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HANDLING GREY INFORMATION IN OBJECT ORIENTED DATABASES

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Efficient handling of inexact (grey) information is an important issue for the new emerging database technology. Inexact or imprecise information has been represented and manipulated by using different techniques, including fuzzy set theory, possibility theory, IVF (Interval Valued Fuzzy) Sets, Time Petri Nets, Fuzzy Clouds, etc. In this paper, different approaches dealing with uncertainty have been introduced. A brief description of uncertainty in object oriented databases has been discussed, also.

Keywords: Fuzzy Sets, IVF (Interval Valued Fuzzy Sets), IFS (Intuitionistic Fuzzy Sets), Time Petri Nets, Fuzzy Clouds, Rough Sets.

1. Introduction

Object oriented databases are considered better than the relational and other databases, due to increasing demand of new approaches to deal with complex data and complex relationships existing among such data and large data intensive applications. These databases are much suitable for modern database applications, like CAD/CAM (Computer Aided Design/Computer Aided Manufacturing), CASE (Computer Aided Software Engineering), GIS (Geographical Information Systems), Spatial Databases, Office Automation; Knowledge based Systems, Hardware and Software Design, Network Management, Multimedia databases, VLSI (Very Large Scale Integrated) Design. In these applications, several types of information inexactness exist. Such incomplete and ill-defined information has been accepted, represented and manipulated with a certainty measure of acceptance using fuzzy techniques.

The integration of fuzzy techniques in databases makes these systems to be closer with human activities. These may include, dealing with different fuzzy concepts, like ‘almost all’, ‘majority’, ‘approximately’, which include a certain vagueness or uncertainty.

As far as the usability point of object oriented database systems is concerned, these are much suitable for scientific and engineering applications, but not very much suitable for industrial and commercial applications. The complex imperfect information has been represented, stored and retrieved in object oriented databases using fuzzy techniques. Complex object structures can be represented well in object oriented databases without fragmentation of aggregate data and also model complex relationship among attributes. As far as the shortcomings are concerned in fuzzy object oriented database, it shows lack of formal semantics and algebra for manipulation and representation of knowledge as well as the inexact information data/ information.

2. Related Work

There may be several kinds of uncertainty happening in such modeling like imprecise attribute, relationships and in the type of uncertainty. These uncertainties can be handled by using fuzzy techniques. Different approaches developed for the purpose of conceptual modeling are discussed in this section.

Attribute imprecision values as well as fuzzy set of objects and different uncertainty issues are modeled in a unified manner using a semantic data model in [1].

Several major ER/EER concepts are fuzzified to conceptually model the imprecise and uncertain data in [2]. Fuzzy extensions to subclass/ super class, generalization/ specialization and shared sub class / category has been discussed. Attribute inheritance, multiple inheritance and selective inheritances and inheritance for derived attributes are discussed and introduced in fuzzy context.

The object oriented representation of uncertain and complex information has been proposed using $ExIFO_2$, an extension of IFO data model [3]. Also, different graphical notions for fuzzy, incomplete and atomic types, complex types, function types and ISA links has been introduced.

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A constructive approach using ExIFO to model complex and uncertain information conceptually and then transformation of the ExIFO into NF_2 Logical Data Model has been proposed with the help of algorithms in [4].

An existing IFO data model [5, 6] has been extended to model fuzziness at different levels in [7]. The new model is titled as IF_2O. Fuzzy printable types, fuzzy abstract and free types, fuzzy constructs, fuzzy fragments and fuzzy ISA relationships are discussed here in this study.

A system for expressing flexible constraints, which can be used in the conceptual modeling using enhanced entity relationship, has been introduced in [8,9]. The restrictions have been proposed using fuzzy quantifiers. In this study, fuzzy participation constraint, fuzzy cardinality constraints, and fuzzy completeness constraint in the representation of specializations and fuzzy cardinality constraints in overlapping specializations are proposed. Also, it has studied the fuzzy (min, max) notation.

A fuzzy extended entity relationship model has been proposed in [10] to deal with inexact information. Also, a formal framework for mapping a fuzzy extended entity relationship model to fuzzy object oriented database schema has been provided.

Several points of fuzziness have been identified in UML class diagram to model and represent inexact information in [11]. Fuzzy class generalization, aggregation and dependency have been discussed here.

Classical database models at conceptual and logical level lacks the rules and semantics to represent such information. To model such type of information, different classical database models, like ER/EER, IDEF1X, UML, EXPRESS-G are extended using fuzzy logic, a theory of uncertainty handling. The fuzzy extensions of these models are proposed in [12]. Also, a SDAI implementation of the object oriented database and Fuzzy EXPRESS implementation of Fuzzy Object Oriented Database has been proposed in [12].

The fuzzy extension of XML to model information imprecision has been proposed in [13].

