Fundamentals of Parameterised Covering Approximation Space

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ABSTRACT
Combination of theories has not only advanced the research, but also helped in handling the issues of impreciseness in real life problems. The soft rough set has been defined by many authors by combining the theories of soft set and rough set. The concept Soft Covering Based Rough Set be given by J.Zhan et al (2008), Feng Feng et al (2011), S.Yuksel et al (2015) by taking full soft set instead of Covering. In this note We first consider the covering soft set and then covering based soft rough set. Again it defines a mapping from the coverings of element of universal set U to the parameters (attributes). The new model "Parameterised Soft Rough Set on Covering Approximation Space" is conceptualised to capture the issues of vagueness, and impreciseness of information. Also dependency on this new model and some properties be studied.

***KEYWORDS**: Rough Set, Soft Set, Soft Rough Set, Approximation Space, Parameterised Soft Rough Set*

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1. INTRODUCTION

Philosophers and logicians for a long time have been attracted by the concept of vagueness which is related to the so called boundary line view. Vagueness present in a concept indicates that there are some objects which are related to the boundary line view and which can be classified neither to the concept nor to its complement and thus these are the boundary line cases . The underlying assumption behind the concept of rough set is that knowledge has granular structure, which is caused by the situation when some objects of interest cannot be distinguished and they may appear to be identical. The indiscernibility relation thus generated is the mathematical basis of Pawlaks rough set [19] with the assumption that any vague concept is characterised by a pair of precise concepts called the lower and upper approximations of the concerned vague concept.

In 1999 a new model called soft set theory was proposed by Molodtsov [2]to tackle the problems of the vagueness and uncertainty of the data (information).In the rough set theory it is considered an equivalence relation to classify the object or data.

But, in practical, it is difficult to get an equivalence relation in our day to-day life to handle the uncertainty and impreciseness . In the soft set theory these difficulties are eradicated but not entirely. In the past years the theories like algebraic approach to rough set [16],covering based rough set[17], fuzzy rough set [1], rough fuzzy set [1], intuitionistic fuzzy rough set [8] are developed to overcome the difficulties faced in Pawlaks Rough set.

The soft set has come to light by Maji et al [11],[12] after defining the operations in the soft set. The properties and applications on the soft set have been studies by various authors [7],[9],[18]. Both soft set theory and rough set theory are treated as Mathematical tools to deal with uncertainty. Connections between these two theories, the new model are borne as soft rough set and rough soft set. Four types of coverings based soft rough set are defined by the present authors [6] to act on the problem of impreciseness in daily life.

Feng Feng et al [4] has given the notion of soft rough set and Saziye Yuksel et al [14];[15] has defined soft covering based rough set. However the concept of soft covering based rough set given by above authors are somehow faulty and unable to solve the problem of uncertainty and vagueness in real life situations. Without taking covering on soft set or covering on the rough set, the Authors J.Zhan et al [5], Feng Feng et al [4], S. Yuksel et al [14],[15] used only the full soft set to define Soft Covering Based Rough Set. Though named as modified soft rough set, it is actually inverse soft rough set presented by M.Sabir et al [10] and S.K.Ray etal [13] and established some properties.

In this note we first write the covering of the universe U and then define soft covering of U. This shows us path to find covering based soft rough set. Covering of a universe is an improved form then that of partition of universe. Next we introduce Parameterised Soft Rough Set on Covering Approximation Space. Here dependency and independency on the parameterised soft rough set are established and We interpret the notion of Rough Soft Set by help of fruitful examples.

2. PRELIMINARIES

Definition 2.1. A set of objects, U, known as universal set, be a finite one. Let A is a set of attributes. Then we denote Knowledge Representation System (an information system)by (U;A). A function e, e: U → V_e is called a set of values of attribute e, for each e ϵ A.

Definition 2.2. Let R be an equivalence relation (knowledge) defined on the non empty finite Universe U . The pair (U;R) is called approximation space and R is known as indiscernibility relation.

