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User Models for Information Systems: Prospects and Problems

ABSTRACT

Expert systems attempt to model multiple aspects of human-computer interaction, including the reasoning of the human expert, the knowledge base, and characteristics and goals of the user. This paper focuses on models of the human user that are held by the system and utilized in interaction, with particular attention to information retrieval applications. User models may be classified along several dimensions, including static vs. dynamic, stated vs. inferred, and short-term vs. long-term models. The choice of the type of model will depend on a number of factors, including frequency of use, the relationship between the user and the system, the scope of the system, and the diversity of the user population. User models are most effective for well-defined tasks, domains, and user characteristics and goals. These user-system aspects tend not to be well defined in most information retrieval applications.

INTRODUCTION

The topic of this conference is artificial intelligence and expert systems in the library setting. The question addressed in this paper is where do "user models" fit in this discussion.

Systems generally are considered "expert" when they have some reasoning ability. The problem domain is usually the object of the reasoning—a knowledge base is built from data about the domain, often

combined with knowledge about the relationships among the data drawn from interviews with human experts. User models, in contrast, consist of reasoning about the person who is manipulating personal characteristics that may influence the user of the system, with or without additional data about the problem the user brings to the system. User models may be implemented in combination with other expertise or as the primary expertise in the system.

User models start with some expectation of the knowledge the user brings to the system and about how he or she will interact with the system. The user model allows the system to adapt its interaction style and content to the individual user. User models have several contributions to make to expert systems, according to Karen Sparck Jones (1989): they can increase system *effectiveness,* helping to ensure that the system makes the correct decision. They can serve system *efficiency,* helping to reach the correct decision in an economical way; and they may increase system *acceptability,* in expressing or presenting the results of the system in a way most comprehensible and usable for the individual.

This paper describes and discusses the various types of user models that have been constructed in the context of information systems, and concludes with an analysis of the usefulness, advantages, and disadvantages of implementing user models in information retrieval systems.

RESEARCH ON USER MODELS

One of the purposes for pursuing the construction of user models in information retrieval is to provide systems with "intelligent interfaces," with ease of interaction as the objective. Brooks, Daniels, and Belkin (1985) describe an intelligent interface as "something that stands or mediates between user and knowledge resource in the information system" (p. 191). In an information retrieval setting, the "intelligent interface" can act as a human surrogate, helping the user to clarify and meet his/her information need. Users may not know precisely what is being sought, but can, to some extent, describe the problem that has brought them to the system. In traditional library reference services, the librarian performs this function. Continued development of intelligent interfaces for information retrieval systems offers the possibility of replacing the human intermediary with a system that can perform the query negotiation function traditionally carried out by librarians.

If the system is to replace the human successfully, it must mimic or model the actions of the human intermediary (Brooks et al., 1985).

One thing the system must do is build a model of the user's problem (Brooks, 1986), rather than request a specific statement of the information need, as required in conventional information retrieval systems. It is a function of the intermediary to assist the user in defining the problem precisely. The system must also build a model of the user. As in human-human interaction, when the system and the user engage in a dialogue, each adapts its model of the other in the process, until the problem has been identified satisfactorily. Asking the user for relevance feedback provides the interactive element necessary to arrive at a more accurate problem assessment, since user perceptions of the problem may change in the course of the session. The interactive element allows modification of the problem image within the system in order, finally, to arrive at the appropriate query formulation or information need.

THOMAS, for example, is an information retrieval system that employs a user model and is designed to retrieve bibliographic references in the area of medicine and biochemistry (Oddy, 1977). The objective of the system is to enable users to present a subject term and have the computer carry out a search based on that term, thereby freeing the user of formulating a full search query. The system matches up the term with the item closest to it and presents the user with references. The user reviews the selections and can reject, accept, or make no judgment on them. From the user's response, THOMAS can modify its image of the user's area of interest if necessary, and present alternative selections. In this case, the system models the user to determine the area of interest and expertise, just as a reference librarian might do.

A brief review of the literature illustrates the various definitions of user models and discusses several applications of those models used to provide intelligent interfaces for information retrieval.

TYPES OF USER MODELS

Research in human-computer interaction, and in particular interface design, focuses heavily on the thought processes, or cognitive processes, of the user. De Mey (1977) states that cognitive processes are involved in all information processing activities, and provide the individual with concepts that serve as a model of the individual's world and a way for the individual to organize his/her knowledge. Knowledge of human behavior in information retrieval tasks will be helpful in systems design as well as in user training (Borgman, 1986a).

