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Practical Approaches to Fuzzy Object-Oriented User Modeling

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ABSTRACT

Fuzzy Object-Oriented User Modeling (FOOUM) extends the original stereotype-based user modeling approach to overcome the limitations on individualization, and feature identification, and handing reasoning under uncertainty. FOOUM employs object orientation to structuralize user models and their stereotypes. Relationships among them are graded using fuzzy set methods to embed uncertainty of user information. FOOUM aims to provide finer user modeling results than does the original stereotypical approach. As a result, FOOUM shows potentials to be employed in several types of systems including cooperative systems, interest-based systems, and user observation and improvement systems. Especially, FOOUM aims to deliver results that are properly relevant to the arbitrary variance of user interests for interest-based systems.

1 INTRODUCTION

User modeling is the process of gathering goals, knowledge, and preferences of users and representing them in data structures called user models. Presently, stereotype-based user modeling is the most frequently used approach for building user-modeling systems. Nevertheless, the approach holds a number of limitations. To overcome the shortcomings of the conventional approach and to enhance the efficiency of user modeling, Fuzzy Object-Oriented User Modeling (FOOUM) is defined such that it is the extension of the stereotypical approach by employing object orientation to construct user model classes and objects and using fuzzy set methods as a way to encode the uncertainty of user information. The practical applications of FOOUM are discussed in this paper.

2 USER MODELING AND USER MODELS

Orwant defines user modeling as "... nothing more than a fancy term for automated personalization" (Orwant, 1996). From this perspective, user modeling is the activity of a system to provide active personalization to its users. In other words, a system automatically adapts itself according to user preferences to enhance users' performance. However, personalization is not the only purpose of user modeling. Indeed, user modeling is a system process of helping users to reach their goals of using the system with less effort and more effectiveness. In order to accomplish the objectives of user modeling, a system must maintain information about knowledge levels of its users. This constitutes user models such that they represent all the necessary information and assumptions required in the modeling processes for particular users (Kobsa, 1994). As a result, users' *goals*, *knowledge levels*, and *preferences* are vitally important elements of user modeling.

To structure user models, the *stereotype-based user modeling approach* proposed by Rich (Rich, 1979) is commonly used. A stereotype is a pre-defined user model in which each stereotype contains one or more name-value pairs of attribute elements called *facets*. Stereotypes are organized in a generalization hierarchy in which stereotypes inherit properties from its ancestors. A stereotype has one or more characteristic properties called *triggers* used to identify its applicability to a user who exposes information according to them.

Conclusively, user-modeling systems gather users' goals, knowledge levels, and preferences to construct user models. The user models are used to facilitate the user-system interaction in order to enhance the users' performance of using the systems. Presently, the stereotypical approach or its variations are typically employed to constitute user models in most user-modeling systems.

3 LIMITATIONS OF CONVENTIONAL STEREOTYPE-BASED USER MODELING APPROACH

Following Chen's discussion (Chen, 1995), the limitations of the traditional stereotype-based user modeling approach that reduce its representational ability are as follows:

3.1 Reasoning under Uncertainty

Uncertainty occurs due to a lack of sufficient information one needs to satisfy the truth of a statement (Smets, 1997). Uncertainty is primarily relevant to the aspect of belief, not knowledge (Smets, 1998). The degree of certainty for a statement depends on the degree of belief one has in the truth of the statement. Therefore, user information tends to be less certain because of its inconsistency. User information always contains conflict, incoherence, inconsistence, and confusion that are four causes of inconsistency (Smets, 1998). As a result, although users continuously reveal their information, the variety of information actually causes uncertainty of the information in the larger picture.

For the stereotype-based user-modeling systems, when conflicted evidence of a stereotype attribute is detected, the stereotype needs revision in order to maintain its truth and consistency (Chen, 1995). However, since stereotypes are organized in a generalization hierarchy, and most properties of stereotypes are based on default assumptions; the revision may cause dependency-directed backtracking effects. Although most stereotype-based user modeling techniques provide conflict resolutions, those methods are mostly ad hoc routines for making immediate modeling decisions. Conflict resolutions are generally inefficient and primarily achieved by either eliminating inconsistency or not considering inconsistency as a factor. Therefore, for user-modeling systems with an extended running period, their stereotype hierarchies eventually need revisions. Nevertheless, the revision process is normally operationally expensive. It consumes both time and processing power. In the real world environment in which conflicts frequently occur, this significantly degrades the stereotype-based user modeling approach.