Definition 2.3. Let R be a family of equivalence relations on U, then (U;R) be called as knowledge base over U. For B ⊆ R, the indiscernibility relation R = IND(B) can be defined as (x; y) ϵ IND(B) if and only if e(x) = e(y) for all e ϵ B and x; y ϵ U. Here e(x) denotes the attribute value of e for the object x.

Definition 2.4. Let R be an indiscernibility relation on U, that is, a knowledge on U. We define two approximations, for any X ⊆ U, LR(X) = { y ϵ U | $[y]_R$ ⊆ X}, HR(X) = {y ϵ U |$[y]_R \cap X \neq \phi$ are called R- lower approximation and R- Upper approximation of X respectively where $[y]_R$ is an equivalence class of R contains y. The set X ⊆ U is called rough set with respect to R if LR(X) ≠ HR(X),otherwise the set X is said to be an exact with respect to the knowledge R.

The set $POS_R(X)$ = LR(X), $NEG_R(X)$ = U – LR(X) and

$BND_R(X)$ = HR(X) – LR(X) are called R-positive, R-negative, R- boundary region of X respectively. Also X is said to be a rough set with respect to R,

when $BND_R(X) \neq \phi$

Definition 2.5. Let (U;R) be a knowledge base P;Q ⊆ R, then the knowledge Q depends on knowledge P denoted by P ⇒ Q if and only if IND(P) ⊆ IND(Q). That is, if and only if for every $[y]_{IND(P)}$ there exist one $[x]_{IND(Q)}$ such that $[y]_{IND(P)} \subseteq [x]_{IND(Q)}$, for x; y ϵ U.

Definition 2.6. Let U, a non empty finite set be the universe of discourse. Let C = { C_1, C_2, C_3, C_4, ... ,C_n} be a collection of subsets of U. Then C is said to be covering of U if ∪ C_i = U. The pair (U;C) is called as covering approximation space.

Definition 2.7. Let U be the non empty finite set and E be the set of parameters. Let F is a mapping, F: A → P(U), for A ⊆ E where P(U) is the set of all subsets of U, then the pair (F;A) is called a soft set over U. Here F(e) be the set of approximate element of soft set (F;A), for e ϵ A. The soft set (F;A) is said to be full soft set if $\cup_{e \in A} F(e) = U$.

Definition 2.8. Let F be a mapping, F: A → P(U), where F(e) = Z = ∪ C_i for some i, C_i ϵ C and e ϵ A. As $\cup_{e \in A} F(e) = \cup C_i$ = U , then collection F(A) is called soft covering of U and (U,C, F(A)) is called soft covering approximation space.

Definition 2.9. Let F(A) and G(A) are two soft covering of U under the same parameter A, where F(e) = Z, for Z = ∪ C_i for some i and G(e) = D for D = ∪ C_j for some j, Ci, C_j ϵ C. Then the soft covering G(A) is said to be sub soft covering of F(A), if for each G(e) there exist at least one F(a), such that G(e) ⊆ F(a), e; a ϵ A and denoted by G(A) ⊆c F(A).

Definition 2.10. Let (U,C, F(A)) be a soft covering approximation space. For a set X ⊆ U, the soft covering lower and upper approximation are defined and denoted by

L(X) =∪ { Ci: Ci ⊆ F(e) ∩ X }

H(X) = L(X) ∪ { Z ϵ C: Z ∩ {X – L(X)} ≠ ∅

If L(X) ≠ H(X), then X is said to be covering based soft rough set, otherwise X is called covering based soft definable.

3. PARAMETERISED SOFT SET (PSRS)ROUGH

Definition 3.1. Let (F;A) be a soft set over U and C be a covering of U. Let a mapping ϕ: C → P(A), P(A) is the power set of A, be defined by ϕ (Z) = {e ϵ A | Z ⊆ F(e) } for Z ϵ C. We denote (ϕ,C) be the parameterised soft set over E. Then the triplet (U,C, ϕ) is called parameterised soft covering approximation space. The lower and upper parameterised soft approximation of X ⊆ U are defined for C_i,C_j ϵ C, by

L_ϕ (X) = { x ϵ U | x ϵ X; x ϵ C_i ∧ ϕ (C_i) ≠ ϕ (C_j) for all y ϵ X/ and y ϵ C_j for all j }, and

H_ϕ(X) = { x ϵ U | x ϵ C_i and ϕ(C_i) = ϕ(C_j) for some y ϵ X and y ϵ C_j },

Where X/ be the complement of X, that is U – X.

