

Negotiating Goals in Intelligent Tutoring Dialogues¹

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Abstract : This paper describes research towards developing a cognitive model for the generation of negotiation phases in educational interactions. We describe a first prototype model for generating tutorial interactions in Intelligent Tutoring Systems (the 'KANT' system [5,6,7]), and perform a preliminary assessment of the extent to which it models the required phenomena with respect to analyses of a set of computer-mediated tutorial dialogues for teaching the programming language PROLOG. KANT is based on viewing the ITS as a *dialogue participant*, rather than as a 'domain expert' or 'tool'. It incorporates mechanisms for determining which of a set of dialogue goals to negotiate in a tutorial interaction and for deciding whether to cooperate in negotiation, based on a model for dialogue focus. Our critique with respect to dialogue transcripts aims to specify an agenda for future work, and concentrates on variations in turn-taking mechanisms with the propositional attitudes of speakers, the range of negotiable phenomena to be modelled, and the logical representation of mental states in negotiation.

Keywords : tutorial dialogue, tutorial goals, negotiation, conflict, cooperation, turn-taking, motivation

The problem of modelling negotiation

In this paper we aim to describe research directions for developing a cognitive model of how phases of negotiation in tutorial dialogues may be generated in Intelligent Tutoring Systems (ITS). Our discussion concentrates on negotiation of *dialogue goals* rather than negotiating beliefs in the domain. We argue that such negotiation phases fulfill important functions in tutorial dialogues, and that there is therefore a strong case that future ITSs should incorporate a model for their generation. If we look at previous work in ITS on modelling the teaching interaction [10,14,15,19,52], we find that negotiation as such is not addressed, which is not surprising given that none of this work aimed to include a model of "dialogue" in the sense where "... any agent must be regarded as both a producer and an understander, i.e. as a complete agent in interaction with some other complete agent(s)" [42]. We shall attempt to describe the function of negotiation in tutorial dialogues by describing a prototype model for intelligent teaching interactions, incorporated in the KANT system (Kritical Argument Negotiated Tutoring system) [5,6], and by critiquing the model with respect to analyses of a set of computer-mediated one-to-one teaching dialogues. We discuss a number of theoretical issues arising in the context of existing work on negotiation in dialogue, and future extensions to our model in order to incorporate new features identified in the analysis.

Viewpoints on the role of negotiation in education

The rôle of negotiation in dialogue has been considered from two main points of view in what may be broadly termed research in cognitive science and its application to education. The first point of view is the so-called "Standard Theory" [38], according to which "cognitive processes are caused by the execution of stored programs that operate on an internal symbolic representation of the world" (p. 563). The second point of view is that cognition is *situated* within communities of social relations, and 'embodied' in social action, rather than in some sense 'standing behind it'. This is what has become known as the 'situated learning' approach [29,30,47], according to which "'Cognition" observed in everyday practice is distributed - stretched over, not divided among - mind, body, activity and culturally organized settings ... "

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[29, p.1]. This view is sometimes presented as an extension of the first, and other times as a replacement paradigm. Somewhat surprisingly, both views have recently had something to say about the rôle of *negotiation and dialogue* in learning. Within the 'symbolic' view, researchers in conversation analysis [33], artificial intelligence [9], cognitive psychology and the hybrid enterprise of AI and Education [5,6,7] have aimed to specify the changes in mental states (beliefs, intentions, preferences,...) which underly generation of dialogue structures in negotiation. For example, in research on explanation generation, it is argued that explanation must take place within a negotiated dialogue, since it requires a reasonably extended interaction in order to negotiate (i) the knowledge assumed by dialogue participants, (ii) what will be accepted as an explanation, and (iii) mutual goals in the interaction [39,23]. Accordingly, researchers are turning increasingly towards the work of *conversation analysis* [45] in order to model coherence and complex features of turn-taking mechanisms [33], and approaches to discourse and dialogue based on the premises of *discourse analysis* [11]. Analysis of discourse units has generally been approached from the point of view of speech act theory [46]. For example, Levin and Moore [31] defined a set of "dialogue games" used in discourse comprehension, Power [43] showed how "conversational procedures" could be used in a cooperative planning program, and the early work of Allen and Perrault [1] formalised a number of illocutionary acts and described their rôle in simple dialogue planning systems. This early work included preconditions for speech actions which referred to the speakers' knowledge and beliefs, a line of research which has been continued to the development of logics for reasoning with belief [36,28] and with intentions [12]. The field of AI known as 'Distributed Artificial Intelligence' [9] includes an attempt to formalise the logical structure of the mental states of 'Rational Agents', and considers the problem of formalising negotiation from the point of view of distributed problem-solvers.

From the 'situated' viewpoint, negotiation is not something to be modelled by specifying dialogue units and patterns of mental states which generate and comprehend them ; it is rather something to be studied as part of the social context in which the use of computers in education is situated. Thus, Seely-Brown [47] states that:

"Good learning situations and successful ITS are successful not because they enable a learner to ingest preformed knowledge in some optimal way, but because they provide initially underdetermined threadbare concepts to which, through conversation, *negotiation* and authentic activity, a learner adds texture." [47] (my italics).

As with all dichotomies, there are approaches which do not fit into these two viewpoints. Thus, for example, the neo-Piagetian approach of Doise, Mugny and colleagues [16], and Vygotskian approaches to collaborative computer use , also stress the importance of cognitive and social factors in language use in the resolution of conflict in learning and development. Our own approach in this chapter is situated within the Standard Theory : our goals are to specify a theory of the changes in mental states which underlie conflict and cooperation and the generation of negotiation in dialogue , and to apply the theory to the generation of teaching interactions in ITS. In Ohlsson's [38] terms , we retain the Standard Theory as one of dialogue *action* , and attempt to specify the abstract knowledge which underlies it. This is not, of course, an *a priori* argument for the validity of this approach in terms of a philosophy of action (see Clancey, this volume). In the context of AI and Education research, the two views are in fact most often compared using arguments which rely implicitly on the perceived prospects for practical solutions to current problems in the use of computers in education. On these grounds, it may be argued that we will obtain most educational gains from putting current learning environments and educational expert systems into social settings now , and studying their situated use, rather than by expending research resources on theoretical pragmatics, cognitive science, agent theory ... what hope do we have that this research will help us to solve educational problems ? In comment on this debate, we would simply want to stress that the philosophical and practical educational questions should be clearly separated.