A fuzzy EER model has been discussed in [14]. Several issues like, imprecise attributes, fuzzy entity, fuzzy relationship and specialization with fuzzy degree have been discussed also.

A formal approach for mapping a Fuzzy IFO (IF_2O) model to a fuzzy object oriented database schema has been proposed in [15]. Also, a generic fuzzy object oriented database system has been developed by extending the objects, classes, their relationships, subtype/super type and multiple inheritances in fuzzy environment.

A pragmatic model has been transformed to the Fuzzy Petri Net formal models in [16]. Different aspects of behavioral and structural modeling are also presented in this study.

3. Concepts Dealing with Uncertainty

There are several approaches available that are used with information inexactness.

3.1. Fuzzy Sets

The concept of fuzzy sets [17, 18] was introduced by L.A. Zadeh in 1965 to represent /manipulate data and information possessing non-statistical uncertainties.

Let U be a universe of discourse. A fuzzy value on U is characterized by a fuzzy set F in U.

$$F = \{\mu_F(u_1)/u_1, \mu_F(u_2)/u_2, \ldots\ldots\ldots\ldots\ldots\ldots, \mu_F(u_n)/u_n\}$$

Where, U is an infinite set, then the fuzzy set F can be expressed by $F = \int_{u \in U} \mu_F(u)/u$, here, μ_F is a membership function, with the following condition.

$\mu_F : U \to [0,1]$ defined for a fuzzy set F.

3.1.1. Interval Valued Fuzzy Sets (IVF)

IVF sets are introduced in [19]. It is defined by a mapping F from the universe U to the set of closed intervals in [0, 1].

Let $F(u) = [F^{\theta}(u), F^{\gamma}(u)]$

The union, intersection and complementation of IVF's are calculated by canonically extending fuzzy set theoretic operations to intervals.

Union: $E \cap F(u) =$

$$[\min(E^{\theta}(u), F^{\theta}(u)), \min(E^{\gamma}(u), F^{\gamma}(u))]$$

Intersection: $E \cup F(u) =$

$$[\max(E^{\theta}(u), F^{\theta}(u)), \max(E^{\gamma}(u), F^{\gamma}(u))]$$

Complementation: $F^{c}(u) = [1 - F^{\gamma}(u), 1 - F^{\theta}(u)]$

IVFs can be considered as a special case of type 2 fuzzy sets.

3.1.2. Intuitionistic Fuzzy Sets (IFS)

It is defined by a pair of membership functions (F^+, F^-), where $F^+(u)$ is the degree of membership of u and $F^-(u)$ is its degree of non-membership. These fuzzy sets support the constraint: $F^+(u) + F^-(u) = 1$. The following operations are defined as:

Conjunction: $(F^+, F^-) \cap (G^+, G^-)$

$$(\min(F^+(u), G^+(u)), \max(F^-(u), G^-(u)))$$

Disjunction: $(F^+, F^-) \cup (G^+, G^-) =$

$$(\max(F^+(u), G^+(u)), \min(F^-(u), G^-(u)))$$

Negation: $(F^+, F^-) = (F^-(u), F^+(u))$

3.1.3 Cloud Fuzzy Sets: A cloud can be defined as an Interval Valued Fuzzy Sets such that $(0,1) \subseteq U_{u \in U} F(u) \subseteq [0,1]$. It is defined on a finite set U or it is an interval – valued fuzzy interval (IVFI) on the real line, then it is called a cloudy number. In the second case, each fuzzy set has cut, which are called intervals. Thin cloud: If the upper membership function coincides with the lower one $(F^{\theta} = F^{\gamma})$, then it is called thin cloud. Fuzzy cloud: When the lower membership function is identically 0, the cloud is said to be fuzzy.

3.2. Time Petri Nets

A Petri net can be defined in terms of the following tuples. N = <P, T, F, m>, where P = Set of places, T = Set of transitions, F $\subseteq$ (P × T) (T × P) is a flow relation, $m : P \to N^+ \cup \{0\}$ is an initial marking that assigns $m(p) \geq 0$ to each place.

In Time Petri net the non-determinacy with respect to time is partially removed. It is defined in terms of the following tuples: N_t={P, T, F, m, S}. Here, $S : T \to (\tau \times \tau)$.

It defines a time interval within which an enabled transition is to fire. The mapping S gives each transition with a pair of times (u, v). When the transition becomes enabled at time t, then it must fire within the time interval (t + x, t + y), unless it has become disabled before time t + v due to the firing of some other transition.

3.3. Rough Sets

The concept of rough set is related to the notion of an approximation space, which is a pair (u, v), where u is a non-empty set (universe of discourse) and Q is an equivalence relation on U. Q is reflexive, symmetric and transitive. The relation Q decomposes the set U into disjoint classes in such a way that two elements a and b are in the same class if and only if (a, b)$\in$Q. Let U/Q denote the quotient set of U by the relation Q and $U / Q = \{A_1, A_2, ..., A_m\}$, where A_i is an equivalence class of Q, where i = 1,2,3,………..,m. When two elements a, b in U belong to the same equivalence class $A_i \in U / R$, we say that a and b are indiscernible. The equivalence class of Q and empty set φ are the elements in the approximation space (U/R).

