Intuitionistic Fuzzy Rough Relational Database Model

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Abstract

In this paper, the new intuitionistic fuzzy rough relational model that expands the traditional model with the ability to represent indiscernible and imprecise information is presented. We utilize the notion of indiscernibility from rough set theory coupled with the idea of membership and non-membership values from intuitionistic fuzzy set theory to represent uncertain information in a manner that maintains the degree of uncertainty of information for each tuple of the original database and also those resulting from queries. First, we design our database using some type of semantic model and then use a variation of the entity-relationship diagram i.e. intuitionistic fuzzy rough E-R diagram. We also define the operators for the intuitionistic fuzzy rough relational database and demonstrate the expressive power of the model through its intuitionistic fuzzy rough relational algebra.

Keywords: *Intuitionistic fuzzy set, Intuitionistic fuzzy rough set, Intuitionistic fuzzy rough relational database model*

1. Introduction

Many real world applications and systems deal with imprecise or uncertain data. For such systems, we need information management systems that provide support for managing this imprecise and uncertain data. Significant work has been done in incorporating uncertainty management in relational databases using such theories as fuzzy set, probability, possibility, rough set, vague set and intuitionistic fuzzy (IF) set to name a few. Each of the theories has advantages and is better at modeling some type of uncertainty over another. Wong model [4] can process only incomplete information, Bagai and Suderraman [7] clearly pointed out that their model can process incomplete and inconsistent information and Beaubouef- Petry model [10, 13] can process only indiscernibility. In this paper we develop IF rough relational database model by using IF set [5] and rough set [14, 15] theories for handling impreciseness, vagueness and uncertain data in a relational database model. We utilize the notions of indiscernibility from rough set theory coupled with the idea of membership and non-membership values from IF set theory.

In Section 2, some important required information is cited. In Section 3, the concept of IF-rough relational database model is introduced and the application is shown with an example of medical database. In Section 4, IF rough relational operators in terms of an IF rough relational algebra is also defined and sample queries to the medical databases are also expressed. Lastly, the conclusion is drawn.

2. Preliminaries

In this section, some of the important required concepts necessary to go further through this paper are shown.

Definition 2.1[5] Let U be a universal set. An *IF set* A in U is an object having the form $A=\{(x,\mu_A(x),\upsilon_A(x)):x\in U\}$,where $\mu_A:U\to[0,1]$, $\upsilon_A:U\to[0,1]$ respectively the membership function and the non-membership function and $\mu_A(x)$ denotes membership degree and $\upsilon_A(x)$ the non-membership degree of the element $x\in U$ to the set A such that $0\le\mu_A(x)+\upsilon_A(x)\le 1$.

The amount $\pi_A(x)=1-(\mu_A(x)+\upsilon_A(x))$ is called the hesitation part, which may cater either membership value or non-membership value or both.

Definition 2.2[14]Rough Set: Let *R* is an equivalence relation (indiscernibility) on universal set *U*. The pair A = (*U*, *R*) is called a Pawlak approximation space. Then for any non-empty subset *X* of *U*, the sets $\underline{R}$ X ={x $\in U$: $[x]_R \subseteq X$ } and $\overline{R}$ X ={x$\in U$: $[x]_R \cap X \neq \phi$ } are respectively, called the lower and the upper approximations of *X* in *A*. The set approximation $\underline{R}$ X and $\overline{R}$ X may also be described as R-positive ($\underline{R}$ X) region, R-negative (U-$\overline{R}$ X) region and R-boundary region ($\overline{R}$ X-$\underline{R}$ X), where $[x]_R$ denotes the equivalence class of the relation *R* containing the element *x*. *X* is said to be *definable set*, if $\underline{R}$ (X) = $\overline{R}$ (X). Otherwise *X* is said to be *rough set*.