3.2 Individualization

The generalization hierarchy of stereotype-based user modeling provides a simple method of stereotypical classification in which each stereotype inherits attributes from its ancestor. According to Rich's original approach (Rich, 1979), stereotype-based user modeling employs the single-inheritance feature, i.e., a stereotype has only one parent. Based on the original mechanism of stereotype-based user modeling, each individual user has only one stereotype to associate with him or her at any given time. The stereotype is chosen from the hierarchy when a user exposes his or her information that matches with the stereotype's trigger attributes. Nevertheless, if there is no appropriate stereotype existing in the hierarchy, a new stereotype is created as a child node of the most-possibly matched stereotype for the user. A required attribute is then added to the newly created stereotype.

This mechanism gives a possibility to implement a simple user modeling system for a closed and definable environment. However, when applying this method to a wider user space, it cannot effectively handle the diversity of users. Nonetheless, as human behavior is indeed distinct rather than similar, providing flexible individualization is an important goal of user modeling (Rich, 1999). In fact, human "traits" can be loosely categorized. However, when considering the traits in detail, each person is unique. Therefore, this uniqueness must be taken into account in order to model users effectively.

3.3 Feature Identification

The original method of organizing stereotypes into a generalization hierarchy limits the flexibility of the stereotype-based approach to adjust attributes in stereotypes. During interactions, users may demonstrate traits that cause adding or dropping attributes from the active stereotypes. However, the stereotype-based approach does not provide an effective way to update those attributes. When a conflict arises, most stereotype-based systems simply replace the active stereotype with its ancestor (Huang, Mccalla, Greer, & Neufeld, 1991). Using that method, it results in losing the attributes that still apply to users. In addition, the ancestor stereotype may not actually be applicable to users.

In another scenario, when users demonstrate their traits that do not concur to any stereotype, a new stereotype for the user is created as a child node of the most-possibly applicable stereotype. Attributes from the parent stereotype are then inherited to the child. Afterward, required attributes are added to the new stereotype. This method introduces inconsistency and ambiguity to the generalization hierarchy because the newly added attributes may already exist elsewhere in other stereotypes located at other paths of the generalization tree. Nonetheless, the stereotype hierarchical technique does not provide the ability to identify and reorganize the required attributes from stereotypes resided in different paths (Chen & Norcio, 1993).

4 FUZZY OBJECT-ORIENTED USER MODELING (FOOUM)

4.1 Problem Analysis

Chiu states that user models are incomplete, uncertain, ambiguous, unstructured, and unstable (Chiu, 1993). These characteristics pose a challenge to researchers on methods for capturing user information and representing it in systematic structures. Certainly, the structures require great flexibility in order to cope with the difficult nature of user models. Furthermore, the structures must be able to overcome the limitations of conventional user modeling approaches as discussed in Section 3 as well.

By analyzing Chiu's statement, the problems of user modeling can be divided into two categories.

1. *Problems of representational structure* Problems in this category are the results of the unstructured and unstable nature of user information.
2. *Problems of uncertainty and vagueness management* Problems in this category are the results of the incomplete, uncertain, and ambiguous characteristics of user information.

Although those problems target different domains, each problem needs solutions that also provide positive conditions to resolve the other. Therefore, in order to develop an effective approach for user modeling, one cannot solve each problem separately. Instead, both problems must be considered as a whole while attempting to overcome each issue. This paper considers that object orientation and fuzzy set theory has potential to overcome those problems as in the following discussions.