Various models have been identified that represent the thought processes that occur when two individuals interact. The three major types of models are conceptual, mental, and user models (Borgman, 1986a). These types of models are distinct but complementary.

Conceptual Models

The conceptual model, according to Norman (1983), is the model of a system presented to the user by someone else, such as the designer or a teacher. Halasz and Moran (1982) add that the conceptual model provides the user with information about the underlying structure of the system, giving the user a starting point with which to reason about the system.

A conceptual model of an information retrieval system might be based on a card catalog, for example. A model for a word processing system might be based on a secretary and a filing cabinet. Halasz and Moran (1982) discuss metaphorical vs. abstract conceptual models at length.

Mental Models

The mental model is part of the thought process of the user when interacting with a system. People develop a mental model internally, as opposed to having it presented to them (Norman, 1983). The user's mental model may be based on a conceptual model that has already been presented to him/her or it may be developed independently (Borgman, 1986a). The mental model is how he/she thinks the system is structured and how it functions. Norman (1983) defines the mental model as "what people really have in their heads and what guides their use of things" (p. 12). The user's beliefs about the system will be incorporated into the user's mental model of the system regardless of their accuracy. It often is difficult to ascertain exactly what elements are at work in a mental model, as the user may not be conscious of the presence of a model and cannot clearly articulate the model. The mental model is helpful to the user when first learning to use a system and later can be employed to detect errors and to determine ways of correcting those errors (Norman, 1983).

User Models

Conceptual and mental models are modeling the system, in contrast to the user model, which describes the *user* of the system. The user model is perhaps the most elusive of the three types of models. Daniels (1986) defines the user model as "the model held by a system of a user" (p. 272). User modeling is based on the notion that any time two individuals interact, they each have a model or knowledge of the other. The assumptions each makes about the other are a key element when attempting to create a system that mimics a human intermediary in the process of interacting with a user. The ability for a system to function

in an interactive capacity allows the computer to "get to know" the user, thereby enabling the system to act as a dynamic participant in the information retrieval process.

Psychologists have studied the processes that occur when two people interact and the models that are formed. Newcomb (1961) presents a model of communication suggesting that when two individuals interact, they each have preconceived assumptions of the other. In other words, each knows what she or he thinks, and also has an idea of what the other person thinks. As communication proceeds and new information is presented, each adjusts their attitude of the other, either reinforcing the existing orientation or reassessing the existing attitudes and developing new ones. Over time, if communication is to continue harmoniously, the attitudes of each will become more similar to the other.

Brooks, Daniels, and Belkin (1985) identify the user model as the element that arises out of communication between two people, or in the system's case, a person and a computer. This knowledge improves the interaction between the user and the system, allowing the system to reason and make judgments based on the information provided by the model, so that the system then can modify its actions in accordance with the user's characteristics (Gilbert, 1987). Clowes, Cole, and Arshad (1985) call the user model a "representation of the user in terms of the user's observed and inferred abilities, beliefs, goals, attitudes, and emotions" (p. 36). The user model serves as a means of distinguishing the user's needs and beliefs from those of the intermediary or system. In human-human interaction, the model can be derived from stereotypes, implicit knowledge, extralinguistic cues, nonverbal communication, the user's situation, or a problem description (Brooks et al., 1986).

There are no strict, mutually exclusive categories by which all user models can be defined, nor is there a consensus as to exactly what is to be included in a user model. Characteristics of the user model can vary according to the system, user, and the task being performed. Daniels (1986) compiles a list of characteristics to be included in the user model: user status, user goals, user knowledge of the field, user experience with information retrieval, and user background (employment, residence, academic background, etc.).

GENERAL CATEGORIES OF USER MODELS

Rich (1979) identifies three dimensions helpful to organize the numerous descriptions of user models. User models are composed of a wide array of information about the user and can be implemented in a variety of types of systems. The dimensions present attributes that

a user model is most likely to have and are helpful in determining how useful each will be across various types of systems. The dimensions are not exclusive and can overlap with one another. Rich's dimensions are "canonical vs. individual," "explicit vs. implicit," and "long-term vs. short-term." Rich's dimensions and others have been incorporated into the following categories.

Static vs. Dynamic User Models

The first category of user models that Rich refers to as "canonical vs. individual" may also be seen as "static vs. dynamic," distinguishing a static, unchanging model that is embedded in the system from a dynamic model that is different for individual users and changes throughout the session. Finin (1983) refers to the canonical model as a "generic model" since this category assumes a single model for all users.