Definition 2.3[2] Let U be a universe and X , a rough set in U . An *IF rough set* A in U is defined by a membership function $\mu_A:U\to[0,1]$ and a non-membership function $\upsilon_A:U\to[0,1]$ such that

$$\mu_A(\underline{R}\ \ X)=1,\ \ \upsilon_A(\underline{R}\ \ X)=0 \text{ or } [\mu_A(x),\upsilon_A(x)]=[1,0] \text{ if } x\in(\underline{R}\ \ X)$$

$$\text{and } \mu_A(U-\overline{R}X)=0,\ \upsilon_A(U-\overline{R}\ \ X)=1 \text{or } [\mu_A(x),\upsilon_A(x)]=[0,1] \text{ if } x\in U-\ \overline{R}\ \ X$$

$$0\le\mu_A(\overline{R}\ \ X-\ \underline{R}\ \ X)+\upsilon_A(\overline{R}\ \ X-\ \underline{R}\ \ X)\le 1.$$

Definition 2.4[2] The union of two IF rough sets A and B is an IF rough set C , written as C=A∪B, whose membership and non-membership functions are related to those of A and B by $\mu_c(x)=\max[\mu_A(x),\mu_B(x)]$ and $\upsilon_c(x)=\min[\upsilon_A(x),\upsilon_B(x)]$

Definition 2.5[2] The intersection of two IF rough sets A and B is an IF rough set C, written as C=A∩B, whose membership and non-membership functions are related to those of A and B by $\mu_c(x)=\min[\mu_A(x),\mu_B(x)]$ and $\upsilon_c(x)=\max[\upsilon_A(x),\upsilon_B(x)]$.

Example 2.6[2] Let *U* = {Teenager, Young-Adult, Adult, Senior, Elderly, Senior-Citizen} be a universe. Let the equivalence relation *R* be defined as follows:
*R** = {[Teenager, Young-Adult], [Adult], [Senior, Elderly], [Senior-Citizen]}.
Let *X* = {Young-Adult, Adult, Senior-Citizen} be a subset of universe U.
X is expressed in terms of its lower and upper approximations as follows:
$\underline{R}X$ = {Adult, Senior-Citizen}, and
$\overline{R}X$ = {Teenager, Young-Adult, Adult, Senior-Citizen}.

Let A be a set whose membership and non-membership functions μ_A: $U \rightarrow [0, 1]$ and v_A: $U \rightarrow [0, 1]$ are defined as follows:
μ_A(Adult) = 1, μ_A(Senior-Citizen) = 1 and v_A(Adult) = 0, v_A(Senior-Citizen) = 0
μ_A(Senior) = 0, μ_A(Elderly) = 0, v_A(Senior) = 1, v_A(Elderly) = 1,
μ_A(Teenager) = 0.4,μ_A(Young-Adult)= 0.5,v_A(Teenager) = 0.4,v_A(Young-Adult)= 0.3.
Such a set *A* defined in *U* on rough set *X* is called IF rough set in which IF values are represented as [μ_A(Adult), v_A(Adult)] = [1,0], [μ_A(Teenager), v_A(Teenager)] = [0.4,0.4] etc.

3. IF Rough Relational Database Model

In the relational database model data are represented in tables called relations. Each column in the table contains values for a particular attribute for each of the data tuples or rows, in the table. All values within a given column are elements of the domain of the attribute for that column. A relation is described by a relation schema R (A_1, A_2, . . . , A_n) where R is a set of tuples of the form { A_l, A_2, . . . ,A_n} and A_i is an attribute of domain D_i defined for each column.

The rough relational database model [12] and fuzzy rough relational database model [13] are the extension of the standard relational database model of Codd [3]. The fuzzy rough relational database model captures all the essential features of the fuzzy sets and rough sets including the notion of indiscernibility of elements through the use of equivalence classes in terms of lower and upper approximation with fuzzy membership values.

In the proposed model, a tuple t_i takes the form (d_{i1}, d_{i2}, . . . , d_{im}, $d_{i[\mu ,\nu]}$) where d_{ij} is a domain value of a particular domain set D_j and $d_{i[\mu ,\nu]} \in [0, 1]$, the domain for IF membership and non-membership values denoted as $d_{i[\mu ,\nu]}=[d_{i\mu},d_{i\nu}]$. In the ordinary relational database, $d_{ij} \in D_j$. In the IF rough relational database, the membership and non-membership values $d_{ij} \subseteq D_j$ and d_{ij} is not restricted to be a singleton, $d_{ij} \neq \varnothing$.

