

# Defining Fuzzy User Models Using the GoM Methodology

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## ABSTRACT

This paper presents a fuzzy representation methodology for classifying user characteristics. The Grade of Membership (GoM) methodology determines pure types for the user population. Each user is then assigned a GoM score for each pure type. It is suggested that this approach captures a clearer picture of the user's characteristics than traditional approaches.

## 1. INTRODUCTION

As computer systems become more complex, interfaces that adapt to the user become increasingly desirable. Rather than the user adapting to the system, an adaptive interface adapts the system to the user. This frees the user from system-specific details, (Norcio and Stanley, 1989) thus improving the efficiency of the interaction between users and computers (Hancock and Chignell 1988).

Individualizing the interaction requires the interface to have information about the user (Norcio, 1989). This knowledge allows the interface to predict the user's behavior, thus ensuring appropriate adaptation (Rich, 1983).

Techniques and strategies for predicting the user's behavior are referred to as user modeling. A user model 'is the knowledge and inference mechanism which differentiates the interaction across individuals' (Allen, 1990). Since the user model is essential to the adaptation, it is important to consider what user characteristics should comprise the user model and what inferential techniques can be used to construct the model (Chiu, Norcio, and

Petrucci, 1991). This paper studies the use of a fuzzy representation for representing the user model.

## 2. USER CLASSIFICATION

### 2.1 Stereotypes

User characteristics are classified using different methodologies. Stereotyping (Finin and Drager, 1986) and fuzzy representations (Chiu, Norcio, and Hsu, 1994) are two classification methodologies. A stereotype is a 'descriptive enumeration of a set of traits that often occur together' (Rich, 1983). The user is classified to one stereotype by some easily observable characteristics. These characteristics serve as a trigger for the entire stereotype (Morik and Rollinger, 1985). However, users display similar behaviors within the same stereotype; and different behaviors are displayed among the stereotypes.

However, assignment to only one stereotype is a disadvantage. A user is assigned to the stereotype that most closely compares to the user's set of traits. However, the user may only demonstrate 60% of the traits of a stereotype, yet interact with an interface developed for 100% of the traits. Further more, that user may demonstrate 40% of stereotype 2. In this case the user needs an interface that can meet 60% of the traits for stereotype 1 and 40% of the traits of stereotype 2. Using stereotypes to develop adaptive interfaces fails to handle the robustness of individual users. A fuzzy representation where users are assigned a grade of memberships for each stereotype would be preferable (Mitchell, 1992).

### 2.2 Fuzzy Representation (Grade of Membership)

By applying fuzzy set theory to user modeling, a user can have a grade of membership in different categories. One such fuzzy classification approach is the Grade of Membership (GoM) methodology used at Duke University's Center for Demographics (Manton, Vertrees, and Woodbury, 1990). The GoM methodology is a multivariate pattern recognition model, developed to describe medical diagnosis and symptom patterns, that applies grades of memberships to assign users to pure types (Manton et al., 1990). Data for each person is represented as a set of binary variables. Pure types are determined from the user population. The number of pure types varies, depending on the smallest number necessary to describe all nonrandom variations (Manton et al., 1990). Using the same factors for one population may elicit four pure types and another population six pure types.

Users are assigned a grade of membership for the pure types that describe their characteristics (Mitchell et al., 1992). Through the use of GoM it is possible to model the user accurately, by assigning grade of membership for the pure types. The GoM scores for each individual will be different. Each user is assigned to a dominant pure type, with other pure types listed. If there are five pure types for a specific user population, a user may demonstrate 70% of characteristics in pure type I and 20% in pure type III and 10% in pure type V. This user's dominant pure type is type I. Another user may be 100% pure type II, with pure type II the dominant pure type.

Though the assignment of a dominant pure type is similar to stereotypes the application of the grade of membership is a major difference between GoM and stereotypes. This methodology differs from stereotypes since users are not assigned to one type. It is noted that the dominant pure type does not fully describe the user's diverse characteristics. Therefore, the assignment of additional pure types captures a clearer picture of the user's diverse characteristics.

### 2.3 GoM Model

The model consists of four parts: raw data, lambda coefficients, grade of membership scores for each users, and number of pure types (Manton et al., 1990). The lambda coefficients predict the probability that a person who is exactly one of the pure types will have a certain response to a certain variable. For example, a person who is exactly Pure Type 2 will answer to the statement "I like my instructor(s) or supervisor(s) to recognize my efforts"

with a 'strongly agree'. This coefficient is used to identify the pure types.

The Grade of Membership scores for a person determine the degree to which a particular pure type describes a person. The GoM scores may vary between .01 and 1 but the sum must equal 1. For example, a person may have a Grade of Membership score of .59 for Pure Type I. That person who has a GoM score of .59 for Pure Type I may also have a GoM score of .30 for Pure Type III and a GoM score of .11 for Pure Type IV. These scores total 1 and describe the person as having a majority of characteristics that are identified with Pure Type I but also include characteristics found in Pure Types III and IV. This differs from stereotyping where the person would be assigned to stereotype one.

The estimation of the lambda and the GoM scores is completed by maximum likelihood procedures. The chi squared statistic is generated from twice the log of the ratio of likelihood values for the models with K pure types and K+1 pure types, where K is an integer starting with two. This statistic is used to describe the input data. The model executes K pure types and then K-1 pure types until the likelihood is not increased significantly by adding another pure type. The number of pure types is different for each data set (Mitchell et al., 1992).

