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A Generalized Definition Language for Implementing the Object Based Fuzzy Class Model

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Abstract— **The emerging application domains in Engineering, Scientific Technology, Multimedia, GIS, Knowledge management, Expert system design etc require advanced data models to represent and manipulate the data values, because the information resides in these domains are often vague or imprecise in nature & difficult to represent while implementing the application software. In order to fulfill the requirements of such application demands, researchers have put the innovative concept of object based fuzzy database system by extending the object oriented system and adding fuzzy techniques to handle complex object and imprecise data together. Some extensions of the OODMS have been proposed in the literature, but what is still lacking a unifying & systematic formalization of these dedicated concepts. This paper is the consequence research of our previous work, in which we proposed an effective & formal Fuzzy class model to represent all type of fuzzy attributes & objects those can be confined to fuzzy class. Here, we introduce a generalized definition language for the fuzzy class which can efficiently define the proposed fuzzy class model along with all possible fuzzy data type to describe the structure of the database & thus serve as data definition language for the object based fuzzy database system.**

Index Terms— **Fuzzy class definition language, Fuzzy data type, Fuzzy class, Object based fuzzy database model.**

I. INTRODUCTION

The advancement in the requirements for modeling & manipulation of complex object and imprecise information in various knowledge intensive applications are emerging as leading problems to the database research. The involvement of complex object and vague information together make the relational model & its extensions, to be apart from modeling of such object or information. Object oriented data models are widely acknowledged at the information modeling arena as they provide hierarchical data abstraction scheme & mechanisms for information hiding [6]. However, they are incapable of representing or manipulating imprecise data values. Mean while, probability theory & fuzzy logic provide measures and rules for representing uncertain imprecise information [2]; that has led to intensive research & development of a high standard database system named "Object based fuzzy Database system". The fuzzy object modeling is being extensively studied to make it a knowledge representation tool at various knowledge and large data intensive applications with inherent fuzzy reasoning techniques incorporating into it [14]. All the concepts regarding fuzzy class, fuzzy attributes, fuzzy object class relation and fuzzy inheritance stated in the literature are specific and applicable for particular application domains [8],[9],[12],[16]. The lacking of formalization of the existing interpretations of fuzzy class, fuzzy object, fuzzy subclass-super class relationships are exerting problems in determining fuzziness at various levels of class hierarchy or establishing fuzziness at inheritance and multiple inheritance structure.

So, to overcome such issues, we have thoroughly investigated the current research proceedings & put an attempt to redefine some concepts to make them more prominent. In this regard, we first introduced the definition of a generalized fuzzy class along with an efficient model to represent the fuzzy class. Here, we extend our ongoing research and propose a generalized fuzzy class definition language to define the proposed fuzzy class model specifying the data type and possible values of fuzzy attributes. The various sections of the paper are organized as follows. In the next section, we discuss about various research work carried out to define the fuzzy class structure. In 3rd section we provide a glimpse of our previous contribution of designing a generalized fuzzy class structure. In section 4, a formal definition language for defining fuzzy class along with fuzzy data type are provided & finally section 5 will take us to the conclusion of this study.

II. RELATED WORK

There is little research in the development of fuzzy object database system which addresses the practical perspective. All the models or concepts stated in the literature are theoretical or analytical in nature. We have investigated the current research and development of fuzzy object based database systems and outlined the concepts proposed by the active researchers.

In [8], the author defined fuzzy class as fuzzy type whose structural part is fuzzy structure. That means all the attributes defined for a class should belongs to the class with certain membership degree. A two layer graphical structure is also proposed in the paper where the author used fuzzy class to define instantiation and inheritance mechanism by the principle of α-cut. An informal definition of fuzzy type is also

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provided in accordance to a specific application of biomedical system where he defined the structure of the class in which all the fuzzy attribute belongs to the class with membership degree equal to 1 and he also discussed about some behavioral aspects of the fuzzy objects. In [16], the author defined the fuzzy class with respect to weights of the attributes to the class, in addition to these common attributes a special attribute has to be added which indicates the membership degree to which an object of the class belongs to the class. The degree that a subclass belongs to the super class is also illustrated in the specifications of class definition. The class definition language provided by the author is as follows:

```
CLASS class name WITH DEGREE of DEGREE
INHERITS super class_1 name WITH DEGREE OF degree_1
.
.
INHERITS super class_k name WITH DEGREE of degree_k
ATTRIBUTES
    Attribute_1 name:[FUZZY] DOMAIN dom 1:
          TYPE of type_1 WITH DEGREE of degree_1
.
.
Attribute_m name: membership degree
    WEIGHT
       W (Attribute_1 name)=W-1
.
.
       W (Attribute_m name)=W-m
    METHODS
.
.
END
```

The language is showing the deficit of providing data types of all type of fuzzy attributes and the nature of their values. There is no data type description for the attributes or any interface for specifying constraints to the class.