Definition 3.1 Let $P(D_i)$ is the power set of D_i. An IF rough relation R is a subset of the product set $P(D_1) \times P(D_2) \times . . . P(D_m) \times D_{[\mu,\nu]}$, where $D_{[\mu,\nu]}$ is the domain for membership and non-membership value of the closed interval [0,1].

Example 3.2 For a specific relation, R, membership and non-membership are determined semantically. Given that D_1 is the set of names of patients, D_2 is the set of place of patients then,

(Anil, Shamli Bazar, [1,0])
(Gopal, {Durga Nagar, Rani Bazar}, [0.5, 0.5])
(Vishnu, Indra Gandhi, [0,1])

are elements of the relation R(Patient Name, Place, [μ, ν]) .

An IF rough tuple *t* is any member of *R*, which implies that it is also a member of $P(D_1) \times P(D_2) \times . . . \times P(D_m) \times D_\mu \times D_\nu$. If t_i is some arbitrary tuple, then $t_i = (d_{i1}, d_{i2}, \ldots d_{im}, d_{i\mu}, d_{i\nu})$ where $d_{ij} \subseteq D_j$ and $d_{i\mu} \in D_\mu$, $d_{i\nu} \in D_\nu$.

Definition 3.3 Let $t_i = (d_{i1}, d_{i2}, ..., d_{im}, d_{i\mu}, d_{i\nu})$ be an IF rough tuple. An interpretation of t_i is a tuple $\alpha = (a_1, a_2, ..., a_m, a_\mu, a_\nu)$ where $a_j \in d_{ij}$ for each domain D_j.

The interpretation space is the cross product $D_1 \times D_2 \times \cdot \cdot \cdot \times D_m \times D_\mu \times D_\nu$ but a given relation R consists only of the set of those tuples that are valid according to the underlying semantics of R.

Let $[d_{xy}]$ denote the equivalence class to which d_{xy} belongs. If d_{xy} is a set of values, then equivalence class is formed by taking the union of equivalence classes of members of the set; i.e. if $d_{xy} = \{c_1, c_2, ..., c_n\}$, then $[d_{xy}] = [c_1] \cup [c_2] \cup \ldots\ldots \cup [c_n]$.

Definition 3.4 Two tuples t_i and t_j are redundant if and only if they possess an identical interpretation.

If relation contains only those tuples of a lower approximation, i.e., those tuples having membership value 1 and non-membership value 0. Then, the interpretation α of a tuple is unique. In IF rough relations, there are no redundant tuples. The merging process, used in relational database operations, removes duplicate since duplicates are not allowed in sets, the structure upon which the relational model is based. Tuples may be redundant in all values except μ and v. If we are supplied with identical data from two sources, one certain and the other uncertain, we would want to retain the data that is certain, avoiding loss of information. So, there is need for another definition, which will be used for upper approximation tuples. This definition captures redundancy between elements of attribute values that are sets.

Definition 3.5 Two sub-tuples $X = (d_{x1}, d_{x2}, ..., d_{xm}, d_{x\mu}, d_{xv})$ and $Y = (d_{y1}, d_{y2}, ..., d_{ym}, d_{y\mu}, d_{yv})$ are roughly-redundant, R if for some $[p] \subseteq [d_{xj}]$ and $[q] \subseteq [d_{yj}]$, $[p] = [q]$ for all $j = 1,2, ..., m$.

Application of the model in "Medical Database"

In this section, we present a simple example of medical database. From this database, some patients are considered. On the basis of diagnosis, some patients are found to be suffering with diabetics, some are suffering with heart diseases and rest of the patients are suffering with both diabetics and heart disease. In the database, indiscernibility lies in the age, lipid profile, fasting blood sugar (FBS) and blood pressure (BP) attributes since they have the values in linguistic terms such as adult, senior, normal, high etc. The indiscernibility also lies in the name of the place of patients since there are some patients who are not able to tell the exact place. We considered 3 tables – Patient Detail (A1), Attributes of Diabetic Patients (A2) and Attributes of Heart disease (A3) as shown in Appendix. The attributes of these data sets are relating to physical examination and diagnostic laboratory tests also shown in Table (A4). Wherever there is indiscernibility in the values of attributes, to handle it, we used rough set theory, e.g., Name of places from Table A1 and Age, Lipid Profile, FBS and B.P. from Table A2 and A3. The values are shown as {Adult, Young-Adult}, {High, Very high}, {Normal, Medium} etc. In all the tables to handle impreciseness we are using IF set theory, the evidence in favor and against in the form of membership and non-membership in each tuple represented as intuitionistic values. For example, for ID 414: the membership and non-membership values are [0.3, 0.6]. Here the indiscernibility lies in the BP and FBS attributes since they have the values such as {Normal, High}.

