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Uncertain Decision-Making Requirements Formalizing with Complement Fuzzy UML Model

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Abstract

Unified Modeling Language (UML) is not a design method but rather a graphic language to represent and communicate the different aspects of an information system. Among the most important research areas in information systems is the enrichment of existing models with a larger collection of semantic concepts, hence the appearance of its extension Fuzzy UML, which despite its advantages to represent qualitative concepts, also suffers from certain restrictions for the uncertain data representation and whose the literature shows that few works are interested in the resolution of this type of problem. In the context of expressing uncertain decision-making requirements, no known solution is proposed to represent data reflecting uncertain requirements. Our contribution presents a flexible process for expressing decision-making requirements by evaluating uncertainty by formalization using our $_{CF}$UML model and the representation of decision-maker preferences by one or more mass functions using belief theory. In this article, we will only present our proposed model $_{CF}$UML.

Keywords: DIS, Uncertainty; Decisional Requirements; Belief theory; Expression; $_{CF}$UML

1. Introduction

The objective of the requirements expression step, located at the start of the decision-making process, is used to identify decision-making requirements and despite the impact of this phase, many problems, related to inconsistency, uncertainty, semantic ambiguity and the difficulty of modeling requirements were detected (Larbi and Malki, 2020). These problems are mainly due to the diversified points of views, to the actors' contexts and profiles and lead to diversity in the requirements expression. We are interested in formalizing uncertain decision-making requirements by proposing an extension of the fuzzy UML model that we called CFUML. This paper is organized as follows: section 2 presents the background, section 3 presents the related work, section 4 describes the proposed solution, and section 5 draws conclusions

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2. Background

We will define four main concepts for this study; it is about decision-making requirement, uncertainty and the belief theory and agile methods.

2.1 Requirement

It is recommended that requirements be formulated in a complete, correct, clear, concise, consistent, plausible way, with a verifiable priority.

There are three main techniques for requirements specification:

- Informal techniques: requirements are built in natural language with or without structuring rules. Their use introduces risks of ambiguities because neither their syntax, nor their semantics are perfectly defined. Among these techniques, we have questionnaires and interviews.
- Semi-formal techniques: are generally based on graphic notations with a specified syntax (like UML language) that allows having a clear vision of the system. These models are good vectors of communication between designers and users.
- Formal techniques: are based on mathematical or logical notations which provide a precise and no ambiguous framework for requirements modeling. Different studies proposed to specify requirements by using ontologies in order to provide a formal and precise specification to the requirement model (Calero,Ruiz and Piattini, 2006).

2.2 Uncertainty

It is a conscious lack of knowledge of a subject, relating to an object, not yet perfectly defined, in a context requiring a decision / action (Ben Rejeb, 2008).

Uncertainty comes from many sources throughout the research process, from unstable measuring tool and the limits it presents. In behavioral science, measurements rarely involve laboratory tools, and the uncertainty comes mainly from human researchers.

2.3 Belief theory

It was developed by Shafer in 1976 as a result of Dempster works on upper and lower probabilities. Then philippe Smets greatly contributed to the development of this theory with his transferable belief model (also called TBM for Transferable Belief Model) derived from Shafer (Masson, 2005; Larbi et al., 2017). The belief functions theory can be adopted for many reasons:

- Allow to take into account and to model the vagueness, uncertainty and incompleteness.
- Allow to model knowledge perfect, partial and total ignorance,
- Allow to represent several types of knowledge, which provides a rich and flexible, framework
- In terms of knowledge fusion, we‘ve tools that allow to combine several opinions.
- Allow to highlight and to manage the conflict between knowledge,
- Have tools that allow the decision-making.

3. Related Work

The uncertainty solution of the decision requirement is not yet exactly studied; the existing solutions solve the uncertainty around the data and not the decisional requirements. At the database level, several studies focus on improving the traditional relational model to make it more flexible in the face of uncertain data.

However, UML still suffers from some deficiencies such as inconsistency, inadequacy, and complexity, which may result in a degradation of the design quality.