The positive region, negative region, boundary region of X be defined respectively by,

POS_ϕ(X) = L_ϕ (X), NEG_ϕ (X) = U – H_ϕ (X),

BND_ϕ (X) = H_ϕ (X) – L_ϕ (X).

If L_ϕ(X) ≠ H_ϕ (X), then X is said to be parameterised soft rough set on covering approximation space,

Otherwise X is said to be parameterised soft definable. Three sets POS_ϕ(X), NEG_ϕ(X), BND_ϕ(X) are mutually exclusive and their union is U.

Example 3.2.
Let U = {a, b, c, d, e, f, g, h } be the universe consisting of eight cars for sale. Let C_1 = {a, d}, C_2 = {b, c}, C_3 ={d}, C_4 = { e}, C_5 = {f}, C_6 = {g}, C_7 = {g, h}.

C ={C_1 ,C_2,C_3,C_4,C_5,C_6,C_7 } is a covering of U as ∪ C_i = U.

Let A = {e_1, e_2, e_3, e_4, e_5 } ⊆ E be set of parameters where e_1 stands for luxurious, e_2 stands for strong, e_3 stands for stylish, e_4 stands for good mileage, e_5 stands for racing car.

and F: A → P(U) such that, F(e_1) = C_1 that is luxurious car be {a, d}, F(e_2) = C_2 ∪ C_3 = {b,c} ∪{d} are strong cars, F(e_3) = C_4 ∪ C_5 = {e} ∪{f} are the stylish cars, F(e_4 }= C_6 = {f} is the good mileage car, F(e_5) = C_7 = {g,h } are racing cars.

Then ϕ(C_1) = {e_1}, ϕ (C_2) = {e_2}, ϕ (C_3) = {e_2 },ϕ (C_4) = {e_3}, ϕ (C_5) = {e_3 }, ϕ (C_6) = {e_4 }, ϕ(C_7) ={e_5 } and (ϕ,C) is called parameterised soft set over E.

Let X = {a,b,d,g}, then X/ = {c, e,f, h} and L_ϕ(X) ={a,d}, H_ϕ(X) = {a, b, c, d, g, h}.

On the covering approximation space (U,C, ϕ), X is a parameterised soft rough set as L_ϕ(X) ≠ H_ϕ(X) .

The POS_ϕ (X) = {a, d}, NEG_ϕ (X) = {e, f}, and BND_ϕ(X) = {b, c, g, h}.

Let Y ={a,b,e}, then L_ϕ (Y) = ϕ, H_ϕ (Y) = {a, b, c, d,e,f}.

If Z = {e, h}, then L_ϕ (Z) = ϕ, H_ϕ (Z) = {e, f, g, h}.

Example 3.3.
Let U = {a, b, c, d, e, f, g, h } be the universe consisting of eight cars for sale. Let C_1 = {a, d}, C_2 = {b, c}, C_3 ={d}, C_4 = { e}, C_5 = {f}, C_6 = {g}, C_7 = {g, h}.

$C = \{C_1, C_2, C_3, C_4, C_5, C_6, C_7\}$ is a covering of U as $\cup C_i = U$.

Let $E = \{e_1, e_2, e_3, e_4, e_5, e_6\}$, $A = \{e_1, e_2, e_3, e_4, e_5\}$, and

$F: A \to P(U)$ such that, $F(e_1) = C_1$, $F(e_2) = C_2 \cup C_3$,

$F(e_3) = C_4$, $F(e_4) = C_2 \cup C_5 \cup C_6$, $F(e_5) = C_6 \cup C_7$.

Then $\phi(C_1) = \{e_1\}$, $\phi(C_2) = \{e_2, e_4\}$, $\phi(C_3) = \{e_2\}$, $\phi(C_4) = \{e_3\}$, $\phi(C_5) = \{e_4\}$, $\phi(C_6) = \{e_4, e_5\}$, $\phi(C_7) = \{e_5\}$.