IF Rough E-R Diagram

An entity-relationship model (ERM) is an abstract and conceptual representation of data. Entity-relationship modeling is a database modeling method, used to produce a type of conceptual schema or semantic data model of a system.

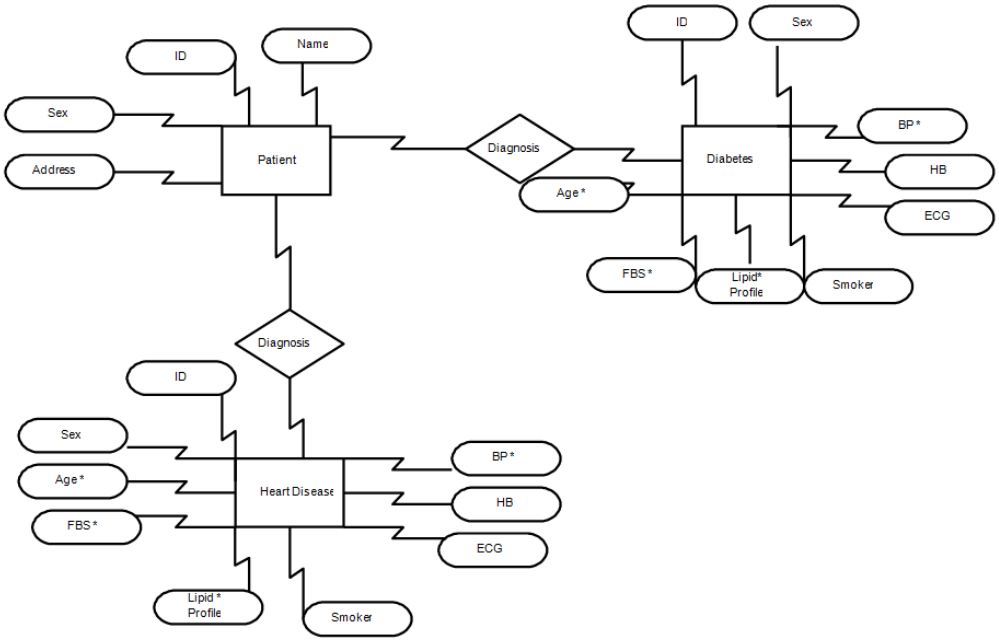

Figure 1. IF Rough Entity-Relationship Diagram

In this section, we first design our database using some type of semantic model. We use a variation of the entity-relationship diagram that we call an *IF rough E-R diagram*. This diagram is similar to the standard E-R diagram in that relationship types are displayed as diamond-shaped boxes, which are connected by straight lines to the rectangular boxes representing the participating entity types and attributes with ovals.

In the IF rough model, it is understood that membership and non-membership values exist for all instances of entity types and relationships. Attributes that allow values where we want to be able to define equivalences are denoted with an asterisk (*). A part of *IF rough E-R diagram* for the considered example appears in Fig.1. Now we have extended this diagram for IF rough relational database. If we have a priori information about the types of queries that will be involved, we can make intelligent choices that will maximize computer resources.

Uncertainty, ambiguity, and indiscernibility are all prevalent in the medical database. In order for any database to be useful, a mechanism for operating on the basic elements and retrieving specified data must be provided. The concepts of redundancy and merging play a key role in the operations. In the next section we formally define the IF rough relational database operators and discuss issues relating to the real world problems of data representation and modeling in the medical field.

4. IF Rough Relational Operators

In this section, we define several operators for the IF rough relational database and demonstrate the expressive power of the model through its IF rough relational algebra with example queries to the ‘‘diabetic’’ and “heart” patient database. The indiscernibility relation is used for equivalence of attribute values rather than equality of values for all of these operators.

