Tailoring Explanations for the User[1]

Kathleen R McKeown
Dept of Computer Science
Columbia University
New York, NY 10027
212-280-8194
MOKKOWN@COLUMBIA-20

Myron Wish
AT&T Bell Laboratories
600 Mountain Ave
Murray Hill, N.J. 07974
201-582-7630

Kevin Matthews
Dept of Computer Science
Columbia University
New York, NY 10027
212-280-8180
MATTOCOLUMBIA-20

Abstract

In order for an expert system to provide the most effective explanations, it should be able to tailor its responses to the concerns of the user One way in which explanations may be tailored is by point of view A method is presented for representing the knowledge to support different points oi view in the current domain In addition, we present a method for determining the point of view to take by inferring the user's goal within a brief discourse segment The advising system's response to the derived goal depends on the strength of its belief in the inference for which a method of determination is also provided This information enables the system to decide what answer to give to a question, which kind of justification is relevant, and when to provide it Some details of the current implementation are included

1 Introduction

While research on explanation for expert systems has addressed some important issues in identifying the kind of knowledge needed to provide acceptable explanations (eg, Swartout 81, Clancey 79), one main problem with existing systems is their inability to iailor an explanation adequately to the needs or perspective of a particular user In this paper, we show now information about the current user can and should influence the type of explanation provided

In past artificial intelligence research, there have been two main approaches to user modelling classifying users according to *a priori* types often by direct interrogation (e.g., Rich 79, Swartout 81, Wallis 82) or deriving information about the current state of the user's goals, beliefs and desires from the ongoing discourse itself (eg, Allen and Perrault 80, Carberry 83) Our work draws from the second of these two main approaches, but while previous research has emphasized the derivation of a user's goal in order to interpret an utterance correctly, we are interested in making use of derived goals to generate appropriate explanations This difference in emphasis has required the development of techniques for handling four specific tasks representing different points of view in a knowledge base to support different explanations, identifying *which* of several possible goals underlying the current discourse should be addressed, determining *when* the derived goal should be taken into account, and specifying *how* a generation system can relate the derived goal to different points of view to determine explanation content This extends Allen and Perrault's (80) approach by showing how a goal can be derived to represent a sequence of utterances as opposed to a single utterance, and goes beyond Carberry's (83) approach by showing how a system can decide to respond to such goals

The work described in this paper was partially supported by ONR grant NOOO14-82-K-0256 and by AT&T Bell Laboratories.

This work is being done within the context of an ongoing project to develop a dialogue facility for computer-aided problem solving A student advising system is being developed which can provide information about courses and advice about whether a student can or should take a particular course The system is currently structured as a question-answering system which invokes an underlying expert system on receiving "can" questions (e.g., "Can I take natural language this semester?") and "should" questions (e g , "Should I take data structures?") This production system uses its rule base to determine the advice provided (i e , *yes* or *no)* and the trace of rule invocations is used to provide a supporting explanation of the advice

The Advisor system consists of an ATN parser (Woods 70), a KL-ONE knowledge base (Brach man 79) with access functions, a goal Inferencer, an underlying production system, and a surface generator to produce responses and explanations in natural language (Derr and McKeown 84) Currently the system can produce responses to information questions by accessing the knowledge base and to "can" questions by invoking the underlying production system Certain ' aspects of response generation and inferencing for should" questions have been implemented

In the following sections, we first show the different types of explanations required and then describe in some detail the techniques we have developed

2 Different Explanations

In this paper, we focus on how the content of an explanation must vary according to the perspective or point of view taken on the underlying problem domain For example, in the student advisor domain there are a number of points of view the student can adopt for selecting courses It can be viewed, among others, as a process of meeting requirements (1 e , *"how do courses t:e in with requirement sequencing?*'), as a state model process (i e , *what should be completed at each state in the process?'),* as a semester scheduling process (i e , *"how can courses fit into schedule slots?* '), or as a process of maximizing personal interests (as in *"how will courses help me learn more about* Al ?') Given these different points of view, alternative explanations of the same piece of advice (i e *yes)* can be generated in response to the question, *"Should I take both discrete math and data structures this semester?"*

1 Requirements Yes, data structures is a requirement for all later Computer Science courses and discrete math is a co-requisite for data structures
2. State Model: Yes, you usually take them both first semester, sophomore year
3 Semester Scheduling: Yes, they're offered next semester, but not in the spring

and you need to get them out of the way as soon as possible

4 Personal Interests (e.g., AI.) Yes, if you take data structures this semester, you can take Introduction to AI next semester, and you must take discrete math at the same time as data structures