In [8], the author defined fuzzy class as a class with fuzzy boundary. He defined such a fuzzy class as : $FC_i=\{(O_{ij}.....a_{ij}, \mu(O_{ij}..))/O_{ij}...$is object, a_{ij} is attribute, $0\leq\mu(O_{ij}....a_{ij})\leq 1\}$. The idea is to represent a fuzzy class in terms of fuzzy object in which the attributes of the object belongs to the object with certain membership degree. No definition language is provided by the author in the creation of fuzzy object data base system for catalytic cracking unit.

In [12], the author proposed fuzzy object database model for GIS application to represent imprecise attribute values and complex object by using the class inheritance concept. The class definition language provided is purely dedicated to GIS domain with little specifications of representing fuzzy attribute values. The proposed class definition is as follows:

```
Interface Water body: feature{
Extent water_bodies;// name of extent
Attribute hecters surface_area;
Attribute meters maximum_depth;
Attribute Fuzzy_value<water quality> quality;
Relationship set<stream> drains_into;
Inverse stream :: drains_from;
Relationship set <stream> drains_from;
Inverse stream :: drains_into;
Relationship set <hillslope> adjacent_to
}
```

In [11], the author defined a fuzzy class in terms attributes belongs to the class take values from fuzzy domain or contains fuzzy value then the class is fuzzy. Similarly when the objects form the class contains uncertain values then the class is fuzzy. No explicit class definition is given by the author.

In [10], the author proposed a deductive probabilistic and fuzzy object oriented database language called FRIL++ which can deal with both probability and fuzziness. Here, uncertainty in class membership & property applicability are measured by lower and upper bound on probability; but attributes type are not mentioned. The class definition language is as follows:

```
(( public class person extends (universal))
  (constants
     (tall [0:0 1.5:0 1.8: 1 2.5:1])
     (not slim [0:1 22:1 28:0 45:1])
     (not fat [0:1 22:1 28:0 45:0 ])
   (properties
      (height_))
      (weight_))
      ((body mass index B)
        (height H)
        (times H H H2)
         (weight w)
       ((person H W)
        (set prop((height H)))
        (set prop ((weight W))))))
((public class Tall Man extends(person))
     (properties
       ((handsome)) : (.91)
        ((is a tall man)
         (height H)
         (match tall H))))
```

All the existing definition of class and the class definition language discussed so far are related to specific application domain and can be applicable to that domain only. The lacking of adequate fuzzy data types has restricted the class definition languages to define the fuzzy attributes or objects more accurately. The traditional definition of fuzzy class also compels the existing fuzzy class definition language to represent a limited type of fuzzy objects or attributes. The lacking of a generalized fuzzy class model and the unexplored data types for the fuzzy attributes have restrained the researchers to design a data definition language for representing fuzzy class structure. So, the prime motto of the research is to first develop a generalized fuzzy class structure with an efficient model and explore the data types possible for all type of fuzzy attributes and then go for design of a fuzzy class definition language to define the fuzzy class model.

In the next section, we discuss our previous contribution to fuzzy object database research by providing a glimpse of our proposed fuzzy object class model, subsequently we discuss the data types required for the fuzzy attributes and finally the definition language for the fuzzy class model will be outlined.

III. OUR PREVIOUS CONTRIBUTION

We addressed the fuzzy class as a specialized crisp class with an added linguistic label which comprises of general attributes or crisp attributes, fuzzy attributes and iterative attribute or special object [3].
A fuzzy class must contain either all of the given attributes or some of the given attributes.
We introduced the concept of "Iterative fuzzy attribute or Special object". An iterative fuzzy attribute is an attribute or special object which is having its own properties or attributes. It is quite often seen in many applications, where we have classes consist of attribute which can be decomposed into further more simplified attributes. The existing fuzzy object models do not provide any interface to represent or manipulate such an attribute, which shows their lacking in uniform formalization towards the global representations of fuzzy class at any circumstances.
The representation of a new fuzzy class structure along with fuzzy iterative attribute is given as follows:

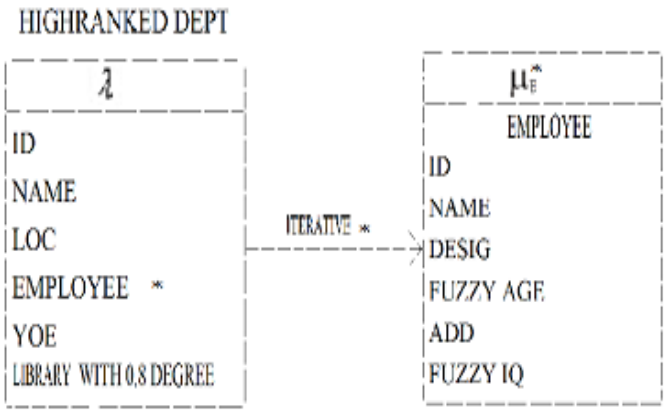

Fig I: REPRESENTION OF FUZZY CLASS

We represented such a fuzzy class by two dashed line class diagrams with little modifications of general object oriented class diagram. For example, an application demands to represent all the departments of our country into three distinct categories: HIGHRANKEDDEPT, MEDIUMRANKEDDEPT, and LOWRANKEDDEPT. All these classes are specialized classes of the class DEPT and are associated with a linguistic label which clearly indicates their fuzziness.
Fig I shows the representation of a fuzzy class HIGHRANKEDDEPT. The proposed model of fuzzy class consists of two dashed rectangles each divided into two parts. The first rectangle represents the fuzzy class whose name placed at top of it, the first part of the rectangle shows the membership degree of the fuzzy class belongs to the data model or its membership degree to the super class if it is the sub class and is represented by the symbol" λ" .The second part of the rectangle represents all type of attributes possible for the fuzzy class. A general attribute is represented as:
ATTRIBUTE NAME.
An attribute which takes value from a fuzzy domain like AGE which might take fuzzy values as young, middle aged, old etc is represented as:
FUZZY ATTRIBUTE NAME.
An attribute whose value is uncertain or imprecise is represented as:
ATTRIBUTENAME WITH m DEGREE.

For example, all the departments may or may not have their own library so we can write LIBRAY WITH 0.8 DEGREE.
A fuzzy iterative attribute is represented as:
ATTRIBUTE NAME *.
For example, EMPLOYEE *.
The second dashed rectangle represents a fuzzy iterative attribute along with its associated properties. The first part of the rectangle shows the membership degree of the fuzzy iterative attribute to the fuzzy class and is represented as:
$\mu_{\text{attribute name}}$*.
The second part of the rectangle represents the properties of the fuzzy iterative attribute headed by the name of fuzzy iterative attribute. The fuzzy class and its fuzzy iterative attribute are associated with a dashed arrow labelled with ITERATIVE *. If the fuzzy iterative attribute contains another iterative attribute then it can also be represented through another dashed rectangle of same type and the association between these two attributes can be represented as a dashed arrow labelled with ITERATIVE **.
The proposed model is flexible enough to represent and manipulate a fuzzy class in a more efficient way considering a wider range of possibilities of fuzziness in the classes to cater services to diversified application domains. The model strictly follows the ODMG guidelines and is easy to implement. The portability inside the model will also encourage adding more features as per requirements. Above all, the model is very simple and easy to understand and it can surely serve as a conceptual modelling for object based fuzzy database. In the next section, we show the extension of the research by putting the concepts of fuzzy data types and designing an efficient framework for fuzzy class definition language.

IV. EXTENSION OF THE RESEARCH

A. Data Types for Fuzzy Attributes

Data type is essential for uniform categorization of attributes while defining the class of the attribute or object [5]. The data type of a fuzzy attribute depends up on the nature of the attribute value and domain from which the attribute takes its value [14]. Fuzzy attributes can be broadly classified into two categories i.e fuzzy attributes whose fuzzy values are fuzzy sets and fuzzy attributes whose values are fuzzy degrees

[10]. We propose data types for all type of fuzzy attributes irrespective of their categories. The proposed data types are outlined as follows:

1. FUZZY STRING : A fuzzy attribute may take a single "string" value with possibility distribution is equal to 1

Eg. { Behavior=good, represented by possibility distribution 1/good}

2. FUZZY INTEGER: The attribute may take single numeric value; it can also be interpreted as crisp type with possibility distribution equal to 1.

Eg. {Age=35 represented by possibility distribution 1/35}

3. MUTUALLY EXCLUSIVE STRING: The attribute may take more than one value and the membership degree of all these values to the attribute is 1.