If X = {a,b,d,g}, then X/ = {c, e,f, h} and $L_\phi(X) = \{a,d\}$, $H_\phi(X) = \{a, b, c, d, g, h\}$.

If Y = {a,b,e}, then $L_\phi(Y) = \{e\}$, $H_\phi(Y) = \{a, b, c, d, e\}$.

If Z = {e, h}, then $L_\phi(Z) = \{e\}$, $H_\phi(Z) = \{e, g, h\}$.

Proposition 3.4. For $X \subseteq U$.
A. $L_\phi(X) \subseteq X \subseteq H_\phi(X)$,
B. $L_\phi(\phi) = \phi$, $H_\phi(\phi) = \phi$,
C. $L_\phi(U) = U$, $H_\phi(U) = U$,
D. $X \subseteq Y$ then $L_\phi(X) \subseteq L_\phi(Y)$ and $H_\phi(X) \subseteq H_\phi(Y)$.

Proof. (a), (b), (c) are direct from definition 3.1., for clarity we prove (d).

(d): Let $x \in L_\phi(X)$ then there exist one C_1, $x \in C_1$ such that $\phi(C_1) \neq \phi(C_j)$ for all $y \in X/$

and $y \in C_j$, which mean $\phi(C_1) \neq \phi(C_j)$ for all $y \in Y/$ and $y \in C_j$ as $Y/ \subseteq X/$. So $x \in L_\phi(Y)$.

Hence $L_\phi(X) \subseteq L_\phi(Y)$.

Let $x \in H_\phi(X)$, then there exist C_2, $x \in C_2$ and $x \in U$ such that $\phi(C_2) \neq \phi(C_j)$, for some $t \in X$ and $t \in C_j$, which is true for some $t \in Y$, as $X \subseteq Y$ and then $x \in H_\phi(Y)$.

Hence $H_\phi(X) \subseteq H_\phi(Y)$.

Proposition 3.5. For $X \subseteq U$:
A. $L_\phi(X) \cup L_\phi(Y) \subseteq L_\phi(X \cup Y)$,
B. $H_\phi(X \setminus Y) \subseteq H_\phi(X) \setminus H_\phi(Y)$.

Proof. a) $X \subseteq X \cup Y$ and $Y \subseteq X \cup Y$, from Proposition 3.4 (d) we have $L_\phi(X) \subseteq L_\phi(X \cup Y)$ and $L_\phi(Y) \subseteq L_\phi(X \cup Y)$. Hence $L_\phi(X) \cup L_\phi(Y) \subseteq L_\phi(X \cup Y)$.

b) $(X \cap Y) \subseteq X$ and $(X \cap Y) \subseteq Y$, from (iv) we have $H_\phi(X \cap Y) \subseteq H_\phi(X)$, $H_\phi(X \cap Y) \subseteq H_\phi(Y)$

Hence $H_\phi(X \cap Y) \subseteq H_\phi(X) \cap H_\phi(Y)$.

Proposition 3.6. For $X \subseteq U$:
A. $H_\phi(X/) = (L_\phi(X))/$
B. $L_\phi(X/) = (H_\phi(X))/$

Proof. $H_\phi(X/) = \{x \in U \mid x \in C_i, \phi(C_i) = \phi(C_j)$ for some $y \in X/$ and $y \in C_j\} = A$(say)

$\Rightarrow A/ = \{x \in U \mid x \in C_i, \phi(C_i) = \phi(C_j)$ for all $y \in X/$ and $y \in C_j\}$

$= L_\phi(X)$.

$\Rightarrow A = (A/)/ = (L_\phi(X))/$

$\Rightarrow H_\phi(X/) = (L_\phi(X))/$.

Similarly (b).

Proposition 3.7. For X; $Y \subseteq U$.
A. $H_\phi(X \cap Y) = H_\phi(X) \cap H_\phi(Y)$ iff $L_\phi(X) \cup L_\phi(Y) = L_\phi(X \cup Y)$.
B. $H_\phi(X \cup Y) = H_\phi(X) \cup H_\phi(Y)$ iff $L_\phi(X) \cap L_\phi(Y) = L_\phi(X \cap Y)$.

