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Adaptive Interfaces: Modeling Tasks and Users

A. F. Norcio
Department of Information Systems
University of Maryland
Baltimore, MD 21228-5398

***Abstract*—An adaptive interface is an interface that adapts to the user rather than the user adapting to the system. For an intelligent interface to adapt in a meaningful and supportive manner, the adaptive mechanisms need the capability to construct representative models of both the application tasks as well as the characteristics of the user. A number of issues must be considered when constructing and implementing these models. This paper suggests the use of fuzzy logic for constructing user models, referred to as fuzzy user models, and for defining fuzzy users that are classifications of actual users.**

I. INTRODUCTION

During the past few years the concept of an adaptive interface has emerged as a realistic approach for developing intelligent human-computer interfaces [13,20]. A reasonable and intuitive definition of an adaptive interface is an interface that adapts to the user rather than the user adapting to the system [16]. While this definition presents a noble goal, there are many underlying issues that are fundamentally difficult to define, conceptually demanding to implement, and experimentally formidable to study. There are a number of reasons for these difficulties. They include increasing the complexities of interface systems, confounding the mental models of users, and decreasing a user's control of system activities.

However, there has been recent progress in addressing these issues and approaches have been suggested that may eliminate or at least reduce these concerns [15,20].

In order to adapt to the user successfully , at least four domains of knowledge are needed by an intelligent interface [16]. They are:

1) knowledge of the system;
2) knowledge of the interaction;
3) knowledge of the application; and
4) knowledge of the user.

This paper focuses on the last two domains; namely, the application and the user.

II. KNOWLEDGE OF THE APPLICATION

A successful adaptive interface must necessarily be able to make some level of inferential judgements concerning the goals and tasks the user is attempting to accomplish. Typically the only source of information which the system has available is the information that results from the user interaction itself.

In short, if an intelligent interface is to adapt to the user in a meaningful and supportive manner, the adaptive mechanisms of the interface need the capability to construct dynamic models of the application. These application models must focus with some detail on modeling the task and modeling the user's goals and plans.

A. Task Modeling

Task modeling concerns modeling the task in order to assist the user in accomplishing the task more quickly and more effectively [7]. Typically, adaptation resulting from task modeling is based upon system performance of the task rather than any specific characteristic of the user. That is, no information about the user is internalized in the system through task modeling. The adaptation is based solely upon the system's past performance with the task.

A number of approaches to task modeling have been proposed [22]. Greenberg and Witten have developed an adaptive telephone directory [9]. In their system the structure of the entire database is reconfigured depending on the frequency that a specific user retrieves various telephone numbers.

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The purpose of the restructuring is to give the system the capability of retrieving frequently called numbers more quickly.

Croft uses a document retrieval system in which each search is rated for its effectiveness. An associative search network is used to support effective search strategies [5].

B. Goal Detection and Plan Inference

The purpose of modeling a user's goals and plans is to provide meaningful assistance to the user for accomplishing the tasks. It is necessary for the system to determine the appropriateness of a user's actions if the system is to adapt satisfactorily. This determination can be made by comparing the user's actions with the system's goal model [16].

There are two possible situations under which plan detection occurs. First, there is the case in which all possible plans are known. And second, there is the case in which all possible plans are not known. Clearly the first case is the easier because the system merely has to search all possible plans to find the one that is closest to the user's actions.

Not only is this the simpler situation but it is also the more unrealistic. In complex tasks and systems, it is very unlikely that all possible plans or actions can be known.

The Unix Consultant provides an excellent example for inferring the user's intentions in a complex setting [25]. Natural language systems provide another example for deducing goals in a complex interaction environment. Allen and Perrault point out that in natural language interfaces it is frequently necessary to determine plans and goals from indirect speech acts [1]. In these complex systems, it is impossible to know all types of plans.

Help systems are still another area in which it is necessary for the system to model the user's plan and goals. There is an extensive large literature on help systems as well as the more advanced concept of intelligent tutoring systems.

Fischer *et al.* have developed an active help system to provide assistance on the Unix system. The system monitors a user's behavior and intervenes when it detects that user performance is below an optimal level [8].

III. KNOWLEDGE OF THE USER

An adaptive interface must have some knowledge of the user. Specifically, the interface must be able to classify each user into meaningful categorical classes [2,4]. The primary purpose of this classification is to incorporate into the system the capability of predicting a user's behavior. Accurate predictions of a user's behavior are essential so that the interface can appropriately adapt to the specific characteristics of a user [17].

Techniques and strategies for making these classifications are generally referred to as user modeling. A user model comprises the system's knowledge of the user. Ultimately the user model forms the basis of the interfaces's adaptive mechanisms.

The composition and construction of a user model is fundamental to an interface that is able to adapt to a user successfully. Consequently, it is important to consider those user characteristics that should comprise the model as well as the inferential techniques that can be used to construct the model.