Defining negotiation

From the point of view of social psychology, negotiation is defined as the process of "conferring with another for the purpose of securing agreement on some matter of common interest." [37]. Note that negotiation is not necessarily or exclusively concerned with the *resolution of conflict*, but rather with the *achievement of cooperation*. Galliers [22] gives a number of precise logical definitions of the mental states underlying negotiation and conflict, upon which our subsequent discussion in this paragraph is

based. "Negotiation" is the name of a kind of interaction, and also of a process which takes place during that interaction, whereby the mental states of participants are altered so that they cooperate with respect to some proposition. She defines three "propositional postures" (attitudes of an agent with respect to some proposition): CONFLICT, COOPERATE and INDIFFERENT. In these terms, *negotiation is the process by which either of the propositional postures CONFLICT or INDIFFERENT are changed to COOPERATE*. These postures are defined with respect to beliefs, goals, preferences and commitments of agents, based on an extended version of the logic of Cohen and Levesque [12]. For example, CONFLICT can occur with respect to beliefs or goals; it can be individual (one agent is aware of conflict with respect to a proposition believed by another agent), or mutual (both agents possess individual conflict). For example, There is *individual goal conflict* between x and y concerning proposition p iff x has a goal for p to be true from now into the future, and x believes y to have the goal eventually not p, and x has a persistent goal for y to change his mind and to adopt the goal eventually p relative to q :

$$(G\text{-CONFL-I } x \ y \ p) = \text{def } (GOAL \ x \ (\text{possibly } p)) \ \& \\ (\text{BEL } x \ (GOAL \ y \ (\text{possibly } (\text{not } p)))) \ \& \ (P\text{-R-GOAL } x \ (GOAL \ y \ (\text{possibly } p)) \ q)$$

Individual COOPERATION is the recognition by x of y's goal that p be eventually true and x preferring p to (not p), resulting in the generation of a persistent goal for p, relative to y's possession of the goal:

$$(COOP\text{-I } x \ y \ p) = \text{def } (\text{BEL } x \ (GOAL \ y \ (\text{possibly } p)) \ \& \ (\text{PREFER } x \ p \ (\text{not } p)) \ \rightarrow \\ (P\text{-R-GOAL } x \ p \ (GOAL \ y \ (\text{possibly } p))))$$

INDIFFERENCE is somewhat simpler. X is indifferent to y with respect to p iff x does not have a goal for y to believe or have a goal for p, or has not a goal for p which is relative to y's goal for p:

$$(\text{INDIFFERENCE } x \ y \ p) = \text{def } [(\text{not } (GOAL \ x \ (\text{possibly } (\text{BEL } y \ p)))) \ \& \\ (\text{not } (GOAL \ x \ (\text{possibly } (GOAL \ y \ p))))] \ \text{OR} \\ (\text{not } (P\text{-R-GOAL } x \ p \ (\text{possibly } (GOAL \ y \ p))))$$

In order, therefore, for agent x to negotiate the cooperation of another with respect to a proposition p, what is required is that x generates a belief in y that p or not-p is to be adopted as a goal, and that y has a preference for p, which leads to y adopting p as a goal. In general, what we observe is that change in belief takes place by supporting or contesting the reasons for holding a particular belief. Galliers' definitions give us some theoretical tools with which to approach the creation of a cognitive model for the processes underlying negotiation, with respect to analysis of dialogue transcripts. We adopt the following modified definition of negotiation :

Negotiation (definition)

'Negotiation' is the term for a sequence of dialogue exchanges during which the mental states of interlocutors are changed from the propositional postures of INDIFFERENCE (absence of cooperation or conflict) or CONFLICT with respect to one or more propositions, to one of COOPERATION with respect to one or more propositions, and where one or more interlocutor possesses the goal that this posture should be achieved.

Note the following with respect to this definition :

1 Negotiation is the name of a sequence of communicative actions defined with respect to changes in complex mental attitudes.

2 Initial attitudes do not have to be identical - one agent may be indifferent and the other in individual conflict.

3 The proposition(s) with respect to which do not have to be identical to those with which conflict existed initially - some other compromise may be achieved which leads to dropping the persistent goal that the other should adopt a speaker's belief. Where this is not the case, we view this as 'adversarial' negotiation, in analogy with argumentation [34].

4 We do not fix or define the range of utterance types which must occur in negotiated dialogue. Generally, in the case of goals, these will be some kind of OFFER/ACCEPTANCE/REJECTION, given the context of the persistent goal of achieving cooperation with respect to some proposition. In the case of beliefs, the speaker will generally ASSERT the proposition, which, according to Perrault [41] implies

some intention that the proposition will be mutually believed - i.e. it is an offer of a candidate for mutual belief.

5 It is of course possible that negotiation takes place in which neither speaker has the goal that cooperation be achieved - such as 'arguing for the sake of it'. In tutorial dialogues with reasonably clear goals, we therefore make a minimal assumption of cooperativity.

As stated earlier, negotiated propositions may be goals or beliefs. In this paper we concentrate solely on negotiation of joint dialogue *goals*. Finally, we must emphasise that we use the term "dialogue" in the general sense of the *socio-cognitive processes which generate the structure of interaction at the level of propositions and the attitudes of agents towards them*. We are interested in the problems of how an interlocutor decides which proposition (goal or belief) to negotiate, how it is negotiated, and how an agent decides whether to cooperate or not with a proposition negotiated by another.

Negotiating dialogue goals : examples and analysis

Let us now consider some examples of the phenomena which we are trying to model. The following are examples of phases of negotiation between an adult human teacher and an adult learner in computer-mediated tutorial dialogues for teaching the programming language PROLOG. These dialogues will be used as examples throughout this paper. We use the following notation: "T = teacher", "L = learner", "<<...{comment}>> = omitted section from dialogue". The speakers adopted a number of idiosyncratic communication clichés, such as " ° " for ending a turn, and " ? " for an asynchronous interrupt, which we omit in the extracts for clarity. The dialogues were collected over a period of two years, and were conducted via electronic mail at a distance of over 400 miles. Due to space restrictions we shall discuss only short extracts from a single dialogue (the second of eight). The approach to dialogue analysis used depends on the questions we are seeking to answer. For example, Elsom-Cook [20] analyses this same set of dialogues in terms of a set of predicates for mentalistic concepts - beliefs, wants, commitments and preferences. In the long term, we aim to make similar analyses and to instantiate them within a cognitive architecture. There are of course a great many aspects of these dialogues which could be analysed : at the present stage in our research we are principally concerned with analysing: (1) the *turn-taking structures* associated with negotiation, and (2) the *range of propositions negotiated* in tutorial dialogues. The interest of 1, lies in the fact that since negotiation in dialogue can be viewed as one form of social interaction [45], conformity to and divergence from 'preferred' turn-taking structures gives evidence for *propositional attitudes* of agents [22] - CONFLICT, COOPERATION and INDIFFERENCE. Since there are probably no *a priori* limitations on what propositions can be negotiated in a dialogue, we aim to establish , some *empirical* limits on the range of such propositions for specific kinds of domains. In addition, we make some initial hypotheses which aim to explain *why negotiation occurs* in educational dialogues, *why negotiation succeeds or fails* and *why negotiation is implicit or explicit* . These questions can be viewed as preliminary to what is in a sense the hardest and most interesting problem : *through what dialogue actions and changes in mental states is conflict resolved by negotiation ?*

Negotiation Example 1 : INDIFFERENCE -> COOPERATION

T1: I would greatly enjoy doing some prolog. Did you have something in mind?

