USER MODELLING PANEL

D. Sleeman (Stanford: Moderator), Doug Appelt(SRI), Kurt Konollge(SRI),
Elaine Rich(MCC), NS Sridharan(BBN Labs) & Bill Swartout(ISI).

INTRODUCTION

In various sub-areas of AI we talk about "tailoring" the system's response to the user. NL systems and Tutoring systems being two prime examples. Additionally, some discussion of this issue arises in building explanation facilities tor Expert Systems.

- How explicit are the user models even in systems which are able to adapt to the user?
- How do they achieve this tailoring? How similar are the techniques used?
- How do such user models differ from the plans inferred in planning systems?
- How deep/knowledgeable do User models need to be?
- How is this sophistication dependent on the type of interaction (superficial conversation versus diagnostic/tutorial), the goal of the dialogue, the nature of the domain etc?

In this panel we will review many of the areas in which some form of user model is used, look at commonalities of approaches, and seek to characterize when a particular approach is appropriate.

USER MODELLING: SOME APPROACHES

Elaine Rich

User modelling straddles the boundary between artificial intelligence and data base technology. It has all of the problems that each of these areas possesses; we hope it will also be able to draw on both areas for solutions. This double dependency arises from the interaction between the two main subproblems that user modelling must address:

- How can models of users (their knowledge, goals, etc.) be inferred from their behavior and used In reasoning to improve the performance of a target system? This is where A.I. comes in.
- How can models of a large number of users be maintained efficiently so that each is available when necessary but system performance does not degrade even if the user population is very large? This is where data bases are important.

User models capture many kinds of information about users. Two important dimensions that characterize this information are shown in the following chart:

	individual user	canonical user
short-term information		
long-term information		

Square 2 does not make much sense, but each of the other squares poses specific problems that user-modelling systems must address.

When user modelling is looked at from the A.I. point of view, the following issues emerge:

- How can specific user plans be inferred from behavior? (This relates to square 1.) Doing this requires a system that is itself capable of forming plans but it also, since it is a diagnosis task and not a design task the way most planning problems are, requires a sophisticated matching procedure so that the plan that the user has selected can be isolated from other possible plans,
- How can user knowledge and planning strategies be inferred from behavior? (This relates to square 3.) People's knowledge and their problem-solving strategies change quite slowly over time and should be remembered from one session to the next because they may substantially influence both the way the user will behave and the way the system should behave for maximum effectiveness.
- How can general knowledge and planning procedures be represented and used effectively? (This relates to square 4.) This is the standard A.I. question.

When user modelling is looked at from the database point of view, the following issues emerge:

- How can information about a large number of users be stored most efficiently? (This relates to square 3.) Is it more efficient to store each model separately or to store models as differences from some canonical model? Is it better to organize the model around a particular user, clustering together everything known about that person, or is it better to arrange the model around a particular topic or piece of knowledge, clustering together what is known about all users with respect to that issue?

- How can a lot of detailed knowledge about a particular session be collapsed into a concise description of the knowledge that may be useful for later sessions? (This relates to square 3.)

STUDENT MODELS in INTELLIGENT TUTORING SYSTEMS

D. Sleeman

The field of Intelligent Tutoring Systems identified the need for having a model a database which summarized the student's actions some time ago. The earliest adaptive CAI programs often represented the student's level of sophistication by a scalar value. SCHOLAR, a program which discussed the geography of South America, was the first to use a more sophisticated representation - namely a semantic network. Essentially, the knowledge of the domain was represented as such a network and each node had a numerical value associated with it indicating the likelihood that a particular student knew the knowledge associated with the node. This type of model is referred to as an *overlay* model. A *differential* model which simply reports the differences between an expert's and the student's knowledge was introduced in the WEST system.