3.1 How to formalize the fuzzy UML model?

Without including formal representations, different levels of fuzziness were introduced into the class in UML in and the formal mapping of the fuzzy UML data model in the fuzzy XML model was developed. In addition, the fuzzy UML data model was simply used in (Fasel, 2014) for mapping to the fuzzy nested relational database model.

Authors in (Jasberg and Sizov, 2017; Sadiq and Neha, 2017), based on fuzzy set and possibility distribution theory, different levels of fuzziness are introduced into the UML class diagram model and propose the corresponding formal representations. They also propose the formal mapping of the fuzzy UML data model into the fuzzy relational database schema. In (Sillitti et al. ,2005), authors propose a conceptual model, which is called “Uncertain”, that is supported by a UML profile (the UML Uncertainty Profile; UUP) and enables the inclusion of uncertainty into test models. In (Wang, 2005), Sheng & al. concentrate on modeling probabilistic data with fuzzy probability measures in the UML class diagram model. We introduce the semantics of fuzzy and probabilistic information into the UML class diagram model and extend several major constructs of UML class diagrams accordingly.

3.2 Fuzzy UML Model

Different fuzziness levels have been introduced into the UML model:

- Fuzzy object, Fuzzy class, Fuzzy association, Fuzzy aggregation, Fuzzy generalization
- Fuzzy object: An object is fuzzy because of a lack of information
- Fuzzy class diagram: A class may be fuzzy because of some objects that have similar properties are considered fuzzy or a class is intentionally defined.

4. Solution Modeling

The expressing traditional requirements process does not consider the uncertain requirements case, for this reason we propose a flexible UML model extension with Agile-based requirements uncertainty called Complement Fuzzy UML and a belief theory-based solution. The process representation is illustrated by this diagram (Figure 1), we just present in this paper our proposed model $_{CF}$UML

4.1 Uncertain Requirements Collection

For this step, the Agile approach is used to collect the dynamic and uncertain requirements of the decision maker. Agile (Sillitti et al., 2005) methods support client intervention at each iteration collection, so they see every change request as an opportunity to improve the expression in order to increase customer satisfaction. Agile methods are therefore adaptive to uncertain requirements.

4.2 Formalization

The computer scientist is the actor who manages this activity. The masses distribution is done with the expert help according to the decision maker beliefs.

4.3 Our Solution Modelling : Complement Fuzzy UML ($_{CF}$UML)

UML class diagrams can model fuzzy information through the FUZZY UML concept, since the Fuzzy UML (Wang, 2005) only deals with a corner of uncertainty "vagueness", we add the formalization concept of diversity.

- Formalization of uncertain requirement

Complement Fuzzy UML (CFUML) is applied to the collected requirements. Note that the computer scientist is the actor who manages this activity. The masses distribution is done using the expert according to the decision maker beliefs (opinion).

- Why $_{CF}$UML?

One of the major research areas in databases is the continuing effort to enrich existing database models with a broader collection of semantic concepts. It is in this context that an object-oriented conceptual modeling methodology has been developed for the fuzzy modeling of information.
UML class diagrams can model fuzzy information through the concept of FUZZY UML, Due to the fact that the Fuzzy UML (Wang, 2005) only deals with a corner of uncertainty "vagueness", we add the diversity formalization concept, so Fuzzy UML diagrams can model uncertain requirements through the concept of FUZZY Complement UML.

4.4 Our contributions & Illustrative examples

To better illustrate our proposal, we have turned to a fictitious case of a "A" company which wants to collaborate with the company "B". The Japanese automaker A and its German counterpart B will launch a car model assembled on a common platform. The essential purpose of this collaboration is the ability to produce a new model merges the best features of two companies. The overall vision of the collaboration is clear, but the uncertainty lies in the details of their requirements: Category, Color, Price, Fuel Consumption, ... etc.

