, respectively.

Now, we express the knowledge of the knowledge reduction of SNIS by introducing the discernibility matrix.

Definition 8. Let (U, A, F, D, G) be the SN- information system. Then $M = [D_{ij}]_{k \times k}$ where

$$D_{ij} = \begin{cases} \{a_l \in A : f_l(X_i) \neq f_l(X_j)\}; & g_{X_i}(D_t) \neq g_{X_j}(D_t) \\ A & : g_{X_i}(D_t) = g_{X_j}(D_t) \end{cases}$$

is called the discernibility matrix of (U, A, F, D, G) (where $g_{X_i}(D_t)$ is the maximum of $\underline{RP}_A(D(X_i))$ obtained at D_t, i.e., $g_{X_i}(D_t) = \underline{RP}_A(D_t(X_i))$

$= \max\{\underline{RP}_A(D_z(X_i)), z = 1, 2, \ldots, q\}$)

Definition 9. Let (U, A, F, D, G) be the SNIS, for any $B \subset A$, if the following relations holds, for any $x \in B$:

$\underline{RP}_B(D_i)(x) > \underline{RP}_B(D_j)(x) - \underline{RP}_A(D_i)(x) > \underline{RP}_A(D_j)(x)(i \neq j)$

then B is called the consistent set of A.

Theorem 2. Let (U, A, F, D, G) be the standard neutrosophic information system. If there exists a subset $B \subset A$ such that $B \cap D_{ij} \neq \emptyset$, then B is the consistent set of A.

Definition 10. Let (U, A, F, D, G) be the SNIS

$$D_{ij}^C = \begin{cases} \{a_l \in A : f_l(X_i) = f_l(X_j)\}; & g_{X_i}(D_t) \neq g_{X_j}(D_t) \\ \emptyset & : g_{X_i}(D_t) = g_{X_j}(D_t) \end{cases}$$

is called the discernibility matrix of (U, A, F, D, G) (where $g_{X_i}(D_t)$ is the maximum of $\underline{RP}_A(D(X_i))$ obtained at D_t, i.e.,

$g_{X_i}(D_t) = \underline{RP}_A(D_t(X_i)) = \max\{\underline{RP}_A(D_z(X_i)), z = 1, 2, \ldots, q\}$).

Theorem 3. Let (U, A, F, D, G) be the SNIS. If there exists a subset $B \subset A$ such that $B \cap D_{ij}^C = \emptyset$, , then B is the consistent set of A.

The extension of a SNIS present on the following definition:

Definition 11.

(i) Let (U, A, F) be the classical information system and $B \subseteq A$. B is called the SN extension of the classical information system (U, A, F), if B satisfies the following relations: for any $X \in PFS(U)$,

$$\underline{RP}_B(X) = \underline{RP}_A(X), \overline{RP}_B(X) = \overline{RP}_A(X)$$

(i) B is called the SN lower approximation extension of the classical information system (U, A, F), if $A \subset B$ satisfies the following relations: for any $X \in PFS(U)$, $\underline{RP}_B(X) = \underline{RP}_A(X)$

(ii) B is called the SN upper approximation extension of the classical information system (U, A, F), if $A \subset B$ satisfies the following relations: for any $X \in PFS(U)$, $\overline{RP}_B(X) = \overline{RP}_A(X)$

where $\underline{RP}_B(X), \underline{RP}_A(X)$ $\overline{RP}_B(X), \overline{RP}_A(X)$ are SN lower and upper approximation sets of SN set $X \in PFS(U)$ based on R_A, R_B, respectively.

We can be easily obtained the following result.

Definition 12. Let (U, A, F) be the classical information system, for any hyper set B, such that $A \subseteq B$, if A is the SN-reduction of the classical information system (U, B, F), then (U, B, F) is the SN extension of (U, A, F), but not conversely necessary.

Example 3. In the approximation of the SN decision in Table 1, Table 2. Let $B = \{a_1, a_2\}$ then we obtained the family of all equivalent classes of U based on the equivalent relation $R_B = IND(B)$ as follows

$U / R_B = \{X_1 = \{u_1, u_3, u_9\}, X_2 = \{u_2, u_7, u_{10}\}, X_3 = \{u_4\}, X_4 = \{u_5, u_8\}, X_5 = \{u_6\}\}$

We can get the approximation value given in Table 3.

Table 3: *The approximation of the SN decision*

U / R_B	$\underline{RP}_B(D_1(X_i))$	$\underline{RP}_B(D_2(X_i))$	$\underline{RP}_B(D_3(X_i))$
X_1	(0.2,0,0.5)	(0.15,0.05,0.6)	(0.1,0.05,0.5)
X_2	(0.05,0.05,0.9)	(0.3,0.1,0.3)	(0.05,0.1,0.4)
X_3	(0.15, 0.1,0.7)	(0.1,0.05,0.8)	(0.2,0.4,0.3)
X_4	(0.05,0.2,0.7)	(0.2,0.3,0.4)	(0.05,0,0.6)
X_5	(0.1,0.3,0.5)	(0.2,0.3,0.4)	(1,0,0)

It is easy to see that B satisfies Definition 7 (ii), i.e., B is the SN lower reduction of the classical information system (U, A, F).

The discernibility matrix of the SN information system (U, A, F, D, G) will be presented in Table 4.

Table 4: *The discernibility matrix of the SNIS*

U/R_B	X_1	X_2	X_3	X_4	X_5
X_1	A				
X_2	A	A			
X_3	$\{a_2\}$	$\{a_1, a_3\}$	A		
X_4	$\{a_1, a_3\}$	A	A	A	
X_5	$\{a_1, a_3\}$	A	A	$\{a_2\}$	A

VII. CONCLUSION

In this paper, we introduce the concept of SN-information system, study the knowledge discovery of standard neutrosophic information system based on rough SN- sets. We investigate some problems of the knowledge discovery of SNIS and the knowledge reduction and extension of the SNIS in section 6. In the future, we introduce the application of this study in the practical problems.

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