Modeling and Guiding Cooperative Multimodal Dialogues

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Abstract

In this paper we claim that a consistent conversational approach to human-computer interaction can be applied feasibly to multimodal interaction. A comprehensive conversational model is presented that covers interrelated levels of the dialogue structure, i.e. illocutionary, rhetorical, and topical aspects. It thus provides the basis for a consistent interpretation of the linguistic as well as graphical actions of both participants during the ongoing dialogue. The model comprises a descriptive part capturing local dialogue tactics and the possible patterns of exchange. In our prototypical information system MERIT we have integrated another prescriptive part that relates sequences of dialogue contributions to global information-seeking strategies and allows a dialogue to be guided by dialogue scripts.

1 Introduction: Multimodal Conversation

Historically, the two major existing user interface metaphors, the "model world" and the "conversation" metaphor, were associated with divergent views of human-computer interaction promoting different interaction styles (cf. e.g. Hutchins 1989). *Direct manipulation interfaces* adopt in general the view of a computer system as a "tool" that can be used to manipulate virtual objects located in space. Objects and actions on these objects (e.g. clicking, dragging) are modeled and performed graphically. The user can thus invoke complex system operations and at the same time gets the impression that her graphical operations have immediate observable effects. Thus, the distance between the user's intentions and the objects she manipulates is reduced to a minimum (cf. Hutchins, Hollan & Norman 1986).

On the other hand, *dialogue-oriented interfaces* based on the conversation metaphor promote the view of a computer system as a "partner". The user's actions are seen as a conversation with an intelligent intermediary/ assistant that has the task of interpreting the user's commands or intentions. Cooperative conversation has mostly been investigated in the field of natural language interfaces for information systems, tutoring systems, and explanation components (cf. e.g. Carenini & Moore 1993, Moore 1989, Paris 1990; for surveys see McCoy et al. 1991, Perrault & Grosz 1986).

In our approach to modeling cooperative multimodal dialogues we propose to disentangle the direct coupling of the major metaphor with a prominent interaction style. Instead, we claim that a consistent conversational approach to human-computer interaction can be applied feasibly to a hybrid interaction style. To this end, we have developed a comprehensive conversational model that is based on an extended notion of 'dialogue acts'. In this model, linguistic as well as non-linguistic (graphical, deictic) user actions are interpreted as *communicative actions* (cf. Perrault 1989), the complete interaction is referred to as *'multimodal conversation'* (cf. Stein & Thiel 1993). Similarly, the system's generation or modification of graphical objects are interpreted as conversational contributions to the ongoing (visual) dialogue. An object-oriented presentation allows users to investigate information items directly. In critical situations, for instance, such visualizations are to be complemented by cooperative system responses in natural language. Recent approaches of combining graphics and natural language explanations in multimodal user interface systems have been worked out for various application areas (cf. Arens & Hovy 1990, Feiner & McKeown 1990, Maybury 1991, Stock 1991, Wahlster et al. 1991). While all of these systems exhibit a varying degree of user-adaptivity, only some of them include elaborated dialogue models. AlFresco, for instance, uses both an interest model of the user which is continuously updated as the discourse proceeds and a simplistic dialogue grammar which describes the possible interactions.

2 The Conversational Interaction Model

In this paper, we introduce a comprehensive conversational model for structuring, planning, and controlling information-seeking dialogues between a human user and an information system. It models the temporal structure of dialogues by providing an abstract, modality-free representation of 'dialogue acts' which can be realized by linguistic and/or non-linguistic means such as direct graphical manipulation. The proposed model consists of two parts, first, covering the *illocutionary* and *rhetorical* and, second, the *topical* aspects of the interaction (whereas the semantic and syntactic aspects are only discussed as far as needed). The illocutionary components of dialogue moves and exchanges are described by a formalism called the "Conversational Roles" (COR) schema (see section 2.1). It models the conversational *tactics* and *mutual role-expectations* of speaker/ hearer, and information seeker/ information provider on a formal level. This speech-act oriented part of the dialogue model has been extended and refined by adopting concepts of Rhetorical Structure Theory (RST, Mann & Thompson 1987) in order to describe the links which establish coher-

ence between dialogue moves (see section 2.2). The second part of the model takes into account the global information-seeking *strategies* pursued by the participants; it structures a dialogue by using case-based dialogue plans (see section 2.3). These dialogue plans or scripts are prescriptive in that the user is suggested a meaningful order of dialogue steps or iterative cycles to pursue a certain strategy which has been selected/ negotiated before. Experiences with the conversational approach applied in the MERIT system and lessons learned will be presented in the last section.