All these systems assumed that the student's knowledge was merely a subset of the expert's. Recent studies in Cognitive Science have shown this is frequently *not* a valid assumption, and so models which allow both the correct and incorrect knowledge to intermingle have been introduced. *Perturbation* models have boon used by Brown & Burton in their DEBUGGY system to model student's errors with Arithmetic tasks, and by Sleeman in LMS/PIXIE to capture student's knowledge of Algebra.

An important aspect of these latter models is that they are *process* models - and so can be executed by an appropriate interpreter - thus enabling them to be used predictively. Both DEBUGGY and PIXIE address the issue of *inferring* models by observing the student's performance on a series of tasks. Technical issues addressed by these systems include how to make the search computationally tractable, and how to overcome noise (i.e., spurious responses). Additionally, PIXIE is addressing the issue of how to remove the closed-world assumption - making the systems *truely* responsive to the student's input. Currently, modelling systems merely search - an albeit very large - model space generated by combining more primitive components (in PIXIE's case of correct and incorrect rules).

EXPLANATION & the ROLE of the USER MODEL: HOW MUCH WILL IT HELP?

Bill Swartout

There seems to be a growing consensus among researchers In explanation and text generation that a solid, detailed user model (if we only knew how to build it) would significantly improve the kinds of explanations and texts we can produce mechanically. Currently proposed system designs often call for a detailed user model that expresses what facts the system believes the user knows, how he likes to have information presented, and so forth. In such designs, presentation strategies use the model to select just the right thing to present to a user. Is such a detailed model feasible? Do people seem to have detailed knowledge of their listeners? This approach may place too much emphasis on the user model. It often seems that people do not have detailed knowledge of their listeners but instead rely on general, stereotypical knowledge and an ability to alter their explanation tactics when the listener appears not to understand. I would like to suggest that an explanation system that allows for feedback from the user about the understandability of explanations and that relies on a general user model expressing knowledge of stereotypes might be more feasible that one that depends on a detailed user model.

THE ROLE OF USER MODELLING IN LANGUAGE GENERATION & COMMUNICATION PLANNING

Doug Appelt

The analyses of Searle and Grice clearly demonstrate that communication is a process of *intended recognition of intention,* whereby the speaker formulates utterances with the intention that the hearer use that utterance to understand the speaker's intentions that the hearer hold some different prepositional attitudes as a result of understanding the utterance. This intention recognition property is *essential* to communication - - if it is absent, then whatever activity is going on is something other than communication.

If a user perceives natural language being used as input and output to a system, it is very natural for him to assume that it is being used as a medium of communication, much the same as people use it among themselves. Therefore, there is a very strong tendency for the user to impute intention recognition capabilities to the system and to assume that it is taking his own intentions into account. Of course, most users of currently available natural language interfaces soon learn that this is not the case. The objective of research in communication planning is not so much being able to construct ever more complex sentences involving increasingly difficult semantic concepts, but rather to understand the processes of intention communication and recognition well enough to enable a system to participate in a natural dialogue with its user.

Therefore a system that plans communication must have a very detailed model of the user. There are a large number of alternative means of representing the beliefs and intentions of agents, and the requirements of communication planning do not dictate what form such a representation must take, but rather dictates a set of requirements about what kinds of reasoning must be done. The following is at least a partial list of the representation and reasoning capabilities necessary for communication:

- The ability to represent Believe(A, P), Believe(A, ~P), ~Believe(A, P).

- The ability to represent all of the above with respect to mutual belief.

- The ability to represent all of the above with respect to intention.

- The ability to deduce for any P whether or not A believes P, and similarly for mutual belief and intention.

- Given an individual, reason about what is believed or mutually believed about it.

- The ability to reason about the effect of actions on belief, mutual belief, and intentions. Must be able to reason for any act and proposition P about whether or not [act]Believe(A, P) holds, and Believe(A, [act]P).

Language production is not a faculty that can, in general, be isolated from the general reasoning processes of a system. Natural communication requires knowing about the plans and goals of a speaker with respect to the entire task, and the ability to plan goals having to do with the communication process itself as well as the domain. Therefore, it is impossible to take some existing system, add a user model, tack on a natural language font end and back end, and expect it to engage in natural communication. The need for communication must be in the mind of the designer from the beginning, with domain and communication reasoning incorporated as a consistent whole.