L2: No, not really. Like I said I haven't really looked at your program with the idea of extending it yet. Could we do something simplish, just to make me feel good?!

T3: Certainly. You have a choice of something simple and interactive now, or something fairly simple with an interactive session later on today.

L4: Um. I'd like to do something now, cos I really should do the vp stuff later on ... is that ok?

T5: Fine. Ummm... How about writing a predicate called second_word, which takes as its argument a string, and instantiates its second argument to be the ATOM corresponding to the second word of that string <<continues>>

In this extract the interaction structures are of the socially expected form, according to the Schegloff and Sacks [45] turn taking rules:

speaker1:		negotiation
speaker2:	response,	negotiation
speaker1:	response

This shows a high level of social cooperation in the definition of joint goals. Since the extract occurs at the beginning of the dialogue, there are no explicitly agreed joint goals (although there is certainly background common knowledge - [18,20]), so propositional attitudes (or "postures" [22]) are

INDIFFERENCE, moving to COOPERATION. A wide range of phenomena are negotiated, all of which are *goals* for one or both speakers, rather than *beliefs*. This relates to the problem-solving domain discussed, and we would expect a greater degree of negotiation of belief in dialogues concerned with explanation. Propositions negotiated include: general and specific topics for problems to work on (prolog, strings, arguments, "write a predicate called `second_word`") and their level of difficulty, the interaction style of problem-solving, future planning of joint problem-solving goals, that the other speaker should negotiate a goal for a given topic (U2), and even 'time to think' (U12). Other remarks which may be made about this extract are that negotiation is exclusively *explicit* - presumably because at the beginning of the dialogue there is insufficient shared understanding of beliefs and goals to permit indirect and implicit utterances - negotiation of goals proceeds from general to specific in terms of the speaker, interaction style, and in terms of goals and subgoals in the domain, and *almost all negotiated goals succeed* (except for U3). We hypothesise that the gradual increase in specificity of goals negotiated is designed to minimise the probability of direct conflict. In this context, the cooperative turn-taking structure gives both conversants the chance to modify agreed goals successively.

Negotiation Example 2 : CONFLICT -> COOPERATION

T31: ? Can I say something?

L32: yes

T33: That's quite a lot wrong, I'm afraid. D'you want to tell me about it in English?

L34: Not really

T35: Ah. What do you want to do then?

L36: Stop?

T37: Oh. Really? I'd quite like to talk through this one, and it isn't exactly all that ego-boosting for your prolog morale so far is it?

L38: What prolog morale?

T39: Oh, come on. You can do it. It's just a lot of things to remember and you're out of practice. I suspect you've got the problem quite well sussed in english, but the difficulty is mapping it into prolog;

L40: no, the problem is that I haven't got it sussed in English.um can I just talk about the `first_word` bit for now?

T41: Yes, that's fine. <<continues>>

In this extract, the interruption of the socially preferred or expected turn-taking structure is evidence for the propositional posture of CONFLICT, in which L responds negatively, and exchanges of negotiation and opposed counter-negotiation follow one after the other, for example :

T31: interrupts
negotiates

L32: responds

T33: utterance

U4: negotiates

and so on. The principal propositions negotiated are: that L explains and discusses their problem, that L negotiates another goal - a case of 'nested' negotiation - and that they stop or continue the dialogue. There are two cases of conflict : in the first, there is *individual then mutual goal conflict* with respect to the goal "T explains L's errors", and in the second with respect to the goal "continue the dialogue". *Why did conflict, and hence negotiation, occur at this point in the dialogue?* The teacher's initial negotiation succeeds in virtue of its non-specificity ("Can I say something?") thus making it less likely to directly conflict goals or beliefs, and in terms of its placement in the dialogue almost at the end of the student's (erroneous) problem-solving. We can imagine that an interruption in the middle of this process, and with greater specificity, would be less likely to be successful. The subsequent negotiations fail because the student is not *motivated* to continue to pursue the proposed goals because of their self-assessment of the likelihood of achieving agreed problem-solving goals (see the analysis in [20]). The first CONFLICT situation "T explains L's errors" is removed by the teacher succeeding in motivating the student sufficiently so that she agrees to choose a different and simpler sub-problem to work on. A prerequisite to this goal being pursued is that the second conflict with respect to "continue the dialogue" be resolved. In this case we may say that the teacher persuades or even *coerces* the student, by appealing to the reason why L wanted to stop.

In summary, we would make the following brief points with respect to these analyses, which will be relevant for assessing our current prototype model KANT :

1 At least for problem-solving dialogues, it seems clear that the range of propositions negotiated concern *the determination of joint problem solving goals, the temporal planning of actions to achieve them, and execution monitoring of their success*. An ITS which negotiates goals should therefore be potentially capable of negotiating almost any primitive of the domain and dialogue models.

2 Goals are negotiated with successive levels of specificity, and gradual assignment of speaker and negotiator roles, which we suggest is one strategy for avoiding potential conflict. Other strategies include indirect or implicit negotiation of goals (eg "Can I say something?", "I don't know what I'm doing") in cases of *interruption*.

3 Conflict is often resolved by criticising or supporting the reasons for adopting a particular goal. Successful negotiation of a goal from postures of CONFLICT is often closely related with attempting to *motivate* (or even *coerce*) the other to accept the goal by reference to affective factors ("I can't do it", etc.), and convincing the student that their metacognitive self-assessment of their problem-solving abilities is not correct. In terms of agent theory, the use of motivating moves in negotiation therefore requires a representation of *affective preferences and interests*.

4 Turn-taking structures and their conformity to expected forms vary with the propositional attitudes of speakers. Their attendant generation in a dialogue model therefore assumes the capacity to *recognise propositional attitudes* (CONFLICT, COOPERATION, INDIFFERENCE).

Now that we have introduced some of the phenomena which we aim to model, we describe and critique our current prototype model.