## 3. RESEARCH

### 3.1 Defining User Characteristics

The Productivity Environmental Preference Survey (PEPS) instrument was used to determine user's preferred preference for structuring their learning and work environment. PEPS determines the user's preference in four areas: immediate environment, emotionality, sociological needs, and physical needs (PEPS, 1992). Responses are recorded as either a strong preference for the element, a strong preference for lack of the element or no preference at all.

The environmental elements include noise, light, temperature, and design of the environment (either a formal setting of tables and chairs or an informal setting of couches or the floor). The emotionality elements include motivation, persistence, responsibility, and structure. The sociological elements include alone/peers, authority figures, or both ways. The physical elements include auditory, visual, tactile, kinesthetic, time of day, and preferences for eating and drinking.

Although these are important factors to consider when structuring a learning or work environment, not all of them pertain to the development of computer interfaces. The areas of PEPS that were included in this research are: motivation, persistence, responsible, structure, alone/peers, authority figures, auditory, visual, tactile and kinesthetic. The factors of motivation, persistence and responsible would influence the amount of feedback and reminders the interface provides. A person who is not highly motivated may prefer more help comments while learning new software.

The preference for structure would influence the amount of guidance and direction the interface provides. Direct manipulation interfaces provide more directions than command line interfaces. Alone/peers and authority figures would influence the type of help comments provided. If a person wants to work with someone or someone in authority, comments can be programmed into the interface. This way the user feels that attention is being paid to their interaction. Auditory would require voice output, visual would require screen displays, and tactile/kinesthetic would require an interface that allows the user to work through tasks.

### 3.2 Subjects

The PEPS was administered to 98 students enrolled in an introductory computer analysis and design class to determine user characteristics. The students were enrolled at University of Maryland Baltimore County and Anne Arundel Community College. Thirty-four percent were female and sixty-six percent were male. Thirty-two percent were under the age of twenty-two, thirty-three percent were between the ages of twenty-two and thirty, nineteen percent were between the ages of thirty-one and forty, eight percent were between the ages of forty-one and fifty, and eight percent were above fifty.

### 3.3 Pure Types Defined

The scored PEPS results were coded and used as input for the Grade of Membership methodology program. Six pure types were defined.

#### Pure Type One

These users have no preferences for auditory, visual, persistence, alone or authority.

#### Pure Type Two

These users have a strong preference for praise, structure and authority. An interface that structures the task, leading the user through the steps and providing plenty of praise matches this pure type.

#### Pure Type Three

These users lack persistence and motivation, requiring visual cues and like to work with someone in authority. An interface that reminds the user what needs to be done, giving plenty of visual instructions matches this pure type.

#### Pure Type Four

These users are highly motivated, persistent, visual, tactile, and prefer to work alone without structure. An interface that allows the user to explore, without going through computer determined steps matches this user.

#### Pure Type Five

These users are auditory and kinesthetic, motivated and do not like constant checks. An interface that includes voice output, direct manipulation and lets them explore without reminders matches this user.

#### Pure Type Six

These users are extremely motivated, persistent and prefer to work alone, without assistance.

Pure Type Six users have a stronger preference for working along than Pure Type Four users. Likewise Pure Type Two users have a stronger preference for reminders and help than Pure Type Three. The difference lies in the strength of the preference.

### 3.4 GoM Scores

Each user is assigned a GoM Score for each pure type. A user may have characteristics of three pure types or only one pure type. Only fourteen percent of the users scored 100 percent of one pure type. This differs from stereotyping where one hundred percent of the users are assigned to one stereotype. Twenty-nine percent of the users received GoM scores in two pure types, twenty-nine percent received GoM scores in three pure types, and twenty-one percent received GoM scores in four pure

types. Only six percent of the users received GoM scores for 5 pure types and no one received GoM scores in each pure type. The GoM scores indicate that users need to interact with different interfaces. Only fourteen percent of the users have all of their characteristics met with one interface.

Table 1 displays the percentage of users that have their highest and second highest GoM scores for that pure type.

**Table 1**  
**Percentage Assigned to Pure Type**

Pure Types						
I	II	III	IV	V	VI	
<b>Highest</b>						
21	10	15	23	19	12	
<b>Second</b>						
13	15	12	17	28	15	

Pure Type Four, One, and Five are the most preferred interface types. Pure Type One has no preferences for auditory, visual or authority. There is no preference for amount of structure. Pure Type Four prefers to work alone without structure and with visual displays of information. These users need an interface that allows them to explore. Pure Type Five prefers to work in groups with sound and movement, preferring no authority intervention.

The interface a user interacts with is determined by the user's GoM scores. A person with a GoM score of .59 for Pure Type One needs to interact with an interface with no structure. If that same person has a GoM score of .41 for Pure Type Four that interface should also include visual displays of information. A person with different GoM scores would require a different interface.

#### 4. CONCLUSION

This paper presents a fuzzy approach to classifying user characteristics. The PEPS data, collected from users, was used to identify six pure types. Each user was then assigned a GoM score for each pure type. User's could be assigned a GoM score for one pure type or many pure types, depending on the user's specific characteristics. Fourteen percent of the users classified displayed one hundred percent of one pure type. The rest of the

users displayed characteristics in more than one pure type. However, in stereotyping the users with characteristics in more than one pure type would be assigned to one stereotype. The GoM approach captures a clearer representation of the individual user.

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