USER MODELLING, COMMON-SENSE REASONING & the BELIEF-DESIRE-INTENSION PARADIGM

Kurt Konolige

User modelling is important wherever an AI system must interact with human agents. I say here "human agents", but this is not necessarily meant to exclude other types of agents; as computer system become more complex, the same principles used for efficient communication with people will hopefully apply to artificial agents. Indeed, in Methodologies below I note that analyzing the communication requirements of artificial agents may lead to insights about communication in general.

I think it would be an understatement to say that current AI systems which incorporate user models have a long way to go. This is not because too little attention has been paid to the problem, but simply because the problem encompasses • a significant part of current AI research. There may be very restricted situations in which a crude parameter model (for example, a verbosity switch) is all that is necessary; but for the more open-ended dialogues that normally take place in question-answering, explanation, and tutoring (to name a few application areas), a more accurate model of the user's cognitive state is required. I would like to give a personal view of some of the major lines of research that are being pursued or should be pursued to achieve a realistic user model.

Methodologies

At present, most models of cognition in AI are variations of a BDI (belief-desire-intention) paradigm. An agent has beliefs about the world, and desires some states of the world more than others. Rational agents form intentions or plans to affect the state of the world to fulfill their desires, given the current state of their beliefs. This picture is a kind of commonsense psychology, and seems to be implicit in the way we use words like 'belief,' 'desire/ 'plans,' etc. Hardly any work has been done on a general theory relating these cognitive components. Still, the BDI paradigm is a useful general framework for constructing user models for particular applications. In many cases, it is possible to simplify the model considerably: fcr example, in question-answering on a database it is assumed that the user has a goal of extracting information, and the problem of forming intentions from conflicting desires does not arise.

While the BDI paradigm can provide an overall hatrack for organizing cognitive models, it does not tell us what particular hats we should put on it. Agents' beliefs, for example, can be quite complicated, incorporating complex commonsense reasoning about space, time, physical systems, and so on, as well as particular beliefs about the domain at hand. How do we go about developing such theories? This might be called the Knowledge Problem for user modelling. There are two sources for such theories. One is the Cognitive Science path, in which attention to protocols of subjects can yield interesting insight into cognitive processes acting in complex environments. The other is in AI planning systems: artificial agents whose cognitive structure is designed to solve a particular task. The former might be described as theory-poor but data-rich: the subjects actually do act intelligently in the domain, but the actual cognitive structures they employ are not accessible. The latter are theory-rich but data-poor: the design of the agent is useful as a theory of reasoning in the domain, but the agent may not actually act as intelligently as desired. So it would seem that both approaches are desirable •- for example, analyzing the way people use language yields data on desirable properties of a language-using system, while studying the requirements for efficient communication between agents can lead to a simplified model of communication that helps organize linguistic phenomena.

The Knowledge Problem

At the very minimum, a useful user model for open-ended dialogues should include the following:

- Domain-dependent knowledge. This is the type of reasoning most often capture by expert systems, which are good at a very specialized type of problem in a narrowly defined setting.

- Theories of the commonsense world. This type of knowledge is tacitly assumed in all human communication. It includes areas such as:

  - Intentionality and beliefs of other agents.

  - Common-sense theories of time, space, and physical processes.

- Knowledge of the interaction process. This includes principles of efficient communication, such as "new information comes first," or "use the most specific applicable term."

There is much significant work being done in AI on theories of this sort, e.g., work on qualitative reasoning, modelling space and time, naive physics, logics of knowledge and belief, communication act theory, and so on.

The Inference Problem

The most important inference problem for user modelling is the following:

Given the observed behavior of the user, find the appropriate state of the model that accounts for the behavior.