4.1 IF Rough Difference Operator

The IF rough relational difference operator is a binary operator that contains those elements of the first IF rough relation that are not contained in the second IF rough relation.

Definition 4.1.1 Let T_1 and T_2 be two IF rough relations. The IF rough difference between T_1 and T_2 is an IF rough relation $T = T_1 - T_2$ where

$T = \{t(d_1,....d_n,[\mu_i,\nu_i]) \in \underline{RT}_1 : t(d_1,....d_n,[\mu_i,\nu_i]) \notin \underline{RT}_2\} \cup t(d_1,....d_n,[\mu_i,\nu_i]) \in \overline{RT}_1$ and

$\{t(d_1,....d_n,[\mu_i,\nu_i]) \in \overline{RT}_2 if \mu_i > \mu_j\} \cup \{t(d_1,....d_n,[\mu_i,\nu_i]) \in \overline{RT}_1$ and $t(d_1,....d_n,[\mu_i,\nu_i]) \in \overline{RT}_2$ if $\mu_i = \mu_j$ and $\nu_i < \nu_j\}$.

i.e., the lower approximation of $T = T_1 - T_2$ contains all those tuples belonging to the lower approximation of T_1 which are not redundant with a tuple in the lower approximation of T_2. The upper approximation of the IF rough relation T contains those tuples in the upper approximation of both T_1 and T_2, but which have a higher μ values in T_1 than in T_2 or equal μ values and lower ν values.

For example, consider the IF rough relation between Diabetic Patient and Heart Patient in Table A2 and A3 from the Appendix. The query **"Retrieve the information on individuals who are suffering only with Diabetics but not Heart disease"** can be expressed in Table 1.

Here, ID 402, 410, 419 and 422 belongs to the lower approximation whereas ID 420 belongs to the upper approximation because it satisfies the condition $\mu_i > \mu_j$ and $\nu_i < \nu_j$.ID 414, 415 also exists in both Tables A2 and A3 but not taken in the resulting table because $\mu_i = \mu_j$ but ν_i is not $< \nu_j$, it does not satisfy the condition $\mu_i > \mu_j$ or $\mu_i = \mu_j$ and $\nu_i < \nu_j$. This example clearly shows, the IF rough set technique is more useful than the fuzzy rough set technique where only membership values are considered at the time of comparison. If we use fuzzy rough set technique the tuple with ID 414 and 415 would have retrieved.

Table 1. IF Rough Difference of the Attributes of Diabetic and Heart Patient

ID	Sex	Age	Lipid Profile	BP	FBS	[μ,ν]
402	M	Adult	Normal	Medium	Normal	[0.3,0.6]
410	M	Senior	High	High	Normal	[0.7,0.2]
419	M	Senior	Very high	Very high	Very high	[0.8,0.1]
420	F	Senior-Citizen	High	Very high	High	[0.7,0.2]
422	M	Adult	Medium	High	High	[0.4,0.3]

4.2 IF Rough Union Operator

The IF rough union operator is a binary operator applied to two IF rough relations that result in a third relation that has as its tuples, all the tuples contained in either or both of the two original relations.

Definition 4.2.1 Let T_1 and T_2 be two IF rough relations. The IF rough union of T_1 and T_2 is an IF rough relation $T = T_1 \cup T_2$ where

$\underline{RT} = \{t : t \in \underline{RT}_1 \cup \underline{RT}_2\}$ and $\mu_{\underline{R}\ T}(t) = MAX[\mu_{\underline{R}\ T_1}(t), \mu_{\underline{R}\ T_2}(t)]$, and if $\mu_{\underline{R}\ T_1}(t) = \mu_{\underline{R}\ T_2}(t)$, $\nu_{\underline{R}\ T}(t) = MIN[\nu_{\underline{R}\ T_1}(t), \nu_{\underline{R}\ T_2}(t)]$.