One of these explanations may be more appropriate than others depending upon the user's goal in pursuing the dialogue For example, we might supply explanation (1) above if the users goal were to complete requirements as soon as possible and explanation (2) if the user's goal were to keep apace with the normal rate of progress Thus to address the problem of selecting a perspective to use in an explanation, we must develop techniques that allow a system to infer a user goal from a discourse segment as well as techniques that can indicate information that is relevant for any given perspective

3 Knowledge Representation

In order to identify information that is relevant to a user's goal, we are using intersecting multiple hierarchies to represent different points of view in the underlying knowledge base The hierarchies are cross-linked by entities or processes (often courses in the student advisor domain) which can be viewed from different perspectives (and thus occur in more than one hierarchy) Hence to construct the content for explanation (1) above the system would extract information about the relation between data structures and discrete math from the *requirements* hierarchy, and for explanation (2) extracts information from the *state model* hierarchy A diagram of a portion of these two hierarchies containing information for the two points of view is shown in Figure 1 below.

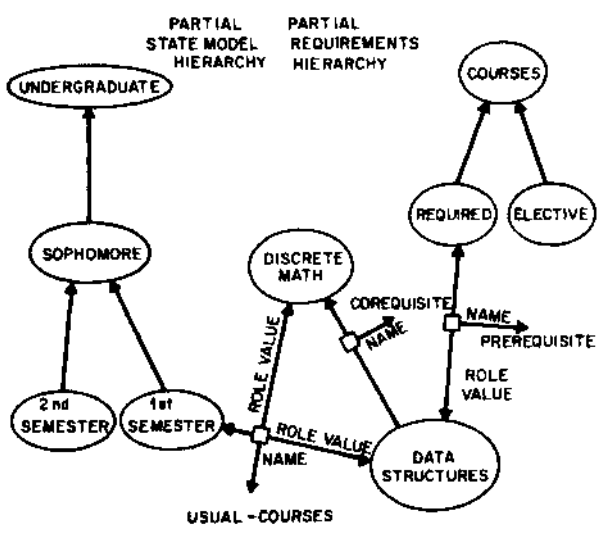


Figure 1: Representing Points of View

The partitioning of the knowledge base by intersecting hierarchies allows the generation system to distinguish between different types of information that support the same fact From this partitioning, the system ran select the portion that contains the information relevant to the current request and user goal

4 Deriving the User Goal

The system must also be able to reason about the appropriateness of one perspective versus others Since the perspective taken is related to the user's goal in pursuing the dialogue, the large body of work on goal inference techniques (Allen and Perrault 80, Carberry 83, Litman and Allen 84) is applicable for deriving the user's goal We have drawn heavily from Allen and Perrault's (80) work, making use of their plausible inference rules, representation of domain plans, and representation of speech acts as plans While their work has been extremely useful, it falls short for our purposes in several ways For example, their inferenerng procedure derives a plausible? goal for a user based on a single utterance, while we are interested in deriving a goal based on the current sequence of utterances[2]

Consider the discourse shown in (6) below Assuming that a database of domain plans common to the student advising domain is maintained, Allen and Perrault's techniques could be used to derive the domain goal shown following each question But the explanation shown in (6c) addresses not the derived goal of (6c), nor any of the derived goals of the previous utterances but instead addresses the higher level goal indicated by the derived goals of (6a) and (6b) The problem for responding to such goals in an explanation, then, is to be able to derive a higher level goal relating the goals of individual utterances

6a S I've read about the field of AI and I'm interested in learning more about it eventually Is natural language offered next semester?
Plausible goal = take natural language

A Yes.

b S Who is teaching artificial intelligence?
Plusible goal = take AI

A Lebowitz this semester

e S I haven't taken data structures yet Should 1 take it this semester?
Plausible goal = take data structures