Note that this is a very different problem from performing inferences using one of the commonsense theories just mentioned. In general, the latter is a deduction problem: find the consequences of a given theory. The inference problem for user modelling is inductive: from a pattern of behavior, induce the correct structure that produces the behavior. Much of the work in script- or frame-based systems addresses this problem. However I think it is a much more difficult inference problem, and deserving of much more intensive research.

USER MODELLING & PLAN RECOGNITION

N.S. Sridharan

A number of interesting and important questions have been raised for this panel. I wish to survey a small set of different tasks and show the diversity of responses possible depending on the characteristics of the task. I conclude by discussing a set of *task dimensions* which forms a framework for understanding, in a broad manner, the connections between tasks and user models.

I. Discussion of different domains

I.A Automatic prompting and simple help on workstations

An implicit assumption is made that the user may wish to know some information relevant to the command to be issued; and that it wont hurt to display such information automatically. A sketchy finite state machine model can be used compute allowable actions, allowable operands and a canned help text can be put up on the screen. No detailed user modelling is used.

I.B Tutoring introductory programming: (Elliott Soloway, Yale)

There is an intimate connection between plan recognition and user modelling. In fact, not viewing user-modelling as *plan recognition* has hampered progress in this field. The student must be seen as trying to follow a plan; a program that is being constructed is a realization of a plan. What the student is trying to accomplish, his goal is important; *goal recognition* is an important problem. An approach using bug catalogs or plan catalogs is inherently limited. That kind of approach will not go beyond small and simple programs. Plan recognition must be viewed as a constructive task; *plan revision* approach is very important. It will be not enough to think of selecting a user plan from a finite set of pre formed plans. (For approaches to student modelling in tutoring domains where strong assumptions can be made about the student s goal at any stage, see the earlier section *Student Models in Intelligent Tutoring Systems.)*

I.C Sensor signal interpretation: (C.F. Schmidt, Rutgers)

The problem arises in connection with an interactive system to assist in interpreting multiple unreliable sensor signals. An implicit user model is used to effect (offline) tailoring of the system. Only the pragmatic consequences of accepting a model of user needs to be represented. The model used need only be accurate enough to predict the right actions; that is, the model is viewed only in terms of it implications for the system.

I.D Pilots assistant: (Dick Pew, BBN)

In automating the cockpit display for a military aircraft, it is clear that the display function must be customized to the user. However, in this domain, plans of pilots can only be defined is vague terms; e.g. as phases of a mission, and a conditional set of responses plus model of goals to maintain their priorities. The pilot is operating in an extremely dynamic situation, and operates generally by adopting *opportunistic behavior* and *reactive behavior.* In this domain it appears that the user model is better structured in terms of *attributes* such as focus of attention, span attention, attention switching speed, memory limitations, speed of observation and assimilation.

I.E Natural Language Dialog systems (Candy Sidner and Jim Schmolze, BBN)

Question-answering systems often limit themselves to dealing with individual questions separately; whereas, dialog systems attempt to include the context of the dialog so far. An important aspect of such contexts is a model of the user's intentions, capabilities, beliefs, knowledge, and preferences. Formation of such a model is viewed as an *incremental process.* Understanding communication requires accessing/hypothesizing the intentions. This process is one of forming a hypothesis, and thus is *inherently* error-prone. The process used should be robust enough to recognize errorful hypotheses and to take steps to rectify them.

I.F Office automation task: non-linguistic, non communicative domain (Vic Lesser, U of Mass.)

The user is engaged in a task such as filling out a purchase order for equipment. The system is watching over his shoulders, so to speak, and attempting to guide the user. The user may be in error; the system is watching to predict and correct the steps taken by the user. Plan recognition relies mostly on domain-based heuristics; and is less dependent on modelling the user, his beliefs or plans. This is because the goal is to get the task accomplished rather than to train or educate the user.