Rough set theory has been developed by Palwak. This concept can be well applied in separating large amounts of data into equivalence classes.

4. UNCERTAINTY IN OBJECT ORIENTED DATABASE SYSTEMS

4.1. Uncertain Objects

Real word entities and abstract concepts are modeled using objects. These objects may be characterized by their attributes and relationships (associations) existing among one object and another objects. The two kinds of uncertainty may be defined in objects. 1. When the values of some attributes are not exactly defined (ill defined). 2. When it is not certain that any attribute is associated with an object or not.

4.2. Uncertain Classes

Similar types of objects are collected to form a class. Two kinds of classes may be identified in general. 1. Extensional class: Such type of classes is defined by a collection of its object instances 2. Intensional classes: These classes are defined by a set of attributes with their admissible values. Except, the above two methods for creating classes, we can also derive new classes from the existing classes by means of the inheritance concept.

There are many reasons available for the classes to be uncertain:

1. A class may be uncertain, when it is defined by the collection of uncertain objects. Such objects are associated with a class using a membership degree.
2. The second point of uncertainty is due to uncertainty in the values of imprecise attributes, when the classes are in intensional implementation.
3. The third issue of uncertainty in classes is related with inheritance. The subclasses produced by the imprecise super classes due to above two reasons and by means of specialization and generalization are also imprecise classes. A class is a sub class of another class with a membership degree μ[0,1] using fuzzy logic.

4.3. Uncertain Relationship

Four types of class object relationship have been identified. 1. Precise class and precise class 2. Precise class and imprecise object 3. Imprecise class and precise object 4. Imprecise class and imprecise object. In the above relationships, except first all the other relationships are uncertain.

1. Certain Class and Certain Object: In this case, it is fully decided that any object is associated with class or not. For example, object ‘Cricket’ and ‘aero-plane’ for the class ‘Play’.

2. Certain Class and Uncertain Object: In this case, a class is precisely defined but objects are ill-defined, since its attribute values may be uncertain. In this case, the object may relate to the class with a degree of membership [0, 1] using fuzzy logic.

3. Uncertain Class and Certain Object: A fuzzily defined class may be associated with certain object. These objects will also be associated with class with a degree of membership.

4. Uncertain Class and Uncertain Object: An ill defined class is associated with an ill defined object.

4.3. Uncertain Inheritance Hierarchies

In fuzzy object oriented databases, classes may be uncertain. But, a class produced by an uncertain class must be imprecise. In this case, the super class/ sub class relationship is also uncertain. In this situation, such relationships are defied as follows using fuzzy techniques:

1. For any (uncertain) object, if the membership coefficient that it is associated with sub class is less than or equal to the membership coefficient that it is related to the super class.

2. The membership coefficient that it is associated with the sub class is greater than or equal to the given threshold.

Then, the sub class is the sub class of the super class with membership coefficient that is minimum in the membership degrees to which these objects belong to the subclass.

Let F_1 and F_2 are the fuzzy (uncertain) classes and α is the given threshold. Then, F_2 is the sub class of F_1 if $(\forall x)(\alpha \le \mu_{F_2}(x) \le \mu_{F_1}(x)$.

The membership coefficient that F_2 is a subclass of F_1 should be $\min_{\mu_{F2(o)\ge\beta}}(\mu_{F2}(o))$.

4.4. Uncertain Types using Fuzzy Concept

When we want to define the structure and behavior of a class in a soft or fuzzy way, that is a good enhancement in the capability of modeling complex real world problems, a concept of fuzzy type has been used. Particularly, the structure and behavior of a class may collectively, termed as its type. Fuzzy types are the new kinds of type by defining the precision at the different levels. It is termed as the set of properties and each property belongs to it with a membership coefficient in [0,1].

The set of properties, which can be used to specify the type at any moment, is the support set of the fuzzy set associated to the type. The basic attributes characterizing the type are called Kernel Set. Subsequently, each one of the á-cuts defines a precision degree with which the type can be considered. As per the need of precision required by the every object, the programm er chooses the right α-cut of the class type in order to represent it.

5. CONCLUSION

Next generation data and knowledge intensive applications require efficient handling of imprecise and uncertain information. Integration of different techniques, dealing with such type of information in object oriented databases is an important research issue. These databases are the natural fit for many engineering and scientific applications suffering from the representation and manipulation of inexact information, precisely. These databases have been rapidly developed due to increasing demand of knowledge based applications, GIS, Spatial Databases, multimedia systems and Image Processing applications. This paper introduces different places of uncertainty in object oriented databases systems as well as with brief description of different uncertainty handling approaches.

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