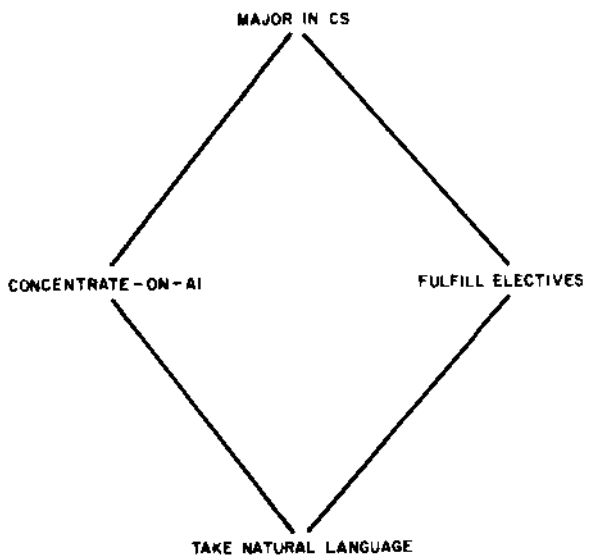
A Yes, if you take data structures this semester, you can take AI next semester which is necessary for all later AI courses

We use Allen and Perrault's rules to derive the domain goal of each individual utterance, which we term the *current goal* We also identify a goal representing the discourse sequence which we term the

[2] "In this work, we restrict ourselves to a discourse segment that deals with a single or related set of goals. Over a longer sequences of discourse, topics may shift and the user may reveal very different goals across such boundaries. Detecting topic shifts and radical changes in goals is a difficult problem that we are not addressing.

relevant goal since it will bo used to generate later explanations Intuitively, the relevant goal is a higher level goal, if there is one, relating the goals of several utterances

The process of determining the relevant goal involves the following steps The current goal is first derived from the initial utterance All higher level domain goals are then derived from the current goal using Allen and Perrault's *body-action* inference rule fie if the user wants a step in the body of a plan to hold it is plausible that s/he wants the action to hold) Any one of these is a candidate for the relevant plan A derivation of the higher level plans for the utterance "Is natural language offered next semester?" is shown in Figure 2 Note that the action take natural language is a step in two separate plans, concentrate-on-ai and fulfill electives, and thus two parent paths are formed

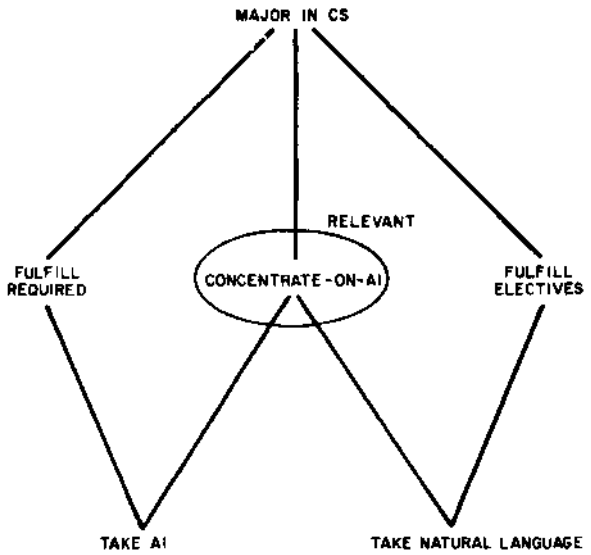


"Is natural language offered next semester?"

Figure 2: Current and Higher Level Goals for Utterance 1

When the second utterance "Who is teaching artificial intelligence?" is entered, the current goal take ai is derived and all higher level goals derived (see Figure 3) from that using the body-action rule The lowest level node where the two paths intersect becomes the relevant plan (concentrate-on-ai in this case). If the second utterance had been "When is operating systems offered?," the higher level goal fulfill electives would have been inferred since this is the only relation between the goals take operating systems and take natural language

This method is essentially a search for the lowest common ancestor of the current goals of two



1 "Is natural language offered next semester?"
current goal = take natural language
2 "Who is teaching artificial intelligence?"
current goal = take ai
relevant goal = concentrate-on-ai

Figure 3: Relevant Goal for Utterances 1 and 2

consecutive utterances When the third, or any subsequent utterances are encountered the relevant goal is determined by performing the search for common ancestor using the previous relevant goal and the current goal of the new utterance

Carberry (83) does present a method for tracking user goals over a sequence of discourse, building in the process a hierarchical model of user plans for the discourse She uses this hierarchy and a set of focus heuristics to determine for the next incoming utterance which of several plausible plans the user could be focusing on She does not specify which plan in the hierarchy best represents the overall discourse purpose and therefore should be addressed in succeeding explanations Our model thus augments hers by providing this information