A. Modeling the User

As Rich points out, users are individuals [18]. The purpose of a user model is to capture the individual characteristics that encompass each specific user. That is, a user model should include information about a user's cognitive abilities and weaknesses [23].

B. Constructing User Models

A number of approaches are used for developing user models. One of the earliest and most direct techniques for categorizing a user is the classification into stereotypes [17]. Under this approach a user is stereotyped into a category after responding to a series of questions or some other form of user input.

One of the major difficulties with this approach is that it relies exclusively on user input. For example, a user may not know how to answer a question. Or a user may not know what the real answer is. In other words, the stereotype approach depends upon a user's input and that input may not be accurate or reliable.

Additionally, the stereotype approach for user modeling lends itself only to certain limited situations. While it may perform well for matching tasks, it seems less appropriate for tasks that require dynamic adaptation such as tutoring systems and complex retrieval systems [16].

Another approach to user modeling is to classify a user as a novice or an expert. In this approach, a user is immediately classified as either a novice or an expert depending on responses to questions, nature of command calls, or other criteria relating to systems or task requirements. This type of user modeling lends itself to more advanced applications [19]. While this approach has intuitive appeal and works well in a variety of settings, it does not fully take into account that wide range of individual differences between users, especially users that may be classified within the same category [11,24].

The presence of individual differences is perhaps the most pervasive reality in attempting to predict and accommodate human behavior. Complex human problem solving generally does not exhibit precise learning stages, definitive solution strategies, or algorithmic processes that are necessarily definable [14,21]. In short, the techniques and approaches that humans use in complex problem solving are not crisp and well-defined.

IV. FUZZY USER MODELS AND FUZZY USERS

In a series of many classic papers, Zadeh has introduced and defined the concepts of fuzzy set theory and logic (see for example [27,28]). One of the primary goals of fuzzy logic is to address real-world inexactness that is inherent in many dynamic systems. These concepts have been extended by Zadeh and others to include fuzzy linguistic variables and grade of membership of individuals into various classes [6]. During the past several years, the use of fuzzy logic and variables has been applied to many task domains (for example [10, 12]).

The application of fuzzy concepts to adaptive human-computer interfaces provides a sound theoretical basis as well as rigorous techniques for dealing with individual differences among users. That is, since the techniques and approaches that humans use in complex problem solving are not crisp and well-defined, fuzzy procedures provide an appropriate methodology for categorizing a user into a user class that is an element in a set of user classes.

A. Research Directions

A number of projects at the the Department of Information Systems of University of Maryland, are now examining these issues. The central thrust of these projects is to develop *fuzzy users models*, which are user models based upon fuzzy concepts. The purpose of these fuzzy user models is to define categorical classes of users, which are referred to as *fuzzy users*. It is anticipated that the categorization of actual users into fuzzy users can become the dynamic mechanism for an adaptive human-computer interface.

One study is investigating techniques for defining fuzzy pure types that can be used to classify a user's level of expertise.[1] A detailed questionnaire has been developed and is being tested. This questionnaire is designed to identify those characteristics that can be used to classify users. After the validation phase is completed, several clustering and probability techniques are to be used to define the pure types. These pure types can then be used to define the prototypical fuzzy users.

Another project is developing a fuzzy student modeling system for intelligent tutoring systems. This project is using fuzzy logic for classifying many students at individual stages of understanding and competencies. The ultimate goal of this effort is to design and implement an intelligent interface that is able to adapt accurately and dynamically as each student's level of understanding progresses or regresses.

Still another project is exploring the possibilities and techniques for building a fuzzy user model shell. The purpose of this shell is to provide the capabilities of building a fuzzy user model quickly and accurately for various task domains.

And yet still another project is exploring the theoretical foundations of uncertainty, specifically as they relate to fuzzy users [3]. This project is also examining the relationships between neural networks

[1]For an initial and detailed explanation of pure types the reader is referred to [26].

and fuzzy user models. It is conjectured that, if a neural network can be trained to recognize indications of user uncertainty, more accurate and complete fuzzy user models can be constructed. In other words, using a combination of neural networks and fuzzy logic, classifications of actual users into fuzzy users can become more precise.

A number of other projects are in the initial planning stages. However, it is premature to describe the specifics of their directions at this point.

IV. CONCLUSIONS

Accurate task and user modeling is critical for constructing intelligent human-computer interfaces that can meaningfully adapt to an individual user. However, there are inherent difficulties in modeling paradigms in that many can not deal with the levels of inexactness, which is always associated with individual differences and human problem solving strategies.

In order to overcome these difficulties, the use of fuzzy logic is suggested as a powerful set of techniques for building user models. With this in mind, this paper has presented a introductory overview of several projects that are approaching user modeling from a fuzzy perspective. The common thread running through all these projects is designing user models based upon the use of fuzzy logic. It is suggested that fuzzy user models and fuzzy users can provide the necessary adaptive mechanisms for intelligent human-computer interfaces.

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