Discourse Initiative: Its Role in Intelligent Tutoring Systems

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Abstract

Research suggests that a student who is actively involved in the learning process has a higher rate of achievement than does a student who is merely a passive recipient of information. Active learning implies that the student will occasionally take the discourse initiative and attempt to shape the information provided by the instructor. However, relatively little attention has been given to the role of discourse initiative in intelligent tutoring systems. This paper argues that intelligent tutoring systems must allow for more initiative on the part of the student.

Introduction

Over the past several years, researchers in natural language discourse have been grappling with the issue of discourse initiative. In the early days of natural language information systems, the user could ask questions or request advice and the system addressed the user's goals by providing the requested information. This has been characterized as a *master-slave* relationship(Grosz & Sidner 1990); in the case of natural language information systems, the user was the master and the system slavishly responded to the user's requests. Grosz and Sidner(Grosz & Sidner 1990) argued for a collaborative approach to discourse. More recently a number of researchers, including (Guinn 1996; Novick *et al.* 1996; Walker & Whittaker 1990; Whittaker & Stenton 1988), have investigated the issue of initiative in problem-solving discourse.

However, relatively little attention has been given to the role of discourse initiative in intelligent tutoring systems. This paper argues that intelligent tutoring systems must allow for more discourse initiative on the part of the student. It presents several examples of discourse initiative that would be typical of training in a medical domain, proposes four hypotheses relating to discourse initiative in intelligent tutoring systems, and discusses some of the issues that must be addressed. Finally, it concludes with a brief description of our current research in this area.

Discourse Initiative in Intelligent Tutoring Systems

Intelligent tutoring systems have been designed to reflect how humans tutor one another. Researchers have studied the types of tutorial strategies used by human tutors and the kinds of responses that they generate. For example, researchers have examined different pedagogical strategies(Reiser 1989; Graesser 1993), the kinds of questions human tutors ask(Woolf 1984), how negative acknowledgements are conveyed (ie., how the student is told that his response is incorrect in some way)(Evens *et al.* 1993), and the form in which human tutors provide hints(Hume *et al.* 1993). The results of these studies have been captured in many intelligent tutoring systems, where the emphasis has been on following good pedagogical strategies, generating good explanations of concepts, and responding appropriately to student answers.

On the other hand, current tutoring systems do not accommodate, much less take advantage of, the many ways in which students can respond during training. With relatively few exceptions, it is assumed that the system or tutor will unilaterally determine what parts of the domain are explored, the order in which topics are addressed, and the way in which information is presented. Thus the master-slave relationship(Grosz & Sidner 1990) is evident in tutoring systems, only in this case it is the reverse of the situation that existed in early natural language systems: namely, in tutoring systems, the tutor is the master and controls the dialogue, presenting explanations and asking questions; the student must slavishly respond as directed by the tutor and is for the most part limited to conveying lack of understanding of an explanation or providing a short answer to a question.

A student who is actively involved in the learning process can collaborate with the instructor on the information that is exchanged and improve the effectiveness of the tutorial interaction. When a student already has considerable knowledge of the domain or of a related domain, the student will apply his or her existing knowledge to the information conveyed by the instructor and attempt to assimilate it into a coherent

whole. However, knowledge deficiencies or misconceptions may hamper the student. For example, a student may fail to immediately accept the instructor's statements, not because the student believes that the instructor is wrong but because the student is unable to consistently integrate the instructor's statements into his existing knowledge base. Since each student is different, the instructor cannot predict on her own when such problems will arise, the source of the difficulty, or how best to remedy the situation. On the other hand, the student may have some idea of where his knowledge base is inconsistent or appears incomplete in some way (perhaps missing links, insufficient support, etc.). Since neither instructor nor student have complete knowledge of the domain and of the student's existing knowledge base and how the student's cognitive processes will incorporate new information into it, learning should improve if instructor and student collaborate on the content and direction of the tutorial dialogue.

Thus student initiative is very important in order to allow the student to raise conflicts with the instructor's statements, to pursue questions in an attempt to clarify his (the student's) knowledge base, and to identify problem areas and sources of misconceptions. Intelligent tutoring systems will never reach their full potential unless they have the discourse capability to take advantage of such student input.