1. Fuzzy class diagram

A class may be fuzzy because of the following reasons:

- Some objects that have similar properties are considered fuzzy. A class defined by these fuzzy objects will be fuzzy. Objects belong to the class with a membership degree between [0,1].
- When a class is intentionally defined, the domain of an attribute can be fuzzy and a fuzzy class is formed (Wang, 2005).
- A subclass produced by a fuzzy superclass by means of a specialization relation is considered a fuzzy class.. So in the UML class, there are three inaccuracy levels defined as follows:

- Level 1: the inaccuracy in the class's membership of the data model or the inaccuracy in the attribute membership to the class. To model this level of inaccuracy, the attribute or class name should be followed by the words: "WITH d DEGREE" (with degree of membership) where $0 < d <= 1$. The degree of membership is used to indicate the degree to which the attribute belongs to the class or class belongs to the data model. Generally, a class or attribute will not be declared if its degree is 0. In addition, "WITH 1.0 DEGREE" can be omitted when the degree of an attribute or class is 1.
- Level 2: It is possible that a class instance belongs to the class with a membership degree. For the second type modelling of inaccuracy, we must indicate the membership degree to which an instance belongs to the class. For this, an additional attribute is introduced into the class to represent the membership degree of the class with an attribute domain in the range [0,1]. This special attribute is represented by "μ".
- Level 3: The imprecision on the attribute values of the class instances. An attribute in a class defines a domain of values. When this domain defines a fuzzy subset, the inaccuracy of an attribute value will appear. To model this level of inaccuracy, the fuzzy keyword is introduced and placed in front of the attribute.

Table 1. Diffrence between Fuzzy Class Diagram & Complement fuzzy class diagram

A fuzzy class diagram structure	Complement fuzzy class diagram structure
Class-name Identifier Attribute 1…. N FUZZY Attribute 1…. N WITH ([0, 1]) DEGREE	Classe-Name Identifier Attribut 1…. N FUZZY Attribute 1…. N WITH MULTIPLE DEGREE ([0, 1])

❖ Complement Fuzzy Classes Diagram : In the Fuzzy UML class, three levels of inaccuracy are already defined, we add the fourth diversity level:

- Level 4: Diversity in requirements' beliefs. To model this diversity level, the requirement which is considered as attribute should be followed by the words: "WITH MULTIPLE DEGREE" (with multiple degree of belief) where $0<d<= 1$. Multiple degree of belief is used to indicate the degree to which the attribute is preferred over each belief. A requirement will not be declared if all its degrees are 0, otherwise (i.e. all of its degrees are 1) it is considered as a net requirement (normal attribute). Noting that the sum of the requirement degrees on a single belief is equal to 1, so the belief class is represented by a discrete frame like the fuzzy class.

Table 2 illustrates an example of a fuzzy class addition to buying Jacket. The fourth level of diversity is present in the class through the color and price attributes. If we take the attribute color, we find two belief degrees (belief1 = 0.4, belief2 = 0.2) and that for belief1 on the color and the price is verified the condition of the sum i.e. belief1 (color) + belief 1 (price) = 0.4 + 0.6 = 1.

Scheduling preferences purpose, the resulting masses using the mass composition operator are requiremented. The belief mass differs from the probability notion by the fact that the belief mass totality is distributed not only on the singletons hypotheses, A, B, C, but also on the combined hypotheses.

Table 2. Complement fuzzy class diagram (Objects examples)