II. Framework for discussion of user modelling

Very simple user models suffice for a number of tasks. In spelling correction a simple model of user errors, rather than plans, can be immediately helpful. In detecting errors in novices' program, a model of errors made frequently by novices, not their plans, may be very useful.

The attempt here is to set up a framework for exploring the analogies portrayed below.

- User customization <> Prediction, correction .modification
- User models <> Plans incorporating beliefs, intentions and goals
- User modelling process <> Plan recognition

The purpose of the framework to be developed is to answer questions like: how complex should the user model be? what characteristics of the task are relevant in deciding how to acquire and use such user models?

Dimensions to consider and evaluate in exploring this analogy

1. Richness of response space: Assuming that the model is to guide a suitable action from a repertoire of actions, the user model must be (just) rich enough to guide choice of response, but should be minimal. If the potential responses are not diverse the model can and should be quite simple.

2. Static vs Dynamic customization: It is useful to consider whether the programmer is customizing the program to the user, or whether the system is adapting itself. Static customization may lend itself to implicit user models.

3. Who bears responsibility? system or user?: How complicated can the system become? In an interactive situation, the user will be formulating a model of the system, while the system is modelling the user. If the system is simple enough, the user may be willing to take responsibility for his own actions, since he can more readily form a model of the system. If the system is taking the responsibility for overall behavior, then the system should model the user accurately. (Black box vs Glass box issue)

4. Risk or penalty for being wrong: Plan recognition and user modelling is inherently error-prone, being an inductive task. One must judge the consequence of this. If the penalty for using a wrong hypothesis is high, one must either not attempt to model the user or be in a setting where interactive *verification* of such hypotheses is feasible.

III. What is user modelling? What is in a user model? There are different considerations that affect how one views the process of user modelling:

- Static vs Dynamic models (built-in vs acquired)
- Focus on immediate actions vs focus on eventual goals
- Deterministic vs probabilistic models
- Predictive vs descriptive models

Similarly one can imagine a variety of ways in which the user model is set up:

- Parameter models
- State machine model (compute allowable actions; has a sense of history)
- Recursive models (user's model of the system; system self-model)
- Plan-based models (has a sense of goal). Beliefs, intentions and knowledge attributable to the user. Often these can be integrated in the form of a plan plus a context in which these plan are likely to be executed. Preferences, which allows the user to make choices.

IV. When should user modelling not be done?

There are a number of tasks where attempting to formulate a user model dynamically is inappropriate. Firstly, in some situations, users are evolving. One must realize that human beings are very adaptable and can evolve more rapidly than the systems. Secondly, in some situations, users are not plan following, especially if a user does not know what he wants. It is futile to model fickle human beings. Thirdly, in some situations the user may not know what the system can do. In such situations, a user lacking knowledge may only get confused if the system beings to alter its behavior. Fourthly, in some applications the boundaries of responsibility between system and user may be shifting. For example, the user may wish to issue standing order;, thus causing the system to do some things routinely; or the user may wish to take away from the system certain tasks because the system too slow or unreliable. A highly interactive operating system, such as the TOPS 20, makes it quite difficult to write script files for automating certain functions - scripts cannot adequately substitute for a human user.

V. Summary:
There is a number of problems where simple models work reasonably well; there are a number of problems where plan recognition is a challenge and can be made to work well if the assumptions about the user and task domain hold; there are task domains where the penalty for being wrong is high and the acceptable complexity of the model is low, that other techniques should be profitably be pursued.

VI. Conclusion:
Plan recognition, especially a constructive process that incorporates techniques for plan revision in addition to plan hypothesizing, see Schmidt, Sridharan & Goodson (1978), is a *fundamental* problem for Artificial Intelligence. This problem deserves the same kind of effort that has been devoted to plan generation. The plan recognition problem is full of interesting challenges and intellectual surprises. It ought to be pursued earnestly and seriously. Yet, in thinking of applications, one must be careful to use a suitable framework to decide what kind of user models and what type of user modelling process are best to adopt.

SUGGESTED READINGS

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