Sample Interactions

Researchers at the University of Pennsylvania and the Medical College of Pennsylvania have developed a decision support system, TraumAID, for addressing the initial definitive management of multiple trauma(Webber, Rymon, & Clarke 1992). Initial evaluation and validation studies indicate that TraumAID produces high-quality plans for managing patient care in both simple and complex trauma cases(Gertner *et al.* 1997). TraumAID's three part knowledge base is encoded declaratively and contains extensive medical knowledge related to trauma care. It includes 1) evidential rules that derive further conclusions from existing evidence, 2) goal setting rules that post goals based on accumulated evidence, and 3) two sets of mapping rules that either map goals onto alternative procedures that can be used to satisfy the goal or map procedures onto an ordered set of actions for performing the procedure. TraumaTIQ(Gertner & Webber 1996) is a plan analysis and critiquing module that compares the user's actions with the diagnostic and therapeutic plan constructed by TraumAID and critiques errors in the user's actions.

We have recently begun collaborating on the use of TraumAID and TraumaTIQ in the development of a system for training medical students in handling emergency room trauma and for training medical corpsmen in handling battlefield trauma. Such training situations have the characteristic that the student may already have some expertise in the domain or may bring to the training situation knowledge from a related area. The following dialogues illustrate a kind of student initiative that can occur in such situations and the kinds of problems that must be addressed if such discourse initiative is to be allowed in intelligent training systems.

Dialogue-1:

Patient has been diagnosed as having a tension pneumothorax as a result of a stab wound to the chest, and the patient is still in shock despite chest decompression.

Instructor:	*"You need to get an xray of the abdomen in order to rule out an intra-abdominal injury."*
Student:	*"But the bullet went into the chest."*
Instructor:	*"Yes, but since the diaphragm extends into the chest cavity, a bullet wound in the lower chest can produce an intra-abdominal injury."*

In the above dialogue, the instructor notes the need to get an xray of the abdomen to rule out an intra-abdominal injury. However, the student responds that the patient has a bullet wound in the chest. Note that although this is a simple statement, it clearly conveys a source of conflict for the student in accepting the instructor's suggestion. The instructor then goes on to explain why a chest wound might produce an intra-abdominal injury. Note that although the student has substantial medical knowledge, he has a misconception about human anatomy[1] that prevented him from accepting the instructor's response.

Dialogue-2:

Patient has a possibility of abdominal bleeding.
Student chooses to do a lavage.

Instructor:	*"You should be doing a CT scan to assess the possibility of abdominal bleeding."* *"Can you determine why?"*
Student:	*"[But] isn't a lavage less expensive?"*
Instructor:	*"Yes, but in this case the patient has abdominal scarring so a lavage is contra-indicated."*

In this second dialogue, the student has chosen to do a lavage and the instructor suggests that the student

[1]Several medical faculty have commented that misconceptions about anatomy account for many of the errors made by medical students.

should be doing a CT scan instead. Instead of explaining why a CT scan would be preferable, the instructor attempts to elicit potential reasons from the student. However, rather than answering the instructor's question directly, the student expresses his surprise that the lavage is not the correct procedure — note that the way in which this is done is by asking what we call a surface-negative question, namely *"But isn't a lavage less expensive?"* The clue word *but* helps to convey the dialogue act that the utterance accomplishes, namely expressing doubt, but it could be omitted. Moreover, a surface-negative question can be used for other purposes than to express doubt, as shown by the following utterance in which the student suggests an answer to the instructor's question: *"Isn't a CT scan used when there is abdominal scarring?"*

Dialogue-3:

Instructor:	*"You need to do an ultrasound of the heart since there is pressure on the heart ."*
Student:	*"Wouldn't there be distended neck veins?"*
Instructor:	*"Normally, pressure on the heart would result in distended neck veins. But in this case, there has been bleeding which has countered the neck vein distention."*

In Dialogue-3, the instructor tells the student that he should do an ultrasound of the heart because of pressure on the heart. The student expresses his surprise or doubt at the existence of pressure on the heart, once again using a surface-negative question that identifies the student's source of conflict, namely *"Wouldn't there be distended neck veins?"* Note that in this case the student is expressing doubt at the condition motivating the recommended procedure (underlined in Dialogue-3), not at the recommended procedure as was the case in Dialogue-2.

Dialogue-4:

Instructor:	*"You need to get a chest xray to rule out a simple pneumothorax."*
Student:	*"Don't decreased breath sounds and distended neck veins suggest a tension pneumothorax?"*
Instructor:	*"No, not by themselves. The patient would also need to be in shock. In this case, ..."*

In all of the previous dialogues, the student has basically been correct about the truth of the queried proposition but wrong about his belief that it conflicts with the information provided by the instructor. Dialogue-4 illustrates an instance in which the proposition that the student is contending to be true is in fact false.