$\overline{RT} = \{t : t \in \overline{RT}_1 \cup \overline{RT}_2\}$ and $\mu_{\overline{R}\ T}(t) = MAX[\mu_{\overline{R}\ T_1}(t), \mu_{\overline{R}\ T_2}(t)]$, and if $\mu_{\overline{R}\ T_1}(t) = \mu_{\overline{R}\ T_2}(t)$, $\nu_{\overline{R}\ T}(t) = MIN[\nu_{\overline{R}\ T_1}(t), \nu_{\overline{R}\ T_2}(t)]$.

i.e., the lower and upper approximation of the resulting IF rough relation T contains all those tuples which are a member of either or both of T_1 and T_2 together and having redundant tuples removed. If T_1 contains a tuple that is redundant with a tuple in T_2 except for the μ value, the merging process will retain only that tuple with the higher μ value. Those tuples redundant in all values except ν will retain the tuple having the lower ν value.

Table 2. IF Rough Union of the Attributes of Diabetic and Heart Patient

ID	Sex	Age	Lipid Profile	BP	FBS	[μ,ν]
402	M	Adult	Normal	Medium	Normal	[0.3,0.6]
408	M	Adult	High	Medium	High	[0.4,0.4]
410	M	Senior	High	High	Normal	[0.7,0.2]
414	F	Young-adult	Medium	{Normal, High}	{Normal, High}	[0.3,0.6]
415	F	{Senior, Adult}	{High, Very high}	High	Very high	[0.4,0.4]
418	M	Senior	High	Medium	Normal	[0.8,0.1]
419	M	Senior	Very high	Very high	Very high	[0.8,0.1]
420	F	Senior-Citizen	High	Very high	High	[0.7,0.2]
422	M	Adult	Medium	High	High	[0.4,0.3]
424	M	Senior	High	High	Normal	[0.7,0.2]

The query **"Retrieve all information for those patients who suffer either diabetics or heart disease or both"** can be expressed as IF rough union of the two relations, which yields **(Table 2).**

4.3 IF Rough Intersection Operator

Definition 4.3.1 The IF rough intersection of T_1 and T_2 is an IF rough relation $T = T_1 \cap T_2$ where: $\underline{RT} = \{t : t \in \underline{RT}_1 \cap \underline{RT}_2\}$ and $\mu_{\underline{R}\ T}(t) = MIN[\mu_{\underline{R}\ T_1}(t), \mu_{\underline{R}\ T_2}(t)]$, and if $\mu_{\underline{R}\ T_1}(t) = \mu_{\underline{R}\ T_2}(t)$, $\nu_{\underline{R}\ T}(t) = MAX[\nu_{\underline{R}\ T_1}(t), \nu_{\underline{R}\ T_2}(t)]$.

$\overline{RT} = \{t : t \in \overline{RT}_1 \cap \overline{RT}_2\}$ and $\mu_{\overline{R}\ T}(t) = MIN[\mu_{\overline{R}\ T_1}(t), \mu_{\overline{R}\ T_2}(t)]$, and if $\mu_{\overline{R}\ T_1}(t) = \mu_{\overline{R}\ T_2}(t)$, $\nu_{\overline{R}\ T}(t) = MAX[\nu_{\overline{R}\ T_1}(t), \nu_{\overline{R}\ T_2}(t)]$.

i.e., the lower approximation of the resulting IF rough relation T contains those tuples of the lower approximation of T_1 which have corresponding redundant tuples in the lower approximation of T_2 and the upper approximation of T contains tuples of the upper

approximation of T_1 which have redundant tuples in the upper approximation of T_2. The MIN operator is used in the merging of equivalent tuples having different μ values, and the result contains all tuples that are members of both of the original IF rough relations. For like μ values in redundant tuples, the ν values are compared and the tuple having the higher will be retained.

The query **"Retrieve all information for those patients who suffer both diabetics and heart disease"** can be formulated as –

Table 3. IF Rough Intersection of the Attributes of Diabetic and Heart Patient

ID	Sex	Age	Lipid Profile	BP	FBS	[μ,ν]
414	F	Young-adult	Medium	{Normal, High}	{Normal, High}	[0.3,0.6]
415	F	{Senior, Adult}	{High, Very high}	High	Very high	[0.4,0.4]
420	F	Senior-Citizen	High	Very high	High	[0.6,0.3]

4.4 IF Rough Select Operator

The select operator for the IF rough relational database model, σ, is a unary operator which takes an IF rough relation T_1 as its argument and returns an IF rough relation containing a subset of the tuples of T_1, selected on the basis of values for a specified attribute.