4.2 The Solution for Representational Structure Problems

As specified above, the representational structure for user modeling must be extensively flexible in order to cope with the unstructured and unstable nature of user information. Considering this requirement, the object-oriented approach shows its proficient adaptability to support varied structures of data modeling and manipulation concepts (Beeri, 1990). In addition, the structural framework of object orientation intends to handle representational activities in the way in which they are completely transparent to the user (Gyseghem, Caluwe, & Vandenberghe, 1993). Furthermore, the object-oriented approach is constructed after the real world system, which consists of objects that are composed of and collaborating with others. Therefore, employing object orientation to represent user models, which are the structures of natural information retrieved from users, is expected to promote effectiveness in the representational and utilization ability of user modeling. Consequently, the extensible structure of the object-oriented paradigm is expected to be able to override the unstructured nature of user information, and the flexibility of object orientation, in conjunction with supporting features from the fuzzy set approach discussed below, aims to overcome the unstable behavior of the information. Furthermore, as each object holds its uniqueness in its system, the object-oriented approach shows high potential to promote the individualization and the feature identification.

4.3 The Solution for Uncertainty and Vagueness Management Problems

Other than unstructured and unstable characteristics, additional properties of user models as Chiu (Chiu, 1993) pointed out are incomplete, uncertain, and ambiguous in which they add intense difficulty in processing and representing user models. Nonetheless, as these characteristics are primary dispositions of user information, an effective user modeling approach must define vigorous methods to handle them properly. Advantageously, for problems in this domain, fuzzy set theory establishes a sound foundation to handle vague data sets efficiently. Fuzzy logic, defined based on fuzzy set theory, addresses a paradigm of managing referential decisions on incomplete, uncertain, and ambiguous information. Noticeably, this type of information is exact as found in user models. Hence, to develop an effective user modeling approach in which it can appropriately handle the vague nature of user information, fuzzy set theory is a potential choice to employ in the development.

As a generalization of classical set theory, fuzzy set theory is applied to nearly every field that the applications of crisp sets has been involved. As a result, fuzzy set theory is extended in various prospects to compromise various areas (Zimmermann, 1996). For databases, Buckles and Petry (Buckles & Petry, 1982) introduce the use of *similarity relation* (Zadeh, 1971) as a foundation of fuzzy relational operations. A similarity relation is defined as a fuzzy relation that is reflexive, symmetrical, and max-min transitive (Zimmermann, 1996). Similarity, in other words, is a generalization of equality (Yazici, George, & Aksoy, 1998). For each attribute domain D, similarity relations are characterized over the domain elements:

$$\mathrm{s} : D \times D \rightarrow [0,1]$$

In similarity relations for $x, y, z \in D$, the following properties hold:

$$\mathrm{s}(x, x) = 1 \qquad \text{(reflexivity)}$$

$$\mathrm{s}(x, y) = \mathrm{s}(y, x) \qquad \text{(symmetry)}$$

$$\mathrm{s}(x, z) \leq \max_{\forall y \in D}[\min(\mathrm{s}(x, y), \mathrm{s}(y, z))] \qquad \text{(transitivity)}$$

Although a number of papers propose several methods of applying fuzzy set theory to database arena, the similarity-based system appears to contain the most mathematical soundness (Ling, Yaacob, & Phang, 1997). George, et al. (George, Buckles, & Petry, 1993), later extend the similarity-based fuzzy database approach to the object-oriented data model. Their *similarity-based Fuzzy Object-Oriented Data model* (FOOD) is primarily adapted to Geographical Information Systems (GIS) as presented in (Morris, 1999) and (Cross & Firat, 2000). However, it also shows significant potential to apply in various fields that involve vague information (Morris, 1999). As a result, it is extended and used for eliciting effectiveness to stereotype-based user modeling as discussed in detail in (Piyawat, 2001).