5 When to Respond

The goal inference techniques just described allow the system to infer what a user's goal *might* be, but this inference may be so tentative that explanations which always address such goals will be as undesirable as those that never take a goal into account Allen and Perrault themselves term their rules *plausible* inference rules since the goals they attribute to the user are only possibilities and not definite However, goals derived from some discourse sequences seem intuitively more definite than those derived from other sequences

If the user directly asserts his/her goal fas in 7)

then it can be definitely inferred The plausible inference rules however, will infer the same goal for an utterance like that shown in (8) Unless we have further indication that the user actually has the goal take natural language, then on receiving a follow-up question such as (9a), a neutral explanation as shown in (9b) is preferable to the tailored explanation in (9c) One problem for a system that generates tailored explanations, then, is being able to determine *when* to respond to a derived goal

7 S I'm planning on taking nip in the future What are the prerequisites?
plausible goal = take natural language

8. S Is natural language offered this semester"
Plausible goal = take natural language

9 a S I'm thinking of taking computability this semester Would that be a good idea?
plausible goal = take computability

b A Yes, it's your last requirement and it's a good idea to get it out of the way before going on to electives

c A Yes, computability is particularly important for nip since it covers grammars so it's a good idea to take it first

To handle this problem we use three levels of likelihood of derived user goals If we can distinguish between derived user goals that can *definitely* be attributed to the user, derived goals that are *likely,* and derived goals that are only *plausible,* then we have a basis for determining when to generate tailored explanations Tailored explanations can be generated for *definite* and *likely* goals and a neutral explanation generated for *plausible* goals

A goal is *definite* if a user states that s/he has that goal, as in I want to concentrate in AI", "I'd like to concentrate in AI", or "I'm interested in taking as much AI as possible" If not stated, it is difficult to infer without doubt that a user has a given goal, but there are cases where it is more *likely* than others Space prohibits providing details, but we note that a goal is more likely if it has been repeatedly derived From consecutive utterances as well as in cases where it is one step in a plan that the user has partially completed The system is currently capable of deriving current and relevant goals for a discourse segment and classifying them as *plausible* or *definite* Classification of coals as *likely* has been designed, but must still be implemented

We have ignored, in this paper, the possibility of responding in other ways than providing explanations In some cases, in fact, it may be preferable for the system to ask the user to clarify his/her goal or to take the initiative in some other way Determining when and how to take the initiative as an alternative to providing explanations is a topic addressed elsewnere (see Matthews 85)

6 How to Respond

Finally, the system must be able to make use of the derived goal in constructing an explanation when a "should" question follows a dialogue sequence The underlying mini production system, consisting of working memory, rule base, and inference engine, is invoked in this process

To construct the explanation, the hierarchy representing the proper perspective is determined directly from the relevant goal, and information retrieved about the questioned object[3] from that hierarchy is placed in working memory The production system uses this information to derive the response, that is whether the user should or should not pursue the queried action The trace of the reasoning is then available to provide the basis for the explanation, as is the case in traditional expert systems Note that the information extracted from one hierarchy will allow a different set of rules to fire than will information extracted from another, thus producing different explanation content

As an example, consider again the question "Should I take both data structures and discrete this semester?" Assume that the system has determined that the user's goal is take required and that the goal should be taken into account in the explanation After deducing that the student *can* take these courses , the production system will attempt to prove that the queried action helps the user achieve his/her goals The information shown in Figure 4, extracted from the requirements hierarchy (refer back to Figure 1), enables rules 1 and 2 to fire with Tx instantiated as data structures, ?y as discrete math, and ?course as required The extracted fact that discrete math is a co-requisite for data structures enables rule 2 to fire Its consequence and the extracted fact that data structures is a prerequisite to required enables rule 1 to fire, which concludes that required can be taken Thus, the advice is *yes* since take required is the user's goal and these two instantiated rules can then be used as the basis for the hypothetical explanation given earlier and reproduced in Figure 4 Other rules in the rule base (such as "A course should be taken if the student is at the right year to take it") do not fire since information necessary to fire that rule does not exist in working memory This processing is partially implemented, but much work is needed before the full explanation can be produced

[3] The Questioned object is the course the user is inquiring about (e.g., data structures in "Should I take data structures? ").

Regardless of whether the user's queried action helps him/her achieve the relevant goal, if it is not permissible or will prevent the student from completing the major, the advice is always negative. Rules encoding such absolute constraints include "a course cannot be taken before its prerequisite", or "a course should not be taken if it prevents the student from completing requirements by the time s/he is a senior". Here, we assume, for convenience, that the student has already taken the prerequisites to data structures and discrete math and is early enough in his/her program that s/he will be able to finish on time, and thus the absolute rules are satisfied.