Definition 4.4.1 The IF rough selection, $\sigma_{A=a(x)}$, of tuples from T_1 is an IF rough relation T_2 having the same schema as T_1 and where

$$\underline{RT}_2 = \{t \in T_1 : \cup_i [a_i] = \cup_i [b_j]\}, a_i \in a, b_j \in t(A)$$

$$\overline{RT}_2 = \{t \in T_1 : \cup_i [a_i] \subseteq \cup_i [b_j]\}, a_i \in a, b_j \in t(A)$$

The lower approximation of $T = T_1 - T_2$ contains those tuples belonging to the lower approximation of T_1 which are not redundant with a tuple in the lower approximation of T_2. The upper approximation of the IF rough relation T contains those tuples in the upper approximation of T_1 which are not redundant in the upper approximation of T_2. The membership and non-membership values for tuples can be calculated by multiplying the original value by: card (a)/card(b) where card(x) returns the cardinality, or number of elements, in x.

The query "**To select all those patients who are senior and suffer heart disease"** can be formulated as Table 4.

Table 4. IF Rough Selection from the Attributes of Heart Patient

ID	Sex	Age	Lipid Profile	BP	FBS	[μ,ν]
415	F	{Senior, Adult}	{High, Very high	High	Very high	[0.2,0.2]
418	M	Senior	High	Medium	Normal	[0.8,0.05]
424	M	Senior	High	High	Normal	[0.7,0.1]

In this Table, with the attribute of Age, the last two tuples belongs to the lower approximation where as first tuple belong to the upper approximation.

4.5 IF Rough Project Operator

The Project operator π is a unary IF rough relational operator that takes a relation that contains a subset of columns of the original relation.

Definition 4.5.1 Let T_1 be an IF rough relation with schema X, and let Y be a subset of X. The IF rough projection of T_1 onto schema Y is an IF rough relation T_2 obtained by omitting the columns of T_1 which correspond to attributes in X − Y, and removing redundant tuples and higher μ values have priority over lower ones and lower ν values have priority over lower ones.

The IF rough projection of T_1 onto Y, $\pi_Y(T_1)$, is an IF rough relation T_2 with schema $T_2(Y)$ where: $T_2(Y)=\{t(Y): t\in T_1\}$.

The IF rough project operator maintains those tuple which belongs to the lower and upper approximation.

The query **"List all ages suffers diabetics"** can be expressed as an IF rough projection on the attribute Age of the Diabetic Patient relation.

Table 5. IF Rough Project Operator

Age	[μ,ν]
Adult	**[0.4,0.3]**
Senior	**[0.8,0.1]**
Young-adult	**[0.3,0.6]**
{Senior, Adult}	**[0.4,0.4]**
Senior-Citizen	**[0.7,0.2]**

4.6 IF Rough Join Operator

The IF rough join operator takes related tuples from two relations and combines them into single tuple of the resulting relation. It uses common attributes to combine the two relations into one.

Definition 4.6.1 The IF rough join, T_1 join T_2, of two relations T_1 and T_2, is a relation $T(C_1,C_2,....C_{m+n})$ where $T=\{t:\exists t_{T_1}\in T_1, t_{T_2}\in T_2$ for $t_{T_1}=t(X), t_{T_2}=t(Y)\}$, and where

$t_{T_1}(X\cap Y)=t_{T_2}(X\cap Y), \mu=1, for \underline{RT}$

$t_{T_1}(X\cap Y)\subseteq t_{T_2}(X\cap Y)$, or $t_{T_2}(X\cap Y)\subseteq t_{T_1}(X\cap Y), \mu=MIN(\mu_{T_1},\mu_{T_2})$, if

$\mu_{T_1}=\mu_{T_2}$, $\nu=MAX(\nu_{T_1},\nu_{T_2})$, for $\overline{RT}$.

The join operator is a conjunction of one or more conditions of the form A = B. Only those tuples which resulted from the "joining"of tuples that were both in lower approximations in the original relations belong to the lower approximation of the resulting IF rough relation. All other "joined" tuples belong to the uncertain region, having membership values less than one.