KANT: a model for high-level processes in tutorial interaction

The KANT system (Kritical Argument Negotiated Tutoring system, [5,6,7]) is a computational model for generation of structures associated with high-level tutorial interaction. A model of 'high-level' interaction [27,20] consists of the specification of a set of representations for cognitive states and processes which operate upon them, required to generate the abstract structure of dialogue, at the level of the *propositional content* of utterances. These representations include those which would be necessary for a model of an interlocutor in dialogue, such as their beliefs (concerning a domain of discourse, the beliefs of some other interlocutor, the previous dialogue which has occurred), their goals, intentions, preferences and other intensional representations. The model should be able to generate (at least) a subset of the phenomena which have been analysed in educational and other dialogues, including turn-taking, interruption, the goal-based dialogue units, and so on. The processes which are required include processes for modelling the intentions of interlocuteurs, how they represent coherence and relevance, how they choose how to respond, and so on. Despite its limitations, KANT was the first computationally tractable model for tutorial dialogue reported in the Intelligent Tutoring Systems literature to address the problems of managing negotiative dialogue, where each interlocutor (computer and human student) was given as great a degree of symmetrical freedom to pursue their goals as was possible at this stage of research. With respect to negotiation, KANT addressed two main questions :

1 how should a dialogue agent decide which goals to negotiate ?

2 how should a dialogue agent decide whether to cooperate or not in negotiation ?

In terms of symmetry in the interaction, each participant (ITS and student) is given approximately the same set of dialogue goals which may be negotiated, and each has the symmetrical ability to accept or reject the negotiated goals of the other. As stated earlier, *KANT is restricted to negotiating dialogue goals, and not beliefs in the domain*. In addition, as we shall discuss, it only models aspects of *one* form of negotiation : from INDIFFERENCE to COOPERATION. The crucial and difficult problem of resolving CONFLICT in negotiation is a major topic for future research. The preliminary solution adopted is that of simple *acquiescence* : the system is not *benevolent* in accepting everything proposed by the student, and in the case of rejection of a negotiated goal, each speaker is simply forced to accept this, the negotiated turn shifting to the rejecting speaker.

Our purpose in this chapter is to introduce an approach to modelling negotiation in tutorial dialogues, to argue for its educational importance, and to establish a future research agenda. We therefore do not have the space to discuss all aspects of the dialogue model incorporated in KANT (see [5,6,7]). After a general summary of the components of the system, we therefore illustrate how it functions with

respect to an example interactive execution trace, and critique the model with respect to our dialogue analyses.

KANT : an outline of the program

The most fundamental representations upon which KANT is based, are *a set of dialogue moves* which represent the goals of a dialogue participant, and *a propositional network of justified beliefs* in the domain discussed. There is a close relationship between these two representations, in that the set of dialogue moves chosen are specifically adapted to communicating *justified beliefs* which characterise the knowledge domain which the dialogue model discusses (beliefs about musical structures in melodies [3,4]). KANT therefore generates dialogue moves corresponding to those which have been described for *critical arguments* [50,44], including structures for stating and illustrating beliefs and their justifications, and for critiquing the beliefs and justifications which have already been stated in the dialogue (by either dialogue participant). We shall give a brief outline of KANT by describing these data representations, then the processes which operate on them to generate high-level dialogue.

We followed existing research [13,31] in representing dialogue moves as planning operators, based on the general theory of language as rational action - "speech acts" [46]. Our dialogue moves had a similar structure, with the differences that extra kinds of preconditions were included for constraints on dialogue focus, the operators were parametrised (for speaker and negotiator roles) in order to be adapted to interactive dialogue, and they included preconditions relating to negotiation of those goals. More importantly, the major differences between our model and previous ones lie in the procedural role which the goal operators play in dialogue generation : *the system does not construct plans* from these goal operators. Given the equal opportunity of each participant to influence the course of the dialogue by negotiation, we opted for a form of opportunistic dialogue, controlled by dialogue focus, and the relevance of sequences of hierarchical goals. In future work we may modify this situation to include a degree of *local planning*. Each dialogue move has

- a *header* (the goal name) ;
- *parameters* for the current negotiator, speaker, concept and instance discussed (n,s,c,i) ;
- *dialogue state preconditions* ;
- *negotiation preconditions* ;
- *submoves* ; and
- *dialogue actions* (if any).

Dialogue moves are represented in a *hierarchical and/or tree with levels of abstraction*, in terms of an increase in specificity of preconditions for relevance of the move descending in the tree. This relates to the fact that speech acts which "prepare the terrain" for others try to obtain "some of the conditions of appropriateness for the dominant act" [21], and to our analyses of general-to-specific negotiations in the dialogues discussed earlier in the chapter. The following is an example of an operator for the 'claim' dialogue move:

```
dialogue move: CLAIM
parameters: (c inst n s)
dialogue_state_preconditions:
  ((not (null c)) & ((null *dialogue_history*) OR ((in_focus? c (ltm_model s)) &
  (not (known? c (ltm_model (dialogue_participant s)))) & (exists_ltm_trace? c (ltm_model s))))))
negotiation_preconditions: ((negotiate s (goal= 'CLAIM)) & (negotiate s c))
subgoals: (OR ((concrete_claim (c inst s)) (abstract_claim (c inst s))))
negotiation_effects:
  ((update_dialogue_history '((goal_name= 'CLAIM) (s= s) (c= c) (inst= inst))))
action_effects: nil
actions: nil
```

At the highest level of the goal tree, a fundamental distinction is made between disjunctive 'claim' and 'challenge' goals. This corresponds generally to a distinction between stating something 'new' in the

dialogue, related to the previous dialogue by local focus constraints, and a direct reference to a previously stated goal in the dialogue (eg critiquing a previous directly referred to claim). Within each branch, goals subdivide into abstract and concrete claims, and the making and justifying of the claim. On the 'challenge' branch, moves are included for essentially *critiquing* claims [14,35], such as disagreeing or agreeing with justifications, stating new justifications, and so on. The and/or goal tree is a fundamental representation used in decision-making in dialogue in KANT: it is searched during the process of trying to find a relevant goal to be discussed. When the student has a 'negotiated turn', the same set of goals is available, with the exception of making an 'abstract claim', or general explanation. This goal is excluded in view of our concentration on high-level decision making mechanisms: since the system does not generate utterances down to the sentence level, neither can it analyse the meaning of sentences input by the student. *Parameters* are values for speaker and negotiator rôles, and topic in terms of concept and instance to be discussed. These may have values inherited from higher in the dialogue goal tree, values which are proposed by the other speaker, or values may be derived 'actively' by procedures associated with satisfaction of dialogue state preconditions (such as 'finding a concept to discuss'). *Dialogue state preconditions* consist of a logical expression into which current parameter values are substituted, and evaluated with respect to a "dialogue state" [43], consisting of a representation of the beliefs of both interlocutors in semantic memory, and a restricted representation of their memories concerning the most recent instantiated dialogue moves negotiated and pursued in the dialogue so far. Other dialogue state preconditions refer to the dialogue history and the mental states of interlocutors. For example, a claim move is relevant if it is the beginning of the dialogue, and in order to make a claim, an interlocutor must have a memory representation for the concept to be communicated, and must believe that the other interlocutor does not "know" that concept. *Negotiation preconditions* simply state that for a *dialogue action* to be performed, the goal selected as relevant must be negotiated and accepted. *Submoves* are the subgoals in the dialogue goal tree, and *negotiation effects* are the set of procedures which update the speakers' belief representations as we describe next. *Dialogue actions* simply communicate the propositions agreed by negotiation, within the context of previous negotiations. For example, if a move "agree supports" is accepted, then the proposition communicated (belief/justifications) is interpreted as agreement with justifications for a stated belief.