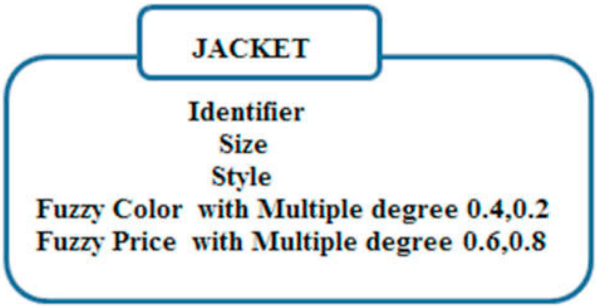
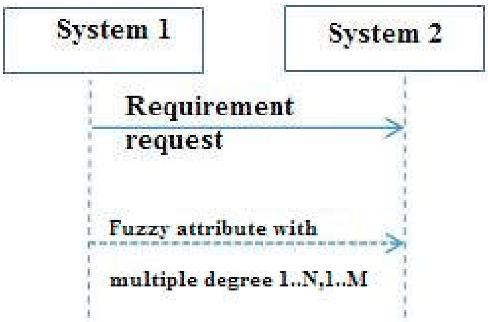
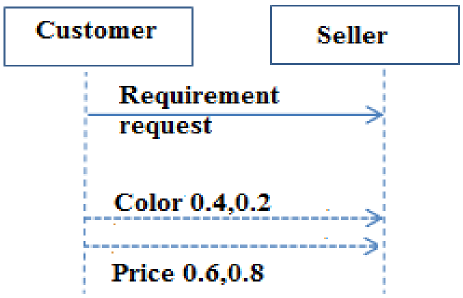
	

Table 3. Complement fuzzy sequence diagram

Complement fuzzy of a sequence diagram	Example
	

For example {A, B}, {B, C},{A, B, C}. Masses from various sources can be fused using the Dempster operator, also known as the connective operator.

1. Complement Fuzzy uses case diagram

The Fuzzy Use Case Diagram allows us to specify the uncertain requirements of a system, our contribution lies in the formalization of several beliefs on a single requirement, respecting the condition that the belief sum of the same level in the requirements is equal at 1. The below Figure illustrates an additional use case of a purchase of cars. The actor admits two uncertain requirements with two beliefs for each requirement. For example, price requirements have two beliefs (belief 1 = 0.6, belief 2 = 0.8). Belief 1 verified the sum condition i.e. belief 1 (price) + belief 1 (color) = 0.6 + 0.4 = 1.

Complement Fuzzy sequence diagram, we keep the fuzzy sequence diagram with its properties; we add only the expression meaning of the uncertain requirements by messages which circulate between two objects. The message in this case will be represented by a discreet arrow with the name and belief degrees of the concerned requirement, respecting the condition that the belief sum of the same level in the requirements is equal to 1.

The below Figure illustrates a fuzzy sequence complement diagram of cars purchase, or both uncertain requirements are color and price. The requirement color admits two beliefs (belief 1 = 0.4, belief 2 = 0.2). Belief 1 verified the condition of the sum i.e. belief 1 (price) + belief 1 (color) = 0.6 + 0.4 = 1.

The class diagram of UML and UML are intended to model the data, we adapt this notion to be able to model the uncertain requirements ($_{CF}$UML). The difference between the components senses of UML, FUML, $_{CF}$UML is explained in the following table:

Table 4. Comparison between UML, $_{f}$UML and $_{cf}$UML models

Components	UML	FUML	CFUML
Class	Static class models the data some.	Fuzzy class models inaccurate data using the membership function of Fuzzy Set Theory.	Class belief model uncertain requirements using the mass function of the belief functions theory
Attribute	Represents a certain data	Represents either a certain data or an inaccurate data.	Represent: - exact data an inaccurate data, uncertain requirement.
Methods	Operations on the data.	Operations on the data.	Operations on: -the data. -the data representing the requirements.
Association	Relation between two classes.	Precise or imprecise relationship between two classes.	Requirement relationship, which means that the source class has requirements in the target class.
Instance	The operation of creating objects from the class.	The operation of creating objects from the class with a membership degree between [0,1].	The operation of creating objects from the class. Procedures are manipulated at the level of the data and data of uncertain requirements, keeping the same belief principle in the data of uncertain requirements.

5. Conclusion

The outcome of our process makes clear and explicit the decision-maker's requirement expression, and subsequently the decision-making project success. Most of the study results confirm that the agile approach capable of providing good collection results, our $_{CF}$UML model formulates successfully the uncertain decision maker requirements without losing the formalization of uncertain data, Belief theory has proven itself in the formalized uncertain requirements evaluation and it produces as a result a preferences order provided to the decision maker. As a perspective, we hope to generalize our solution after a large validation and to generalize our proposed $_{CF}$UML model.

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