Proof. $H_\phi(X \cap Y) = (L_\phi(X \cap Y)/)/ = (L_\phi(X/ \cup Y/))/ = (L_\phi(X/) \cup L_\phi(Y/))/$ (given)

$= L_\phi(X/)/ \cap L_\phi(Y/)/ = H_\phi(X) \cap H_\phi(Y)$. (By using Proposition 3.6)

Similarly(b).

4. DEPENDENCY ON PARAMETERISED SOFT ROUGH SET

Definition 4.1. Let C and D be two coverings of U. Let (ϕ, C) and (Ψ, D) be two parameterised soft set over a common parameter set A .Then (ϕ, C) is said to be parameterised sub soft set of (Ψ, D) if for every $u \in U$, and $u \in C_i \in C$ there exists one $D_j \in D$ such that $\phi(C_i) \subseteq \Psi(D_j)$ and denoted by $(\phi, C) \subseteq_p (\Psi, D)$.

Example 4.2.
Let U = {a, b, c, d, e}, $C = \{C_1, C_2, C_3, C_4, C_5, C_6\}$ and

$D = \{D_1, D_2, D_3, D_4, D_5\}$ are the covering of U, where $C_1 = \{a, d\}$, $C_2 = \{b, c\}$, $C_3 = \{d\}$, $C_4 = \{a, c\}$, $C_5 = \{d, e\}$, $C_6 = \{e\}$, and

$D_1 = \{a, d\}$, $D_2 = \{b, c\}$, $D_3 = \{a, c\}$, $D_4 = \{d, e\}$ and $D_5 = \{e\}$. Let $A = \{e_1, e_2, e_3, e_4, e_5\} \subseteq E$ and $\phi(C_1) = \{e_1, e_2\}$, $\phi(C_2) = \{e_2, e_3\}$, $\phi(C_3) = \{e_4\}$, $\phi(C_4) = \{e_3, e_5\}$, $\phi(C_5) = \{e_1, e_5\}$ and

$\Psi(D_1) = \{e_1, e_2, e_3\}$, $\Psi(D_2) = \{e_3, e_4\}$, $\Psi(D_3) = \{e_4\}$, $\Psi(D_4) = \{e_1, e_3, e_5\}$, $\Psi(D_5) = \{e_5\}$. Here $(\phi, C) \subseteq_p (\Psi; D)$.

Definition 4.3. Let (ϕ, C) and (Ψ, D) be two parameterised soft set of U over a common parameter set A. Then (Ψ, D) is said to be dependent on (ϕ, C) if $(\phi, C) \subseteq_p (\Psi, D)$.

Proposition 4.4. Let (ϕ, B), (Ψ, C) and (γ, D) are the three parameterised soft set of U over a common parameter set A. If (ϕ, B) depends on (Ψ, C) and (Ψ, C) depends on (γ, D) then (ϕ, B) depends on (γ, D).

Proof: The proof follows directly.

Definition 4.5. Let (U, C, ϕ) is called parameterised soft approximation space and $X \subseteq U$, then the four types of rough set defined as
A. If $L_\phi(X) \neq \phi$ and $H_\phi(X) \neq U$, then X is said to be roughly definable
B. If $L_\phi(X) = \phi$ and $H_\phi(X) \neq U$, then X is said to be internally undefinable
C. If $L_\phi(X) \neq \phi$ and $H_\phi(X) = U$, then X is said to be externally undefinable
D. If $L_\phi(X) = \phi$ and $H_\phi(X) = U$, then X is said to be totally undefinable.

Proposition 4.6. For $X \subseteq U$.
A. Set X is roughly definable if and only if X/ roughly definable.
B. If set X is internally undefinable then X/ externally undefinable.
C. If set X is externally undefinable then X/ internally undefinable.
D. Set X is totally undefinable if and only if X/ totally undefinable.

Proof. The proof (a),(b) and (c) follows directly ,but for clarity we prove (d). From proposition 3.6(a) we have $H_\phi(X/) = (L_\phi(X))/ = \phi/ = U$, and $L_\phi(X/) = (H_\phi(X))/ = U/ = \phi$.