The query **"List all patients who resides in Krishna Nagar and suffers Diabetics"** can be expressed as an IF rough join on the attributes of patients details and attributes of Diabetic patient.

Table 6. IF Rough Join Operator

ID	Name	Sex	Address	Age	Lipid Profile	BP	FBS	[μ,ν]
414	Priya	F	Krishna nagar	Young-adult	Medium	{Normal, High}	Normal	[0.3,0.6]
419	Manik	M	Krishna nagar	Senior	Very high	Very high	Very high	[0.8,0.1]
422	Alok	M	Krishna nagar	Adult	Medium	High	High	[0.4,0.3]

5. Conclusions

This paper concerns the modeling of imprecision and vagueness type of uncertainty in databases through an extension of the relational model of data - the IF rough relational database. The new model is defined and relational algebra of the operators for querying are discussed. The new IF rough E-R diagram has been described. In conclusion, the IF rough relational database model is easy to understand and to use. It is more efficient model of the uncertainty of real-world enterprises than conventional databases through the use of indiscernibility and membership and non-membership values.

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Appendix

Consider the following three tables namely Patient, Diabetics and Heart disease having different attributes for getting the results of various operators and queries-

Table A1: PATIENT DETAIL

ID	Name	Sex	Address	[μ,ν]
401	Anil	M	Shamali Bazar	[1,0]
402	Gopal	M	{Durga Nagar, Rani Bazar}	[0.5,0.5]
408	Shambhu	M	Krishna Nagar	[1,0]
409	Rekha	F	{Salbagan, Lambu chera}	[0.5,0.5]
410	Vishnu	M	Indra nagar	[1,0]
411	Nirmal	M	Krishna Nagar	[1,0]
412	Arti	F	Shamali Bazar	[1,0]
414	Priya	F	Krishna Nagar	[1,0]
415	Rita	F	Jogender Nagar	[1,0]
418	Manoj	M	Nandan Nagar	[1,0]
419	Manik	M	Krishna Nagar	[1,0]
420	Saroj	F	Arila Agartala	[1,0]
422	Alok	M	Krishna Nagar	[1,0]
424	Rajat	M	Jogender Nagar	[1,0]

Table A2: ATTRIBUTES OF DIABETIC PATIENTS

ID	Sex	Age	Lipid Profile	BP	FBS	[μ,ν]
402	M	Adult	Normal	Medium	Normal	[0.3,0.6]
410	M	Senior	High	High	Normal	[0.7,0.2]
414	F	Young-adult	Medium	{Normal, High}	{Normal High}	[0.3,0.6]
415	F	{Senior, Adult}	{High, Very high}	High	Very high	[0.4,0.4]
419	M	Senior	Very high	Very high	Very high	[0.8,0.1]
420	F	Senior-Citizen	High	Very high	High	[0.7,0.2]
422	M	Adult	Medium	High	High	[0.4,0.3]

Table A3 : ATTRIBUTES OF HEART PATIENTS

ID	Sex	Age	Lipid Profile	BP	FBS	[μ,ν]
408	M	Adult	High	Medium	High	[0.4,0.4]
414	F	Young-adult	Medium	{Normal, High}	{Normal, High}	[0.3,0.5]
415	F	{Senior, Adult}	{High, Very high	High	Very high	[0.4,0.4]
418	M	Senior	High	Medium	Normal	[0.8,0.1]
420	F	Senior-Citizen	High	Very high	High	[0.6,0.3]
424	M	Senior	High	High	Normal	[0.7,0.2]

Table A4: SUMMARY OF ATTRIBUTES

Attribute	Description	Value description
Sex	Gender	M if male; F if female
Age	Age	18-30 years Young-Adult 31-44 years Adult 45-64 years Senior or Elderly person ≥65 years Senior-Citizen
Lipid Profile	Total cholesterol, [LDL-C, HDL-C and TGs]	<200 mg/DL normal 200-239 Medium(Borderline) 240-249 High ≥250 Very High
BP	BloodPressure	<120/<80 Normal 120-129/80-85 Medium 130-159/86-99 High ≥160/≥100 Very High
FBS	Fasting blood sugar	<100 mg/DL Normal 100-125 mg/DL High ≥126 mg/DL Very high

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