2.1 Conversational Roles and Tactics

A formal description of information-seeking dialogues at the illocutionary level is provided by the "Conversational Roles" (COR) schema (for a detailed discussion of the schema see Sitter & Stein 1992, Stein & Thiel 1993). It was developed and later refined by exploiting results from analyses of a corpus of information retrieval dialogues. COR served as a basis for the design of the MERIT interface prototype (see section 3). According to speech act theoretic terms, dialogue contributions are characterized primarily with respect to the purpose (illocutionary point) the "speaker" expresses by her contribution, e.g. to get the addressee to do something, to make or withdraw a suggestion. Thus, the speaker's and addressee's mutual expectations about possible responses and about the subsequent course of the dialogue are central. It is assumed that both conversational participants have goals and plans to achieve these goals. The system's task is mainly to assist the user in expressing her goals. System and user cooperate in devising a strategy to reach the goals.

COR defines the generic dialogue acts available, e.g. *request*ing or *offer*ing information, *reject*ing offers, *withdraw*ing commitments, etc. COR then describes their possible order in dialogues, i.e. sequences of moves (dialogue acts) and of dialogue cycles. The COR model can be represented as a recursive state-transition network (see figure 1) where nodes mark 'dialogue states' and arcs signify 'dialogue acts' of the discourse participants. Note that the network is recursive in that the arcs are also state-transition networks (see figures 2 and 3 below) which may contain – among other transitions – also dialogues of the basic schema. Additionally, dialogue acts define both the role assignment between information seeker and information provider and the changes of those roles that may occur in certain dialogue situations, e.g. in clarification dialogues.

The net represents the full potential of all possible interactions where successfully completed dialogue contributions (acts) end in specialized states (indicated by a circle). The traversal of the graph stops in states which are marked by squares. State <5>, for instance, is reached when the information seeker has expressed contentment with the given information and quits the dialogue. States <6> to <11> are also terminal states, but here the information need could not be satisfied. Note that a dialogue which ends in one of these states can be well-formed, complete, and cooperative (e.g. a request of A has been rejected by B because the requested information was not available). The transition of the arcs, i.e. the execution of the dialogue acts, is linked to the fulfillment of so-called "*felicity conditions*" (cf. Austin 1962, Searle 1969). The COR model was influenced by the "Conversation for Action" model proposed by Winograd and Flores (1986) where discourses are interpreted as "negotiations". We extended and refined this action model for the genre of information-seeking dialogues. Thus, a more flexible way of interaction has been achieved allowing both dialogue partners to pursue certain dialogue tactics, e.g. correcting, withdrawing, or confirming their intentions as well as inserting subdialogues for clarification (e.g. dialogues for "soliciting context information", cf. figure 2 and 3).