Static User Models

Static models can be configured as lists of characteristics that form a *stereotype.* Stereotypical models, just as the name suggests, make assumptions about the user based on the type of information received while interacting with the person. Rich (1979) defines stereotypes as "clusters of characteristics" assigned to predetermined groups of users (p. 332). Stereotypes in systems are analogous to scripts, frames, and schema in human cognitive processes (Stillings et al., 1987). They provide information about events that occur frequently and facilitate the predictability of events or behavior. Brooks, Daniels, and Belkin (1985) propose that a standard set of frames can be used to capture the knowledge that human intermediaries have of their users. According to Rich, two types of information are involved in the implementation of stereotypes: facets, which are the user characteristics, and triggers, which can be a word or words that indicate that the user is displaying some of the characteristics of a particular stereotype, and then prompt activation of the appropriate stereotype (p. 333).

Dynamic User Models

The dynamic model changes throughout the session and over a period of time to incorporate new information received from the user, such as increased experience or change in goal. Each particular user model can be saved under a user identification code and retrieved at each subsequent use.

A system that employs dynamic models builds and changes its model based on each individual user's characteristics. Rich (1979) describes the dynamic model as being "built on the fly" (p. 330), since it is created

at the time the system is accessed by the user. It is best implemented in situations where users use the system repeatedly. Systems with infrequent users are best equipped with a static model that is designed for the expected user group (Rich, 1983).

Stated vs. Inferred User Models

User models either can be stated by the user or inferred by the system, based on the responses the system receives from the user. Rich (1979) refers to this dichotomy as explicit vs. implicit (p. 331).

Stated User Models

In systems where an explicit model is implemented, the user is presented with questions as to some characteristic, usually knowledge domain or expertise, and from this information the user is assigned a type, such as "expert" or "novice." Gilbert (1987) calls these models "direct" since the user is questioned directly, which may be a more accurate description than "explicit" since information provided by a user is not always fully and clearly stated, as explicit implies. Daniels (1986) views this type of categorization as a user description, and not really a model at all.

Inferred User Models

The implicit model is embedded within the system and is inferred from the actions or responses of the user. The user may be unaware that an inferred model of him/her is at work, since the system does this on its own, and need not ask the user to provide a self description. The stated and inferred models also may work in combination, with a few initial questions for the user to answer, and then the model is built from the user's subsequent actions.

A system utilizing stereotypic models would assign the user to the most fitting stereotype. Each stereotype has information about the most appropriate style of interaction which should be adopted for users of a certain kind, and by monitoring the user's behavior, the system selects a model that most closely resembles that user. The stereotype allows the system rapidly to infer a user model from a small amount of description (Clowes et al., 1985).

The GRUNDY system (Rich, 1979) employs stereotypes to characterize users for the purpose of recommending novels to them. Each stereotype is assigned a group of features which are numerically weighted in order to match the user with a stereotype more accurately. One of the stereotypes utilized in GRUNDY is "sports-person," containing traits such as physical strength and an interest in sports. The "trigger" for "sports-person" is the word "athletic." If the user

identifies him/herself as "athletic," the "sports-person" stereotype will be activated (Rich, 1989).

PLEXUS, an expert system employing a user model to provide referral sources for gardening information, initiates its user model by asking the user questions about prior knowledge of the PLEXUS system, experience with gardening, knowledge of gardening information sources, and objectives in using the system. As the interaction proceeds, the system becomes familiar with the individual and adjusts its responses accordingly (Vickery & Brooks, 1987).

Short-Term vs. Long-Term User Models

Another criteria that Rich (1979) incorporates in her categories of user models is the use of short-term vs. long-term information.

Short-Term User Models

Short-term information is concerned with what the user is doing at the time of the session, what goals the user has, or what is being input by the user. An example of short-term interaction is the library patron's use of the online catalog. Patrons will access the system repeatedly with a specific and most likely different goal each time.

Long-Term User Models

Long-term information involves such elements as expertise and knowledge domain, which can be stored and updated in future sessions. This type of model would be applied to users who interact with the system consistently, where over time a model would be tailored to the individual user. An example of this would be an individual with an account that allows remote access to an online catalog. The user would be recognized by his/her account number to facilitate building and maintenance of a user model.

An example of combining the user model dimensions is found in the case of GRUNDY, where a combination of stated, stereotypic, and long-term models is used. The system asks several introductory questions regarding personality traits of the user to begin creating its model, and as the session progresses the model is modified in accordance with the user's response to the selections made by the system. At the end of the session, the model that has been compiled for that specific user is stored, to be retrieved when she/he returns (Rich, 1979).

Problem Description Models

In the information retrieval domain, it is difficult to separate characteristics of the user from characteristics of the user's problem.