Our model for memory encoding and retrieval during the course of dialogue is based on the ACT* model [2]. The beliefs and justifications of each participant are therefore represented as instances of concepts in a propositional network. We assume that if a concept is mentioned then both interlocutors encode a working memory trace for it, which has a probability of forming a long-term memory representation with repetition. We therefore make the simple assumption that encoded memory traces correspond to 'belief' in the way in which they are *used* in dialogue: beliefs are viewed as representations which when communicated in dialogue, have to be justified, whose justifications can be critiqued, and which can not serve as the basis of straightforward contradiction of a previously stated belief, i.e. belief is treated as a propositional representation upon which certain dialogue procedures may operate. The system distinguishes its own beliefs from those it attributes to the student according to this simple encoding hypothesis (a "student model"), and records a restricted set of propositions representing recent dialogue moves performed by both speakers. Retrieval from long-term memory is based on the phenomenon of *spreading activation* in semantic memory, from an input source. We have applied this feature of Anderson's theory to the definition of *focus* in dialogue [24,25]. From the point of view of the system, when it attempts to satisfy *relevance* [49] conditions for a negotiated dialogue move, it checks the current concept activation value with respect to its own working memory, being the traces with the highest activation level: if the concept is in working memory, then it is viewed as sufficiently in focus to satisfy this relevance condition in the dialogue state preconditions. If no concept is proposed, then it selects the concept with the highest activation level, in order to satisfy this precondition for a dialogue move. When it is the student's turn to negotiate a dialogue goal, the system therefore bases part of its decision as to whether to cooperate or not on checking its own representation of the activation level of that concept, thus judging its relative focus.

We have now discussed the basic data representations which need to be understood in order to describe the fundamental dialogue generation mechanisms of KANT. At the highest level, the dialogue consists of an alternation of *negotiated turns*. KANT incorporates simplified procedures for turn-taking which do not necessarily correspond to the full sophistication of the mechanisms described for natural human conversations [45]. They may be summarised as follows:

- 1 speaker1 negotiates a goal;
- 2 speaker2 responds with agreement or disagreement;
- 3 if speaker2 agrees, then speaker1 utters the agreed goal;
- 4 when the goal is uttered by speaker1, speaker1 may self-select, and attempt to negotiate subgoals of the first goal (step 1). These may succeed or fail.
- 5 depending on the degree to which speaker1 believes that speaker2 understands the subgoal to be negotiated, speaker1 may utter the subgoal, generate a preannouncement, or negotiate it as in step 1. Upon assent to a preannouncement, the subgoal is uttered.
- 6 if the speaker disagrees, then the negotiator role changes, and the disagreeing speaker takes a negotiated turn (goto step 1).

In step 4 above, we can see that the mechanism is in fact recursive - step 4 invokes step 1. We shall see this mechanism in operation when we present an example dialogue generation trace produced by KANT, later in this section. On a specific negotiated turn, the following are factors which are used in determining which goal to negotiate:

- 1 the structure of the and/or decision tree of dialogue moves, which defines mutually exclusive alternatives, and conjunctive possibilities ;
- 2 satisfaction of dialogue state preconditions for the relevance of a dialogue move, with respect to the dialogue state ;
- 3 choice of alternative mutually relevant dialogue moves according to a set of educational preferences.

When either speaker converses, the dialogue move tree is searched in order to find a set of terminal goals in the tree, which have attached dialogue actions (factor 1). For each goal encountered, its dialogue state preconditions are evaluated with respect to the dialogue state (factor 2). If alternative goals are both satisfied, then a set of educational preferences is applied in order to choose one (factor 3). If only one is satisfied, then search continues below that goal, and the conjunction of satisfied dialogue goals with attached dialogue actions will be uttered. If none are satisfied, then the speaker 'can think of nothing [relevant, preferred] to say', and the other speaker becomes the negotiator. The number of educational preferences required is related to the number of points where a choice may be made between goals, i.e. the number of disjunctive branches. In our present simplified goal tree, there are only two: discriminating between claim and challenge goals, and between abstract and concrete claims (other preferences are required for preferred parameter instantiations of these goals, such as 'preferring the student to speak'). These preferences are derived from existing research in educational discourse. For example, the following preference relates to the stable 'initiate-response-feedback' pattern observed by Sinclair and Coulthard [48] in classroom educational dialogues, in effect preferring feedback to a response, thus making more connected dialogue : "Pref 1: Prefer to challenge an existing claim if relevant to do so, rather than making new claim [claim and challenge moves]".

Before considering some examples of dialogue traces generated by KANT, we finally need to say how a negotiator decides whether to *accept* a negotiated goal or not. The simple mechanism which we have adopted in the present version of KANT bases this decision on the same relevance preconditions which an interlocutor uses to decide which dialogue goal to pursue, i.e. *a speaker s1 agrees to accept a goal g instantiated with specific parameters negotiated by speaker s2 if and only if those parameters when substituted into the dialogue state preconditions of g evaluate as relevant*. Note that the restriction is not so strong as to demand that the goal be also *preferred* - in effect, one of the ways in which KANT side-steps the issue of resolving conflict. Clearly, this is a considerable simplification, resulting from the fact that the dialogue system does not incorporate a notion of longer-term and higher-level goals. Our negotiation mechanism is also simplified in that it could be modified to include further exchanges where the respondent does not accept a goal with some parameters, but then attempts to find values under which it would accept, which are then proposed in turn as a 'compromise'. We did not incorporate such further sophistications into KANT at this stage, preferring to reserve them for a phase of evaluating the model with respect to dialogue transcripts. Once a dialogue goal has been satisfied as relevant, discriminated according to preferences, and negotiated as accepted, dialogue actions (if any) may be performed, and effects propagated on the dialogue state. Since we concentrated on describing a model for high-level decision processes in dialogue, the performance of dialogue actions in KANT simply corresponds to *generating a text template* for communicating the concept and instance parameter values which have been

satisfied as relevant and accepted for a goal, for a given speaker. When the student is the speaker, exactly the same dialogue generation mechanisms are used. The principal difference lies in the difference between input and output to the model. In the case of the student as speaker, the system generates summaries of the responses (yes and no) to negotiation, of the beliefs and instances chosen, and presents the set of dialogue moves available at a given point in the goal tree for the student to choose. In accordance with the model of dialogue focus based on spreading activation incorporated in KANT, subgoals which are negotiated as recursive continuation of dialogue actions are explored in order of highest activation level.