Dialogue-5:

Instructor:	*"You need to do a needle aspiration to rule out a tension pneumothorax."*
Student:	*"But won't an xray show both a tension pneumothorax and a herniated diaphragm?"*
Instructor:	*"In this case, there is no reason to suspect a herniated diaphragm since the stab wound is in the upper chest."*

In our previous dialogues, the student expressed doubt at the adoption of a particular goal, the appropriateness of a procedure for addressing a particular goal, or the presence of the condition motivating the recommended procedure. In Dialogue-5, the student does not disagree with a needle aspiration being the recommended procedure for ruling out a tension pneumothorax nor with the possibility of the patient having a tension pneumothorax; instead, the student believes that there are two conditions that must be considered, a tension pneumothorax and a herniated diaphragm, and that an xray would be a more efficient way to diagnose both. Thus the student's conflict derives from both his meta-knowledge about efficient planning and his domain knowledge about appropriate procedures.

In each of these dialogues, the student has taken the initiative, though in a way that perhaps has not been viewed as *initiative* in most previous work. Instead of merely responding to a question from the system or indicating understanding of the system's response (or lack of understanding by saying something such as *Huh?*(Moore 1995)), the student attempts to take temporary control of the dialogue and lead it in a direction that will help resolve his conflicts.

What Kind of Initiative?

A few researchers have considered student responses and discourse initiative in intelligent tutoring systems. The earliest such efforts involved the explanation capability of MYCIN(Davis 1982) and its use in the tutoring system GUIDON(Clancey 1987), where the student could ask *Why?*. However *Why?* is by itself an inadequate mechanism for the student to frame his contributions to the collaborative learning effort.

More recent research has considered other examples of discourse initiative in tutorial interactions. For example, research on the CircSym tutor(Evens *et al.* 1993) considered student initiative; their system handled direct questions such as a request for explanation of a concept and statements that a concept was not understood (thus indirectly requesting further explanation). Freedman(Freedman 1997) describes the current approach of CircSim to student initiative, and

Shah and Evens(Shah & Evens 1997) provide a classification of student initiative in terms of surface form of the utterance, communicative goal, content area, and degree of certainty.

Cawsey also handled requests for explanation of a concept(Cawsey 1993). Her research addressed the issue of whether to relinquish control by considering whether the system's discourse plan would address the student's question and whether the system's agenda could reasonably be altered to deal with the student's question at this point in the dialogue.

In the Duke Programming tutor, Biermann and Guinn implement a model of dialogue that allows for variable initiative(Biermann *et al.* 1997). Their theory of dialogue permits different settings for level of initiative, ranging from strongly directive (where the system considers only its own approach to problem-solving) to very passive (where the system does whatever the user wants). The system can handle general requests for information (such as *"What is wrong with my program?"*) and simple requests for further explanation.

Since all of these research efforts focused on simple requests for clarification, explanation, or elaboration of a concept, they have addressed only a few of the ways in which a student can attempt to shape the tutorial dialogue.

A study of human one-to-one tutoring(Person *et al.* 1994) suggests that students are to some extent capable of *self-regulating* their learning by addressing their knowledge deficits via questions. This study also found that most of the questions arising from attempts to address knowledge deficits resulted from contradictions or anomalies that the student could not adequately explain away. This is exactly the kind of student initiative illustrated in the above dialogues, but current tutoring systems do not account for it. Moreover, it appears that when the student already has considerable knowledge of the domain, this may be exactly the kind of initiative that has the greatest impact on the student's mastery of the subject.

Four Hypotheses About Discourse Initiative in Training Systems

We are currently beginning to investigate four hypotheses:

1. The degree to which a student will take advantage of the opportunity for initiative in a tutoring dialogue is a function of the student's existing knowledge of the domain or closely related domains.
2. Student initiative can help an intelligent tutoring system identify and correct misconceptions and knowledge gaps that might otherwise go undetected.
3. Allowing student initiative will improve learning in many situations.
4. Prohibiting student initiative will result in student frustration and dissatisfaction with the tutoring system.

Hypothesis-1: Students ask more questions during tutoring than during classroom instruction. In one study, Graesser(Graesser & Person 1994) found that 29% of student questions were attempts to correct knowledge deficits. 79% of these questions resulted from conflicts that the students could not explain and 17% resulted from knowledge gaps that the student had recognized. However, studies of classroom instruction have found that students fail to recognize deficits in their knowledge unless they have significant domain expertise. Thus we hypothesize that students with greater knowledge of the domain or a closely related domain will take more advantage of opportunities for initiative provided by an intelligent tutoring system, since they will be more likely to recognize their knowledge deficits and knowledge gaps. A corollary to this hypothesis is that the opportunity for student initiative is more important in the advanced stages of learning or when learning builds on knowledge in other domains.