Some information retrieval systems attempt to incorporate both user and problem characteristics into one model, while others separate them into independent models.

Belkin, Seeger, and Wersig (1983) approach the development of the problem description as a distinct modeling task, where a model is created to represent user's need or anomalous state of knowledge. In this type of modeling, the system and the user participate in a dialogue to describe the specific problem explicitly, determining what gaps exist in the user's knowledge of the problem, not unlike the interaction between the user and the reference librarian. A "blackboard" type of system is one way of managing multiple models of the information retrieval process. Each model (of the user, the problem, the database, etc.) would post status information to the blackboard, which then determines what actions to perform (Belkin et al., 1987).

SUMMARY OF USER MODEL TYPES

The various types of user models all share the common goal of understanding the user in order to make systems more useful. Each type of model may contain different information and be presented in a different way. The model dimensions and resulting categories are summarized in the following figure.

	STATIC • user categories • unchanging	**DYNAMIC** • user specific • changes over time
STATED • canonical • direct • generic	• single model • multiple stereotypic	• individual • long term
INFERRED • implicit	• multiple • stereotypic • short term • long term	• adaptive • unique • short term • long term
STATED AND INFERRED • combination model	• multiple • stereotypic • long term	• multiple • adaptive • short term • long term

User model categories

The choice of model types to apply is dependent upon a number of factors.

The richness and depth of a user model, for example, will depend on the amount of information the system can gain about the user, whether the information is gathered by questioning the user directly or by inferring it from the interaction. Each has advantages. Accurate information can be gained by direct questioning on topics that the user can express, such as purpose of search, status, and some keywords. It may be less useful in determining system expertise or understanding of the search question, which might, perhaps, be gathered more accurately by a record of actual interaction with the system. Each of these is problematic and depends on how variables such as "purpose of search" and "expertise" are defined. Similarly, user models can be built in more depth if they are long-term models constructed over the course of multiple search sessions than if they are short-term models built only in a single session.

Another factor in choosing the type of model to apply is the relationship between the user and the system. In a public-access retrieval system with infrequent, anonymous users, it may be possible only to build short-term single-session models, as privacy and expediency factors may prevail. In the case of private access systems (e.g., internal corporate systems) with frequent users who must identify themselves to the system, much more elaborate models may be possible.

The scope of the information retrieval system also will be a factor in determining the type of model to apply. Large systems with one or more databases covering heterogeneous subject areas and types of material will require more elaborate modeling capabilities than small databases with homogeneous content.

Similarly, the diversity of the user population will be a factor in determining the type of model required. The designers must determine if they are dealing with a diverse population that falls neatly into several stereotypic categories, in which case stereotypic models may be useful. Conversely, it may be a highly diverse population that is not easily segmented into groups, in which case stereotypes may be difficult to apply and more adaptive models will be required. The simplest case is one with a clearly defined homogeneous user population, less likely in information retrieval applications.

Related factors to consider are whether one model will serve all users satisfactorily, or whether a model should be built for each user who approaches the system. Another issue is frequency of use. Do the users tend to be regular, returning users that would benefit from a model that is saved and tailored to them over time, or is their use brief and infrequent, indicating a model that is short term, or perhaps a static model? If the model is a long-term one, are the types of queries by

an individual relatively similar, or do the user's goals change significantly from one interaction to the next?

USER MODELS AND INFORMATION RETRIEVAL

User models clearly have many applications in interactive systems, but they may not be suitable for all tasks and all domains. Most of the environments in which user models have been applied have been more structured than information retrieval, such as computer-assisted instruction or advice to medical patients.

User models are most effective when the task, domain, user population, and user goals are clearly defined. It also is easier to construct user models when the user's goals remain static throughout a session (i.e., results of intermediate stages of interaction do not influence later stages).

Correspondingly, user models are least effective when tasks are poorly defined, when the user population is heterogeneous, and when the user's goals are dynamic (i.e., they change throughout the use of the system).

Characteristics of Information Retrieval

Information retrieval environments vary widely in the degree to which tasks, user populations, and user goals are defined. Information retrieval tasks may be narrow and well defined, as in the case of known-item searching in a very small database of limited scope. They may be broad and poorly defined, as in subject searching of the online catalog of a large collection. The tasks may fall anywhere in between, depending upon a number of conditions, including the size of the database and the clarity of the problem.

The user population for information retrieval is sometimes homogeneous and sometimes has a narrow range of goals. This is most likely to happen with small user groups with known characteristics and goals (e.g., chemical engineers searching a small corporate database on geology for oil exploration). More often they are heterogeneous, as in the range of users and goals on university or public library online catalogs. The population might fall anywhere in between, such as a subset of users (e.g., chemistry faculty) with a subset of goals (e.g., newest items on crystallography).