Example interaction trace generated by KANT

Finally, let us consider an example of a dialogue trace generated by KANT, describing the features of the model discussed so far. We do not have space to illustrate all features here, and so restrict ourselves to a single example which illustrates most features. In the example, typed input by the user is in *italics*, plain text is an output trace generated by KANT. The lines have been numbered (eg "9/") for reference in the commentary. This is an example taken from the middle of a 'dialogue' with KANT, i.e. an interactive trace. There are two negotiated turns, each of which consists of a negotiation phase, followed by a dialogue action, which is recursively continued in the second negotiated turn. In the first turn, the student is the negotiator and the speaker, in the second the system is the negotiator and speaker, and challenges the claim made by the student in the first. The domain discussed is that of a set of justifications for the existence of musical phrase boundaries in an example melody, integrated into a propositional network representation.

(KANT INTERACTION TRACE)

1/My turn over ... your move
2/Are you sure you want to continue the discussion? (y or n)
3/y
4/Please type who you want the SPEAKER to be ...(student or system)
5/*student*
6/Please type in the concept you want to talk about (if you want a full list of possibilities, type 'show')
7/*phrase_boundary*
8/Please type in the instance position you want to talk about
9/*p10*
10/I will tell you if I agree to cooperate ... Ok, I will cooperate
11/Please choose one but not both of the goals to pursue:
12/ CHALLENGE = make a challenge to a previous claim
13/ CLAIM = make a claim concerning a concept
14/*claim*
15/I will tell you if I agree to cooperate ... Ok, I will cooperate
16/Please choose one but not both of the goals to pursue:
17/ CONCRETE_CLAIM = make a specific claim about a concept instance
18/ ABSTRACT_CLAIM = make a general explanatory claim about a concept
19/*concrete_claim*
20/I will tell you if I agree to cooperate ... Ok, I will cooperate
21/Please choose a goal to pursue:
22/MAKE_INSTANCE_CLAIM = state a claim about an instance
23/SUPPORT_INSTANCE_CLAIM = state justifications for an instance claim
24/*make_instance_claim*
25/I will tell you if I agree to cooperate ... Ok, I will cooperate
26/You are pursuing the dialogue goal MAKE_INSTANCE_CLAIM, with
27/PHRASE_BOUNDARY as a concept, and P10 as its instance. Please confirm or disconfirm your intentions (y/n)
28/y
29/Ok, I'll remember that.
30/Please choose a goal to pursue:
31/SUPPORT_INSTANCE_CLAIM = state justifications for an instance claim
32/*support_instance_claim*
33/Please type in the justification(s) for the instance P10
34/(CONTRAST PARALLELISM)
35/I will tell you if I agree to cooperate ... Ok, I will cooperate

Lines 1-35: Negotiation phase (n= student, s= student, c= phrase_boundary, i= p10). At 1 the argument controller gives the negotiated turn to the student, the previous negotiator having been the system. At 2 we

have a 'transition relevance point' [45], where speaker roles may shift and either participant may choose to terminate the dialogue. From 4 to 35 the dialogue goal tree is searched top-down, and at each point parameters which are unbound are presented to the student with the choices available, as well as the choices of dialogue move at that point. At the beginning, the 'DISCUSS' move is satisfied provided that the memory representations of both participants are not equal. For the student, the s, c and i parameters are presented for choice. The system now substitutes these chosen parameters into the preconditions of 'DISCUSS', which evaluate to 'true' and the system agrees to cooperate. The student now chooses the 'CLAIM' move, for which a summary explanation is given (lines 11-14). The system substitutes the parameters into preconditions, the concept 'PHRASE_BOUNDARY' is found to have a high enough focus level in the system's representation of the student's memory (and other preconditions are satisfied), so the system agrees to cooperate (line 15). A similar procedure takes place with respect to the proposed CONCRETE_CLAIM goal and its subgoals (conjunctive).

(KANT INTERACTION TRACE)

36/You are pursuing the dialogue goal SUPPORT_INSTANCE_CLAIM, with
37/PHRASE_BOUNDARY as a concept, P10 as its instance, and (CONTRAST PARALLELISM)
38/as the justifications. Please confirm or disconfirm your intentions (y/n)
39/y

Lines 36-39: Dialogue action. The student performs the dialogue action in the form of agreeing to a summary of the statement generated by the system. This is followed by a similar procedure for the conjunctive 'SUPPORT_INSTANCE_CLAIM' subgoal. After line 39 is generated, the system propagates negotiation and dialogue goal effects, which are to update the dialogue history and the memory models of each interlocutor. This involves 'PHRASE_BOUNDARY' becoming an input source of activation in both network representations, through which activation is spread, and increasing the appropriate node strength.

(KANT INTERACTION TRACE)

40/Are you sure you want to continue the discussion? (y or n)
41/y
42/My move ...
43/Do you accept that we pursue the dialogue goal CHALLENGE (== make a challenge to a previous claim) (y/n?)
44/y
45/ Do you accept that we discuss the concept PHRASE_BOUNDARY (y/n?)
46/y
47/ Do you accept that we discuss the concept instance P10 (y/n?)
48/y
49/ Do you accept that we pursue the dialogue goal CLAIM_SHARED (== agree with a previous claim) (y or n?)
50/y
51/I agree that P10 is an instance of the concept PHRASE_BOUNDARY
52/Do you accept that we pursue the dialogue goal AGREE_SUPPORTS (== agree with some previously stated justification types) (y or n?)
53/y
54/AGREE_SUPPORTS is the dialogue goal currently being pursued with the justification type(s) PARALLELISM.

Lines 40-54: Negotiation phase (n= system, s= system, c= phrase_boundary, i= p10). At 40 the argument controller passes a negotiated turn to the system. Both the claim and challenge moves are satisfied as relevant, but since a 'challengable' claim has been made, preference Pref1 operates to choose the challenge move. The concept parameter is now bound to the concept referred to in the previous dialogue move (i.e. PHRASE_BOUNDARY of CLAIM move), from the dialogue history, together with the instance p10 to be challenged. Examining its own memory representation and the supports claimed by the student in the previous turn, the system agrees with the previous support 'PARALLELISM', performing a dialogue action.