4.4 FOOUM Methodology

Fuzzy Object-Oriented User Modeling (FOOUM) is primarily based on the stereotype-based user modeling. The stereotypical approach contains two primary elements, i.e., stereotypes and user models in which each user models belong to a stereotype, and stereotypes are hierarchically arranged. Similarly, FOOUM approach consists of two types of elements, viz., user model classes and user model objects. In comparison to the stereotype-based approach, user model classes are the stereotypes of user model objects, and user model classes are placed into a multiple-inheritance hierarchical structure. Classes and objects in FOOUM contain multi-valued attributes to represent collections of user traits. In the aspect of representing user information, the fundamental differences between FOOUM and the original stereotypical approach are that FOOUM allows multiple-valued attributes, multiple-inheritance of classes, and multiple-instance of objects from classes. Fuzzy set theory is employed to encode degrees of certainty of values to attributes, attributes to objects, objects to their classes, and classes to their superclasses. As a result, FOOUM is expected to be able to represent user information and resolve user-modeling decision more effectively than does the original stereotype-based approach. The effectiveness of FOOUM is studied in (Piyawat, 2001).

5 FOOUM IN PRACTICE

5.1 Overview

User modeling may be considered as an application area of knowledge representation in which it primarily involves representing the knowledge of a computer system about its users. The computer system uses the knowledge to accomplish its tasks in serving its users. For most computer applications, user modeling enhances their ability of delivering their services to their users. Notwithstanding, several applications, such as tutoring systems, are exclusively relied on their user modeling activities. In this section, application areas in which FOOUM shows its potentials are discussed.

5.2 Cooperative Systems

User modeling has potential to be employed in applications designed to facilitate cooperation among users, i.e., Computer-Supported Cooperate Work systems (CSCW), and between users and systems, i.e., Intelligent User Interfaces (IUI). The ability of applications to identify goals, preferences, and knowledge levels of users in detail as delivered by FOOUM is important for assisting the team cooperation.

5.3 Interested-based Systems

By knowing goals, knowledge levels, and preferences of users, applications can both deliver and filter out contents based on the interests of users. In this e-commerce age, this feature is appealing to both application developers and end users. Especially, FOOUM shows high potentials to use in interest-based systems since user interests are frequently changed and laid into inconsistency areas in which they are difficult to categorize beforehand into groups as required by the original stereotype-based user modeling approach.

5.4 User Observation and Improvement Systems

Systems in this type observe user behaviors. Using the retrieved information, the systems provide users help and guidance according to their purposes of using the systems. Those systems may further be discussed as in the following categories.

5.4.1 Tutoring Systems

Generally, in order to instruct learners successfully and effectively, a tutor must first understand their students. Therefore, when a system assumes the role of tutoring, it certainly needs to model its users in order to provide its services. Tutoring systems are designed to examine and improve some skills of students. Based on this goal, tutoring systems may be considered as user modeling systems that target on specific skills of users. They differ from general user modeling systems in the way that, besides modeling users, tutoring systems provide training for improving the skills as well. FOOUM aims to aid the complex tutoring systems where series of lessons cannot be determined in advance, as FOOUM is designed to open for discovering all possible sets of lessons with different degrees of needs.

5.4.2 Unsolicited Advising Systems

Unsolicited advising systems monitor users while they are interacting with the systems. When they find ineffective patterns of operations, they voluntarily provide advice to users. More advanced unsolicited advising systems may also detect users' goals and supply guidelines to users for achieving their goals effectively. In some circumstances, the systems may perform tasks of detecting goals and completing them on behalf of users as well. FOOUM is expected to outperform the stereotype-based user modeling systems in complex systems where user goals are difficult to identify specifically.

5.4.3 Operational Control Systems

User modeling may be used for the purpose of control. In a critical system that requires precise operational procedures, modeling the person who operates it may be useful to detect and prevent problems before they actually occur. Similar to the benefit of unsolicited advising systems, FOOUM aims to provide ability to determine goals of user in complex environments where operational procedures are unable to serialize to limited sets to be the base to build stereotypes.

5.4.4 User Performance Measurement Systems

Certainly, by modeling its users, a system can reveal the users' performance in various aspects. The result of measuring user performance can later be used in several purposes, e.g., system improvement or organizational management. While the stereotypical user-modeling systems categorize a user into a particular group, FOOUM systems show the belonging of a user to multiple groups with different degrees of certainty. As a result, FOOUM can retain the uniqueness of performance of each user in an assortment of points. This extended information surely helps achieving the purposes of measuring user performance in superior detail.

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