The stability of user goals varies greatly in information retrieval as well. User goals might be static over the course of user-system interaction, as in the case of finding one item quickly. They might be dynamic, as in the case of subject searching that requires browsing,

where the user's own knowledge of his or her information need and of the database changes with feedback from the system.

In general, information retrieval is characterized by a relatively unpredictable range of users and user goals, no matter what the subject domain. Information retrieval systems are much more characterized by the need to respond to unique queries than are other types of interactive systems to which user models have been applied.

Issues in the Application of User Models to Information Retrieval

It is useful at this point to return to Karen Sparck Jones's (1989) explanation of the reasons for building user models: for *effectiveness*—getting closer to the goal of the system, reaching the correct decision; for *efficiency*—getting to the result faster; and for *acceptability*—expressing the result in an appropriate, understandable way. Are these appropriate goals for information retrieval?

Bates (1990) has argued that we should be very cautious about what we automate in the information retrieval process, and not automate functions simply because we understand them. Rather, we should look carefully at what portions of the task are most amenable to automation and which portions are best left under user control. She notes that while the market demands automaticity in technologies such as cars and cameras, a consumer demand remains for stick-shift transmissions and for sophisticated, manually operated cameras (Bates, 1989).

We must ask both whether we understand the information retrieval task sufficiently to construct effective, efficient, and acceptable user models, as Sparck Jones (1989) suggests, and if so, whether it is appropriate to do so, as Bates (1990) asks. Reviews of information-seeking studies suggest that we have only limited models of this complex process (Borgman, 1986b; Fidel & Soergel, 1983; Fenichel, 1980; Penniman, 1975). Information retrieval is a far more complex task domain than most areas in which user models are applied.

User models necessarily reduce the amount of control that users have over the searching process. User models make assumptions about users' goals and intents and make decisions for them. While accurate models indeed are helpful and reduce the burden on the searcher, inaccurate user models may do more harm than good by putting the user in the wrong place in the system or by preventing access to some portions or content of the system.

It is fairly safe to say that user models may be effective for information retrieval in narrow, well-defined task domains with well-defined user populations that do not need to control searching fully.

They are likely to be useful in complex systems that are otherwise difficult to use. One should be cautious, however, in making broad claims for the applicability of user models in information retrieval.

CONCLUSION

User models are a powerful way to add intelligence to an information retrieval system, but information retrieval is a complex task and it is not clear how effective user models will be under what circumstances. Thus user models should be implemented cautiously in well-defined task environments, and experimentation is encouraged. Only then will we know what the benefits and limitations are of user models in information retrieval.

APPENDIX

User Model Example

The following is a hypothetical example of a *static user model* based on *stated* information from the user to assign a *stereotype*. The hypothetical domain is an online catalog in a large academic library, containing 1 to 2 million title records.

The system poses the following questions to the user (answers in caps):

1. What is your academic status: undergraduate, graduate, faculty, guest? UNDERGRADUATE
2. What is the purpose of your search today: class assignment, term paper, work for faculty member, personal interest? TERM PAPER
3. How many times have you used the system before: never, 1-5 times, 6-10 times, more than 10 times? NEVER
4. Are you interested in a general subject area, a very specific subject area, or for a book or journal whose name you know? GENERAL SUBJECT AREA
5. How much searching have you done on this topic already: not looked anywhere, searched journal indexes already, searched other catalogs, collected some books or articles already? NOT LOOKED ANYWHERE
6. Please type in up to 5 keywords that describe your search topic: COMPUTER VIRUSES

The system will assign the user to the following stereotypic model based on the above answers to the questions:

The user is assigned to the novice stereotype, both in use of the system and in the subject domain.

The user is assigned to the subject browsing search stereotype, as he or she needs to develop his or her topic and terminology more fully.

The system will take the following actions based on this user model:

The user will be put into a menu-oriented search mode rather than a command mode that assumes more knowledge of the system.

The user will be put into the subject authority list in the vicinity of COMPUTER VIRUSES to browse for appropriate synonyms or cross references.

The system may also perform a title keyword search on COMPUTER VIRUSES (using variant forms of the phrase) because this is not an authorized LC Subject Heading (LCSH).

The system will limit the user's output to 100 items, assuming that this is a starting point for further research.

The user will be referred to journal literature databases that may be components of the same system or available elsewhere on campus, based on the lack of occurrence of the LCSH and the likely small retrieval.

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