Guinn(Guinn 1996) has argued that initiative in problem-solving domains is dependent on each participant's assessment of who has more domain knowledge. Thus if a participant believes that he can contribute most effectively to the problem-solving, he will take the initiative. However, the situation in tutoring differs somewhat in that the student does not take the initiative because he believes that he has a better approach to performing the task that is the subject matter of the tutorial, but rather because there exist inconsistencies in his knowledge base that prevent him from assimilating the information provided by the tutor. Thus while we might not be able to regard student initiative in the tutoring domain as the result of problem-solving at the domain level, we might be able to treat it as some kind of meta-level problem-solving or perhaps, as suggested by Guinn(Guinn 1997), as problem-solving where the problem is for the student to learn how to perform the task.

Hypothesis-2: Unfortunately, without help from the student, a tutor cannot identify an individual student's knowledge deficits. The tutor is limited to addressing typical gaps in knowledge and stereotypical misconceptions. This prevents the tutor from providing truly individualized instruction. In addition, Vygotsky(Vygotsky 1986) has argued that tutoring should be at the *zone of proximal development.* In other words, tutoring should concentrate on concepts that the student is ready to learn. When the student takes the initiative and identifies deficits, contradictions, and anomalies that are preventing his assimilation of the information presented by the instructor, the student is to some extent identifying what he is ready to learn and where tutoring should be concentrated.

Hypothesis-3 and Hypothesis-4: Researchers have suggested that tutoring is more effective than classroom instruction because of the opportunity for inquiry and self-regulation of knowledge deficits(Graesser & Person 1994). Thus we hypothesize that allowing (and

encouraging) student initiative will improve the performance of intelligent tutoring systems. In addition, we hypothesize that if students are able to identify their knowledge deficits, then they will become frustrated if they cannot temporarily take control of the dialogue and direct it to the source of their problems.

Problems to Address

In order to accommodate initiative in intelligent training systems, we are beginning to investigate the range of student responses in training situations and what they provide the instructor. One kind of discourse act that will be particularly important is an expression of doubt such as was illustrated in our sample dialogues, since such discourse acts are often used to convey difficulty in accepting a set of facts or an explanation. Furthermore, expressions of doubt may provide some evidence about the source of a misconception or conflict.

However, recognizing and responding to such discourse acts is not straightforward. For example, it is not always obvious when an utterance is expressing doubt; note that surface negative questions, ones that start with a negative contraction such as "isn't" or "won't", can also be used to seek verification or to suggest an answer to a question (as was illustrated in the discussion following Dialogue-2). Furthermore, it is not always obvious what is being doubted. For example, the sample dialogues illustrated situations in which surface negative questions were used to express doubt at 1) the appropriateness of a procedure for addressing a goal, 2) the adoption of the goal motivating the recommended procedure, or 3) the planning strategy that led to the recommended procedure.

In our previous work(Lambert & Carberry 1992a; 1992b), we developed an algorithm for recognizing discourse acts in which the speaker expressed doubt at a proposition by contending that some other conflicting proposition was true. This algorithm used contextual knowledge in the form of the existing dialogue model and the current focus of attention in it, world knowledge in the form of stereotypical beliefs, and linguistic knowledge in the form of clue words and the beliefs conveyed by the surface form of an utterance. However, our current system detects evidence of conflict by relying on world knowledge about stereotypical beliefs that agents generally hold. In the case of tutorial dialogues, we will need more sophisticated reasoning techniques to suggest evidence of conflict, and we are now beginning to investigate such strategies.

Conclusion

In this paper we have argued that current tutoring system research has focused on studying the responses of human tutors and incorporating these response strategies into intelligent tutoring systems. Consequently, such systems capture appropriate pedagogical strategies and can provide well-organized and coherent explanations, appropriately phrased negative acknowledgements, and hints. However, relatively little attention has been directed toward providing for the full range of ways in which students might profitably take the discourse initiative in intelligent tutoring systems.

We have presented four hypotheses that we are investigating regarding student initiative in systems for training students. In addition, we will be investigating the kinds of student responses that must be accommodated in order to facilitate student initiative, will be extending our work on recognizing discourse acts and producing appropriate responses(Chu-Carroll & Carberry 1995b; 1995a) to handling expressions of doubt in tutorial dialogues, and will be investigating effective control strategies. We contend that intelligent tutoring systems will not achieve their full potential until they provide for discourse initiative by the student and allow students to participate fully in their knowledge acquisition.

Acknowledgements

This work was supported by the National Library of Medicine under grant R01-LM-05764-01.

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