So, X/ totally undefinable.

Next we define rough soft set with respect to a parameter soft set of E.

Definition 4.7. Let (F;A) be a soft set, where $A \subseteq E$, E be set of parameters. Let (ϕ, C) be parameterised soft set and (U, C, ϕ) be parameterised soft covering approximation space.

Let (G,B) be another soft set, B ⊆ E. Then (G,B) is said to be covering based rough soft set with respect to e ϵ B if

$L_\phi(G(e))) \neq H_\phi(G(e))$.

Example 4.8.
Let U = {$u_1, u_2, u_3, u_4, u_5, u_6, u_7, u_8, u_9, u_{10}$},

E ={$e_1, e_2, e_3, e_4, e_5, e_6, e_7, e_8, e_9, e_{10}$ },

A ={e_1, e_4, e_5, e_7, e_8}, and

B = {$e_1, e_2, e_3, e_5, e_7, e_8$},

C_1 = { u_1, u_2}, C_2 = {u_2, u_5, u_9}, C_3 = {u_1, u_9, u_{10}},

C_4 = {u_2, u_4, u_7 }, C_5 = {u_3, u_5, u_9}, C_6 = {u_4, u_6, u_8},

C_7 = {u_1, u_9, u_{10}}, C_8 ={u_1, u_2, u_4, u_6} be a covering of U as ∪ Ci = U for i = 1 to 8.

Let $F(e_1) = C_1 \cup C_5$, $F(e_3) = C_2 \cup C_4 \cup C_7$,

$F(e_5) = C_2 \cup C_5$, $F(e_7) = C_1 \cup C_3 \cup C_6$, $F(e_8) = C_6 \cup C_7$.

Then $\phi(C_1)$ = {e_1, e_7 }, $\phi(C_2)$ = {e_2, e_4 }, $\phi(C_3)$ ={e_7 },

$\phi(C_4)$ = {e_4 }, $\phi(C_5)$ = {e_1, e_5 }, $\phi(C_6)$ = {e_3, e_8 }, $\phi(C_7)$ = {e_3, e_8}.

Now (G,B) is another soft set on U, where $G(e_1) = C_5 \cup C_6$, $G(e_2) = C_2 \cup C_5$, $G(e_3) = C_1 \cup C_2 \cup C_3$, $G(e_5) = C_1 \cup C_3 \cup C_4$, $G(e_7) = C_4 \cup C_7$, $G(e_8) = C_2 \cup C_6$.

Then we have $L_\phi(G(e_1))$ = {u_3, u_8}, $H_\phi(G(e_1))$ = U,
$L_\phi(G(e_2))$ = {u_3 },

$H_\phi(G(e_2))$ = {$u_1, u_2, u_3, u_4, u_5, u_7, u_9, u_{10}$},

$L_\phi(G(e_3))$ = {u_1, u_5},

$H_\phi(G(e_3))$ = {$u_1, u_2, u_3, u_4, u_5, u_7, u_9, u_{10}$},

$L_\phi(G(e_5))$ = {u_2}, $H_\phi(G(e_5))$ = U,

$L_\phi(G(e_7))$ = {u_7}, $H_\phi(G(e_7))$ = U,

$L_\phi(G(e_8))$ = {u_6, u_8}, $H_\phi(G(e_8))$ = {$u_1, u_2, u_4, u_5, u_6, u_7, u_8, u_9, u_{10}$}.

Thus (G,B) is a covering based rough soft set with respect to the parameters $e_1, e_2, e_3, e_5, e_7, e_8$.

We say (G,B) is to be a full rough soft set (Rough soft set) if and only if $L_\phi(G(e)) \neq H_\phi(G(e))$ for all e ϵ B.

5. CONCLUSION

A new model named "Parameterised Soft Rough Set" with covering on U has been introduced here to handle the problems of vagueness and impreciseness in our day to day life. This model is developed by the help of rough set theory and soft set theory on the covering approximation space. Also we define, in this article, external undefinable, internal undefinable, total undefinable. We find the example for the dependency of parameterised soft rough set. At the end we define covering based Rough soft Set with respect to the parameter.

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