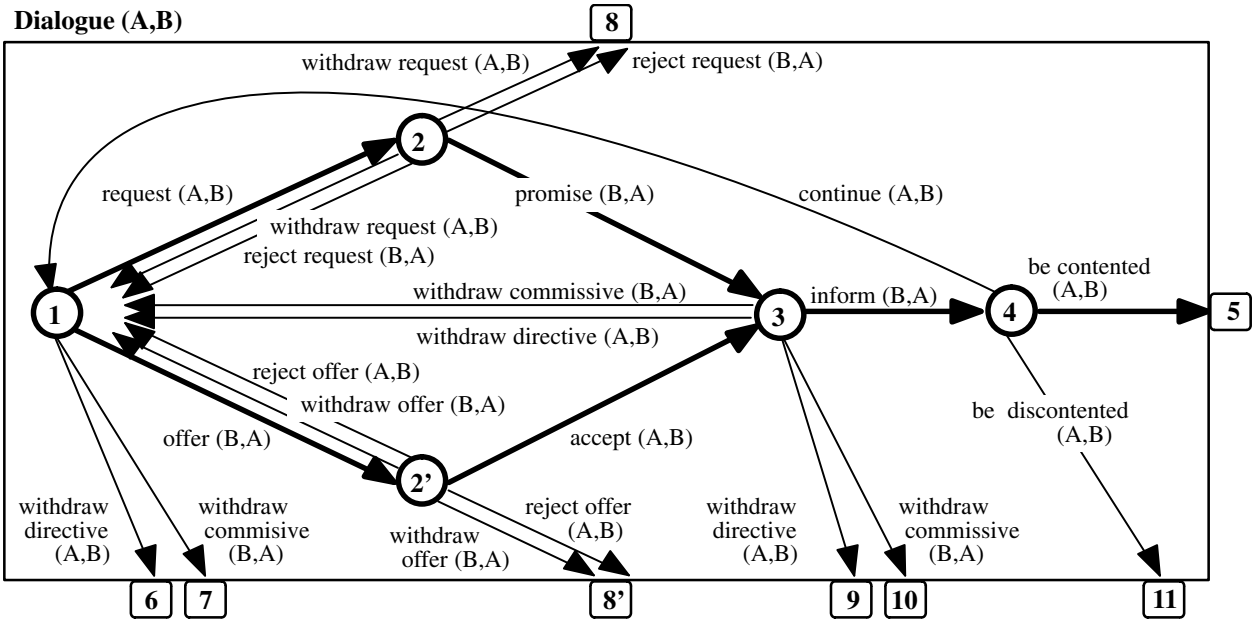

Figure 1: The basic COR 'dialogue' schema

directives: request, accept;
commissives: offer, promise

2.2 Discourse Structure Relations

The COR schema as proposed in the previous section allows the description of expectations and interactions of two partners in a situation of information seeking. Still, the basic schema does not provide a sufficiently detailed description of really encountered information-seeking dialogues, where unexpected reactions might occur and misconceptions must be resolved. In order to cope with such cases, where additional information has to be exchanged in order to present unknown information or to clarify misconceptions, an extension of the basic schema is necessary.

The presentation of additional information and the exploration and clarification of previous dialogue contributions increase the probability of the success of the dialogue. Nevertheless, such moves are always *subordinated* to the purpose of the dialogue contribution itself. The part of the dialogue contribution which expresses the (illocutionary) *point* of the whole contribution is called the *"nucleus"*. The other part, addressing supplementary contextual information, is called the *"satellite"*. These terms have been adopted from RST, which until recently has only been applied for the description of monologues. The occurrence of such subordinated dialogue contributions can also be expressed by state-transition networks, thereby allowing for a recursive traversal of the graph shown in figure 1. The dialogue schemata in figure 2 and figure 3 show two representatives of such embedded dialogues.

In the schemata the inform and request acts (A: inform; A: request) represent the nuclear steps of the dialogue, while the dialogue acts which are used to supply or request additional context elaborating on information mentioned before are satellitic. In general, the nuclei expose a higher degree of relevance than the satellites as far as their importance for the superordinate dialogue act is concerned.