Information Extracted

(prerequisite required data-structures)
(co-requisite data-structure discrete-Bath)

Rule 1

(takes ?x) and (prerequisite ?course ?x) —> (can-take ? course)

Rule 2

(co-requisite *tx ?y)*
and
(taking ?y) —> (can-take Tx)

Yes, data structures is a requirement for all later Computer Science courses and discrete math is a co-requisite for data structures

Figure 4: Constructing Explanation Content

7 Future Directions

More research is needed on explanation, plan recognition and user modelling for our approach to be effective for a broad range of human-computer dialogue As for explanation, in the current implementation the production system needs to be developed further and its reasoning trace interfaced to the operational surface generator for English output On the theoretical side, we are investigating the use of discourse strategies to control the organization of the explanation Tne plans in the current implementation were selected by examining transcripts of actual student advising sessions, but it would be desirable to have a much larger set of plans knowledge about their base rates and importance, ana additional criteria for tracking their relevance and likelihood during the interaction It seems likely, also, that better explanations will require a more complete user model incorporating static, global characteristics of the user as well as those dynamic, local characteristics available from the ongoing dialogue itself Additionally, while we have touched on one way of representing and using point of view, others will doubtless be necessary Such a comprehensive attack on the topics of explanation, plan recognition, and user modelling offers promise from both a theoretical and practical perspective

8 Conclusion

We have demonstrated the need for tailoring explanations to users in consultative or problem solving dialogues with a computer, and have addressed this problem with a new approach integrating research in plan recognition, user modelling, and explanation generation Derivation of goals or plans is based on an extension of Perrault and Allen's (80] work which handles discourse segments rather tnan isolated utterances Our model and implementation provide mechanisms for assessing which goal is relevant to the user at any moment during, the discourse, as well as when that point of view snould be addressed in an explanation It also makes progress toward the determination of how to tailor the explanation to the user's goal In addition to enhancing previous work on goal inferencing, this report shows now research in natural language processing on goal derivation can be applied to generate explanations sensitive to the user's current perspective in expert system interactions

Acknowledgments

We would like to thank Michael Lebowitz for his suggestions on an earlier draft of this paper

References

(Allen and Perrault 80) Allen, J F and 0 R Perrault, "Analyzing intention in utterances," *Artificial Intelligence 15,* 3, 1980

(Braehman 79) Brachman, R , "On the epistemological status of semantic networks " in N Findler (ed) *Associative Networks: Representation and Use of Knowledge by Computer,* Academic Press, N Y , 1979

(Carberry 83) Carberry, S , Tracking user goals in an information-seeking environment, in *Proceedings of the National Conference on Artificial Intelligence,* Washington D C , August 1983, pp. 59-63

(Claneey 79) Claneey, W J , Tutoring rules for guiding a case method dialogue, *International Journal of Man-Machine Studies 11,* 1979, pp 25-49

(Derr and McKeown 84) Derr, MA and K R McKeown, Using focus to generate complex and simple sentences, *Proceedings of COLING-84: Tenth International Conference on Computational Linguistics,* Stanford, July 1984, pp 319-26

(Litman and Allen 84) Litman, D J ., and J.F. Allen, A plan recognition model for clarification subdialogues, *Proceedings of COLING-84: Tenth International Conference on Computational Linguistics,* Stanford, July 1984, pp 302-11.

(Matthews 85) Matthews, K , Initiatory and reactive system roles in human computer discourse, unpublished manuscript, AT&T Bell Laboratories, 1985

(Rich 79) Rich, E A , User modelling via stereotypes, *Cognitive Science,* Vol 3, 1979, pp. 329-54

(Swartout 81) Swartout, W.R , Producing explanations and justifications of expert consulting programs, Technical Report MIT/LCS/TR-251, MIT, Cambridge, Mass , January 1981

(Wallis 82) Wallis, J.W. and EH Shortliffe, Explanatory power for medical expert systems-studies in the representation of causal replationships for clinical consultation Technical Report STAN-CS-82-923, Stanford University, 1982

(Woods 70). Woods, W A , "Transition network grammars for natural language analysis" *Communications of the ACM,* Vol 13, No 10, October, 1970, pp 591-606