Eg. { Behavior = {good, bad} represented by possibility distribution 1/good, 1/Bad}

4. MUTUALLY EXCLUSIVE INTEGER: Attributes of numeric may take multiple values belong to the attribute with membership degree equal to 1.

Eg. {Age={20,21} represented by {1/20,1/21}}

5. FUZZY MUTUALLY EXCLUSIVE STRING: The attribute may take value from fuzzy domain and each possible value of attribute belong to the attribute with certain membership degree.

Eg. Behavior={0.6/good, 1.0/regular, 0.4/bad}

6. FUZZY MUTUALLY EXCLUSIVE INTEGER: The attribute may take numerical value and each value of the attribute belongs to the attribute with possibility distribution.

Eg. Age= {0.9/27, 0.4/20, 1/28, 0.8/26}

7. NULL: The value of the attribute is unknown or undefined, then we can use the type of attribute as null.

Eg. Young= {0/100, 0/75}

The proposed fuzzy data types are the fundamental type for defining imprecise or uncertain fuzzy attribute values. These basic data types can be used in developing of high standard or derived data types to define the fuzzy object data base at complex knowledge intensive applications. In the next section we use these data types in the fuzzy class definition language to describe the structure of the fuzzy object database model.

B. A FORMAL LANGUAGE for DEFINING THE FUZZY CLASS MODEL

The definition of any database model generally describes the structure of the database, type of data stored in the database and their relationships and finally provide the interface for imposing constraint to the database [5]. We have developed a generalized definition language with the fundamental fuzzy data types which will address the fuzzy attribute types, the nature of attribute values and provides the interface for defining constraints to the data base. The pseudo code of the definition language of fuzzy class is as follows:

```
CLASS CLASS Name WITH m DEGREE
{
  ATTRIBUTES:
    Attribute_1 Name: TYPE [Crisp] Value="crisp";
    Attribute_2 Name: TYPE [Fuzzy String] Value="Fuzzy WITH m DEGREE";
    Attribute_3 Name: TYPE [Fuzzy Integer] Value: Number WITH m DEGREE;
    Attribute_4 Name: TYPE [Fuzzy M.E String] Value="Imprecise";
    Attribute_5 Name: TYPE [Fuzzy M.E Integer] Value="Imprecise";
    Attribute_6 Name: TYPE [Fuzzy *] Value="Iterative WITH m DEGREE";

  ITERATIVE Attribute Name WITH m DEGREE to CLASS Name
  {
    ATTRIBUTES:
      Attribute_1 Name: TYPE [Crisp] Value="Crisp";
      .
      .
      .
      Attributes_n Name: TYPE [Fuzzy **] Value="Iterative WITH m DEGREE";

  ITERATIVE * Attribute Name WITH m DEGREE to ITERATIVE Attribute Name
  {
  ATTRIBUTES:
    Attribute_1 Name: TYPE [Crisp] Value="Crisp";
    .
    .
    .
  }
  }
  }
```

We have proposed this language as an universal data definition language for defining the fuzzy object data model. The language is flexible enough to address the structure of the fuzzy object data base and categorically distinguish different type of fuzzy attributes by providing appropriate type to the attributes and describing the nature of their values. We can also add more features to this language as per various application requirements. The generality and built-in features of this language are the incentives for making this language as the universal language for defining fuzzy object data base system.

V. FUTURE RESEARCH DIRECTIONS AND CONCLUSION

In this study, we have shown the continuation of our research by extending our previous contribution and subsequently exploring a couple of advanced concepts in

fuzzy object database design and modeling. First, we have redefined the fuzzy class definition or fuzzy class structure and designed a uniform model to represent all type of fuzzy attributes or objects at various levels of applicability. We have extended the concept to practically implement the proposed model by exploring the concept of basic fuzzy data types to categorically address all type of fuzzy attributes and also describing the nature their values. The proposed data types can also serve as basic type for developing high standard derived fuzzy data types. The fuzzy class definition language is the result of the fuzzy class model defined earlier and the proposed fuzzy data types; the portability inside the language will allow the researchers to add more features at changing application demands. The language is organized in such a way that it can describe the structure of the fuzzy object database in more prominent manner. We will extend the research further to define and manipulate fuzzy inheritance structure, fuzzy casual relations, fuzzy exception handling and also emphasizes on designing an algebra for fuzzy object query and processing of the query. The quest will be on its way till the complete formalization of object based fuzzy database system.

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