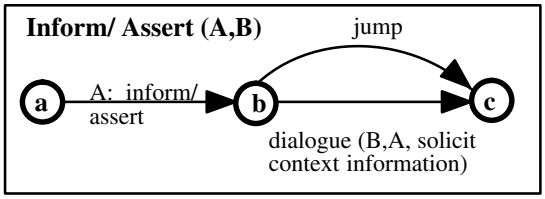

Figure 2: Schema of an 'inform' ('assert') contribution

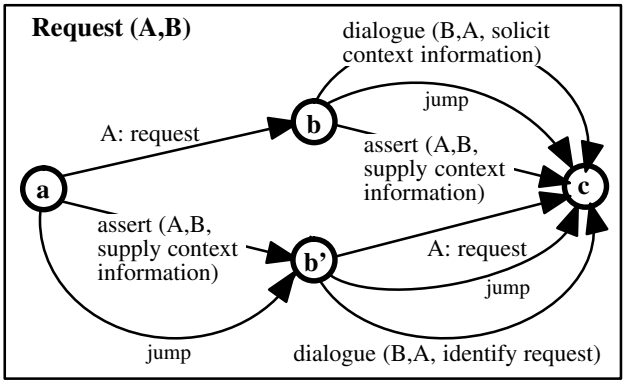

Figure 3: Schema of a 'request' contribution

In the following we sketch an example for the possible embedding of a subdialogue. In the dialogue setting as given in figure 4 below the user had asked for information about projects dealing with multimedia systems. This promotes the dialogue to state <2> in the basic COR dialogue schema (see figure 1) traversing the *request* arc. The system, being able to supply the requested information (*promise*) displays a list of projects fulfilling the requirements. To do this, the *inform* subschema has to be traversed. After presenting the information – the dialogue is now in state b of the subschema depicted in figure 2 – the model offers various options to continue: the user can start a *subdialogue* in order to request new information or she can change the presentation form (see options and graphical objects such as the menu "change presentation form" in figure 4). After the successful conclusion of the subdialogue the superordinate *inform* act is completed and the dialogue has reached state <4>.

The compatibility of basic concepts of COR and RST can be exploited to extend the power of the dialogue model even further: RST provides a framework to treat the possible relations between nuclei and satellites, i.e. between a dialogue act and its subordinated context. This enriches the framework of the COR model – which foresees sequential order as the only relationship between dialogue contributions – by a set of semantic and pragmatic links which describe *how* discourse units are connected.

The requirements of the application, on the other hand, make the extension and specialization of the relation set as proposed by RST necessary. As pointed out in Maier & Hovy (1993) the set of proposed relations needs to be augmented significantly in order to handle the possible links occurring in dialogues – this is particularly true for the subset of the so-called *interpersonal relations*, which are mainly concerned with aspects related to the discourse participants. On the basis of a small set of analyses new relations for the description of information-seeking dialogues have been found. For example, between two moves different ways of providing additional information could be observed, which motivated the introduction of two new relations of the type *"background"* (for more details see Maier & Sitter 1992).

The use of discourse structure relations for the description of man-machine interaction has additional advantages for the automatic generation of natural language output: relations can be used for the inclusion of *linguistic clues* (e.g. conjunctions), which help the reader significantly to recognize the existence and the nature of links between discourse units and thereby support the construction of coherence on the part of the user.

2.3 Dialogue Scripts

Information-seeking activities such as search and retrieval in databases are to be seen as 'interactive processes' (cf. Belkin, Marchetti & Cool 1993). We assume that in the search and navigation process the user initially has only vague ideas about her information need. Also, in most situations there is no objective underlying task-structure which strictly determines the order of navigational steps. The information seeker may change her intentions or the thematic focus during interaction. An intelligent system should be

capable to cope with topic shifts and changing user-strategies. At the same time it is important to facilitate the user's construction of cognitive coherence by adequate guidance and to design a system that can engage in a meaningful cooperation with the user.

The COR schema presented above covers the formal structure of dialogues, but does not supply any means for identifying information-seeking and problem-solving strategies that can be offered to the user. Therefore, another – orthogonal – level is to be provided in order to assist the user cooperatively in fulfilling her task. We need criteria and methods for deciding which of the possible dialogue acts described by COR should be given preference in a given problem domain or application. For the situation of information-seeking dialogues, we assume that prototypical action sequences can be identified in the form of 'scripts' which correspond to certain information-seeking strategies.