(KANT INTERACTION TRACE)

55/I want to try to explain what I mean by the justification(s) PARALLELISM. Is that ok? (y/n)
56/n
57/Ok, maybe we'll talk about PARALLELISM next time around...
58/Do you accept that we pursue the dialogue goal NEW_SUPPORTS (== state some justifications which we not mentioned for previous instance claim) (y or n?)
59/y

60/NEW_SUPPORTS is the dialogue goal currently being pursued with CHORD_PROGRESSION as the new support(s).
61/I want to try to explain what I mean by the justification(s) CHORD_PROGRESSION. Is that ok? (y/n)
62/n
63/Ok, maybe we'll talk about CHORD_PROGRESSION next time around...
64/Do you accept that we pursue the dialogue goal DISAGREE_SUPPORTS (== disagree with some previously stated justification types) (y/n?)
65/y
66/DISAGREE_SUPPORTS is the dialogue goal currently being pursued with CONTRAST as the disagreed support(s).
67/I want to try to explain what I mean by the justification(s) CONTRAST. Is that ok? (y/n)
68/n
69/Ok, maybe we'll talk about CONTRAST next time around...
70/My turn over ... your move

Lines 55-69: Dialogue action. At this point (line 55) the system decides that subconcepts of PARALLELISM are 'possibly known', and so generates a preannouncement in line 55. This is not accepted by the student, so the system continues to negotiate with other satisfiable subgoals of the CHALLENGE move. It states some NEW_SUPPORTS for the claim challenged which the student had not mentioned (line 60), then finally disagrees with the support CONTRAST for this claim (line 64). Again it attempts to pursue this dialogue action, which is refused by the student. After each of these actions, effects are propagated on the dialogue state as before. Finally, at line 69 the system has no further satisfiable subgoals to negotiate, all subactions of dialogue actions have been refused, and its negotiated turn ends. At 70 the argument controller passes the negotiated turn to the student.

There are a number of features which we have not been able to show in this example such as the system refusing to cooperate with negotiation, the system negotiating that the student should speak, the student negotiating that the system should speak, and so on. Nevertheless, we have illustrated the major features of KANT, which would also apply in these other cases. We must emphasise that we are not claiming that the example which we have described would be suitable for 'real' use with students, and no effort has presently been made to develop an educationally suitable and robust interface. The example is *an interactive trace of the execution of a model for generation of tutorial dialogue*, incorporating a notion of dialogue focus and a negotiative style.

Future work: what was right and wrong with KANT?

There are a number of immediate criticisms which may be made. The negotiation phases are very lengthy: it would be possible to condense much of this into a single sentence, for example "Do you accept to tell me where you think there is an instance of a phrase boundary?". We did not adopt this approach initially because any such conjunction would require analysis into the 'finegrained' mechanism shown above in the case where this was *not* accepted - do they disagree with who speaks, with the topic, ... ? Furthermore, it is not clear that goals need *always* be negotiated, nor that they are always negotiated *explicitly*. The range of moves which can be performed with the present version of KANT is limited by the fact that there is no understanding of the student's utterances - propositions are simply compared and 'contrasted' - which is one effect of our initial hypothesis that dialogue mechanisms can be initially specified at a 'high' level. In general, the negotiation mechanism itself is too simple, and does not admit of interactive re-negotiation on a given negotiated turn.

Our analyses of computer-mediated dialogue transcripts have given us some analytical data with which to test the assumptions of the first prototype of KANT. Evidence that negotiation forms an important part of educational dialogues is clearly evident from these (and other) dialogues. As a rough measure, of the 83 exchanges in the example dialogue analysed here, approximately 46 are concerned with explicit or implicit negotiation. This dialogue was the second in a total series of 8, and so we would expect a greater degree of negotiation to be initially required in order to define general goals. In later dialogues, negotiation is much more implicit and compressed.

From our dialogue analyses we established that there are a number of cases in which goals are negotiated from general to specific, as a general conflict avoidance strategy. The general/specific dialogue move tree in KANT models this, together with successive satisfaction of parameters as goals become

more specific. However, this kind of structure usually only occurs near the beginning of dialogues, and negotiation is much more compressed once speakers have more effectively modelled each other's goals and beliefs. This suggests that recognisable subgoals of an already agreed goal may be negotiated assuming the higher-level goal to still hold, even if they are not the current explicit focus. Our assumption was therefore too strong - KANT needs to incorporate negotiation at this general level of successive negotiation of parameters, and to subsequently be able to switch to a smaller 'grain-size', to negotiate completely instantiated goals in a single utterance.

The distinction between negotiation phases and performance of the negotiated goal in KANT, is generally supported by the transcripts - it relates basically to a difference between metacognitive and cognitive activities (and to dialogue/metadialogue). With respect to turn-taking structures, KANT can effectively modify structures occurring in the transition from INDIFFERENCE to COOPERATION, but does not of course model the change in structures in CONFLICT situations. A major part of future work is to study conflict resolution in dialogue, with its appropriate turn-taking and dialogue structures.

With respect to the range of propositions negotiated, KANT is severely limited by the *lack of a model for problem solving in the domain*, to which negotiation often refers. This is understandable given our research emphasis on dialogue rather than domain models. In future research we are exploring the close relationship between negotiation in dialogue and cooperative problem-solving in simple mechanics [8]. One issue which KANT could have dealt with concerns negotiating *termination* of the dialogue (as analysed earlier) : the system simply accepts if the student wishes to terminate the interaction. As Schegloff and Sacks [45] have argued, *closings* of conversations need to be *prepared* in order to be mutually acceptable, which includes the generation and careful timing of *preclosings*. Some aspects of conversation analysis applied to openings and closing of conversations have been incorporated as a 'grammar of adjacency pairs' in the advice system of Frohlich and Luff [33].

KANT includes mechanisms for recursive continuation of dialogue actions by further negotiation. Speakers do naturally extend their dialogue actions to subgoals which are strictly beyond the initially agreed goal, for example, in giving further information than is requested:

L12: ... If I did name("fish and chips", N). would I get N = [no, no, no, no, 32 no,no,no,32, no,no, etc]?

(negotiates (question "name predicate"))

T13: No, actually, you'd get an error.

(dialogue action)

The first argument has to be atomic and the second list.

(extension of dialogue action)

Notice that the teacher remains the speaker, and that the extra information is still of a 'reasonable turn length'. It is clear that a simple 'yes or no' answer to such a question would appear 'unhelpful' and almost *conflictual*. We may therefore hypothesise that if the teacher wished to continue an extended discussion of some concept that this *would* be negotiated, or that if the continued extra information required the other to speak, then this would also be negotiated. The lessons which we draw are therefore that subgoals may be negotiated if they require an extension which is longer than the 'normal' length of a single turn, or require speaker change. Otherwise, a speaker may extend their negotiated and agreed dialogue action without explicit negotiation. We would require further empirical work in order to establish the precise extent to which turns may be extended by a speaker. The initial simplification in KANT of allowing a speaker to continue to negotiate subgoals of an action in a simple depth-first search manner must therefore also be modified. The question of how long a 'reasonable' turn is can probably be simply resolved by giving the student the possibility of *interrupting*. From the point of view of the system, however, we need further research before we could specify exactly *when* the system should interrupt the student. Given a certain educational philosophy which prefers the maximum of initiative to be taken by the student (see the educational preferences included in KANT), it is possible that this aspect should *not* be symmetrical for the system and student: we would want the student to be allowed to continue a turn as much as possible, provided the system recognises that their actions are relevant to achieving the agreed goal.

In the dialogues analysed we have not observed cases which can be straightforwardly interpreted as instances where a speaker refuses to cooperate with a negotiated goal because it is *not relevant* in the

sense of being in focus. From the opposite point of view, all goals negotiated which *were* relevant to the previous goal were accepted, relevance being understood here in terms of focus on the goal and/or topic [25]. The model of relevance incorporated in KANT combines topic-based focus, with speaker roles and dialogue goals, in a complex set of preconditions with respect to the dialogue state. Conflicts arise mostly in the dialogues because the goals proposed concerned the form of the dialogue itself - such as its termination - rather than its topic. The extent to which a speaker accepts such negotiated goals must relate to higher level persistent goals, or commitments (again, in Cohen and Levesque's terms, [12]) - such as "that the student should complete the problem" - and the extent to which they are in direct conflict.

The simple encoding hypotheses used in KANT were consistent with the general theory of memory adopted [2], but are clearly only a first approximation of the features which need to be modelled. The hypothesis of encoding strength increasing with repetition, leading to a memory representation clearly does not address the problem of when a memory trace concerning another speaker's beliefs is genuinely *adopted by the hearer as their own*. This difficult problem will need to be addressed in the future in terms of recent AI theories of *belief revision* (see [26]).

In summary, we would claim that KANT succeeded in providing some initial answers to our two basic questions, as a basis for further research : what to negotiate, and whether to cooperate in tutorial dialogues. Our preliminary answers are based on a model for focus in semantic memory, and a hierarchical representation of dialogue moves. The system is essentially restricted to negotiating dialogue goals from a position where no joint interaction goals are currently established. An ITS which is able to negotiate learning goals, and which accords a larger degree of symmetrical autonomy to the student may be argued to provide a better basis for joint construction of knowledge *qua* justified belief rather than for its communication. Many hard problems for cognitive science remain, the most important of which concern the resolution of conflict in dialogue, and a theory of belief revision as a result of negotiation. KANT has provided us with a cognitive framework within which to situate this future research.

Conclusions

Negotiation plays an important rôle in tutorial dialogues, which argues strongly for its inclusion in interaction models in Intelligent Tutoring Systems. Given the different nature of the goals and beliefs of teachers (and ITS) and learners, it is clear that negotiation in educational discourse fulfills the important functions of securing cooperativity and genuine *engagement* in the educational process on the part of the student, and the possibility of a joint construction of meaning. As a phenomenon in interaction, it is closely linked with *metacognitive awareness* on the part of a speaker, as a prerequisite for negotiation of future cooperative control of joint dialogue goals. An important feature of metacognitive awareness is a speaker's assessment of their own capabilities and their *affective attitude* to towards the possibility of achieving their goals, in conditions of apparent failure. When we consider the problem of how one speaker can successfully negotiate their goals, therefore, the questions of affect and motivation are particularly important : in order to persuade a speaker to adopt a goal or belief we need to convince them to *prefer* that goal or belief, and it is clear that this is closely linked to motivation and other affective states. Progress for cognitive modelling in the area of affect [17], the emotions [40] and motivation [51] is now at the stage where we may have reasonable hope of including such aspects in models for dialogue in Intelligent Tutoring Systems. In future research we plan to validate and refine KANT by a combination of techniques. From the dialogues analysed we have already identified a number of modifications to be made. Modelling these additional phenomena requires the inclusion of additional *theoretical primitives* - to be derived principally from aspects of agent theory - for representing commitments, intentions, interests, preferences and affective states [22,12]. We aim to combine these theoretical primitives into a model which is situated within a *cognitive architecture* [2]. In order to model resolution of conflict by negotiation, we need to situate results from *belief revision* research in AI and agent theory within the cognitive architecture, in order to model the strategic dialogue action performed by human interlocutors. The dialogues which we have analysed are concerned with a *problem-solving domain*, and hence show strong emphasis on the negotiation of *goals* as opposed to *beliefs*. To explore the rôle of negotiation in the joint 'construction of meaning', we are currently analysing dialogue transcripts for students working in pairs, attempting to explain phenomena in physics (simple mechanics) [8]. Finally, in order to test an extended version of KANT with real users, we plan to develop a graphical interface to the system (which is implemented in LISP). This should enable us to test the extent to which students agree with the

relevance decisions of the system, whether the dialogues are perceived to be coherent, and the extent to which conflicts which arise can be resolved.

Postscript

In the context of a collection of papers on "New Directions in ITS", we would like to propose a relatively new direction. Amongst current directions, we have a view of the ITS as 'guide', 'collaborator', 'tool', 'learning environment', 'domain expert', and so on. Each view has its own educational, philosophical, psychological and sociological theories, with its own answers concerning the most effective means for achieving its educational goals. All of these approaches do, however, have something in common : they assume that the student(s) will learn *during the interaction with the computer*. We would like to raise the question as to whether this needs to be the case - are one-to-one interactions of an hour or less duration between students and tutors in higher education and adult training principally concerned with *learning*, or are they rather concerned with assessing progress, negotiating new appropriate learning goals and motivating the student to achieve them outside that interaction ? An answer to such a question relies crucially on our assumptions concerning the social educational setting of computer use. Thus understood, we believe that the two viewpoints on negotiation discussed at the beginning of this chapter are in fact essentially complementary. We propose as a direction for ITS research that the computer may be viewed as a *negotiator of appropriate learning goals*, and *manager of the students' motivation to achieve those goals* in the wider educational context. Such a direction for ITS requires fundamental research on both the cognitive processes underlying negotiation in educational interactions and the wider social context within which educational goals may be achieved.

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