Belkin et al. suggested a classification of information-seeking strategies (ISSs) by using multiple dimensions (cf. Belkin, Marchetti & Cool 1993). On top of this classification, a set of typical dialogue scripts related to the ISSs was developed for a given domain and task (cf. Belkin, Cool, Stein & Thiel 1993). A script is a representative of a specific class of dialogues or of a specific dialogue sequence. During interaction, several scripts can be combined to longer sequences which are to be provided by the system as a *dialogue plan* which guides the user through interaction. In addition, an actual dialogue contains iterations, inserted clarifying sequences etc. The actual course of a dialogue can be seen as a concrete 'case', i.e. an instantiation of a dialogue plan, that can be stored by the user as a new case after the session (cf. Tißen 1993).

One sample script defined for interaction via *searching*, with the goal of *selecting*, by *specification*, in an *information* resource can be roughly described as follows (cf. Belkin, Cool, Stein & Thiel 1993): After an introductory sequence common to all dialogues, where the global strategy/ starting point is negotiated, the user can pose a query to the database, i.e. a request that can be paraphrased as follows: "Search for objects of the class ... which have the following features: ...." (e.g. the user may insert search terms in a graphical query form, click on icons representing possible search terms, or select terms from a menu). The system indicates when no item can be found and suggests alternative strategies or it presents the items found (inform act performed by graphical and/or textual presentation forms, tables, pictures, or videos). The user gives feedback about the item she is interested in (e.g. by pointing at an item); she is then asked whether an item is to be stored, or if she likes to see more detailed information about one item (request for more context information); etc. This example demonstrates how dialogues are represented as well-formed sequences of dialogue steps that correspond to transitions of the COR schema and at the same time offer a meaningful topical and strategic structure.

It is interesting to note that another analogy to observations made in text linguistics can be drawn. As the main concepts behind COR and RST are very similar and both models therefore compatible, the idea of scripts for the description of prototypical action sequences resembles very much what has been termed *Generic Structure Potential* (GSP) in Systemic Functional Linguistics (Halliday & Hasan 1989). GSPs are descriptions of conventionalized patterns of social interaction, which have been used, for example, to model sales encounters. Recently, the interdependencies between discourse structure relations and Generic Structures have been made more transparent. It has been shown that in every element of a GSP or – in the terms used here – in every action or step of a script certain relations are preferably used while others only very rarely occur (cf. Hovy et al. 1992). If we apply these findings to the interrelationship between COR and scripts, we can assume that the elements of scripts already constrain the possible transitions in the COR network and also restrict the number of applicable relations. It is a topic of future research to examine this interrelationship in more detail.

3 Lessons Learned: the MERIT System

First experiences of guiding the user by case-based dialogue plans were made with our prototypical system MERIT – "Multimedia Extensions of Retrieval Interaction Tools". MERIT is a knowledge-based user interface to a relational database on European research projects and their funding programs (cf. Stein, Thiel & Tißen 1992). The database contains textual and factual information complemented by interactive maps, scanned-in pictures, and audio files. The interface permits form-based query formulation and situation-dependent visualizations of the retrieved information in various graphical presentation forms. One major system component is called CADI – "Case-Based Dialogue Manager" (cf. Tißen 1991). It provides a library of 'cases' stored after previous dialogue sessions, which the user may access by using a case-retriever component. In an alternative mode, the user is offered a preselection of cases in the introductory phase of the dialogue. Once a case has been selected, the user is guided through the session in that she follows the suggested sequence of query- and result steps by simply clicking on a 'continue icon'. The user can also depart from that suggested path by, e.g., going back to a previous state of the dialogue history (by clicking on an icon representing a state), by changing the case, inserting a meta-dialogue or a short retrieval dialogue, etc.

These variety of options in every step of the dialogue can be interpreted consistently as conversational actions in terms of our model. Whereas in other advanced graphical user interfaces options such as undo, history, and help functions are not modeled as an integral part of the dialogue, but as separate extensions, in MERIT they are represented explicitly by the underlying dialogue model in the dialogue knowledge bases. There are, for instance, several local options such as "help", "change presentation/ content of presentation" which are visualized by special dialogue icons (see figure 4). The user's manipulations of these icons are interpreted as requests initiating a sub-dialogue to solicit context information (e.g. a paraphrase of a given information). "Continue", "withdraw (a step)", "reject offer" also comply with transitions of the COR schema. Other (global)

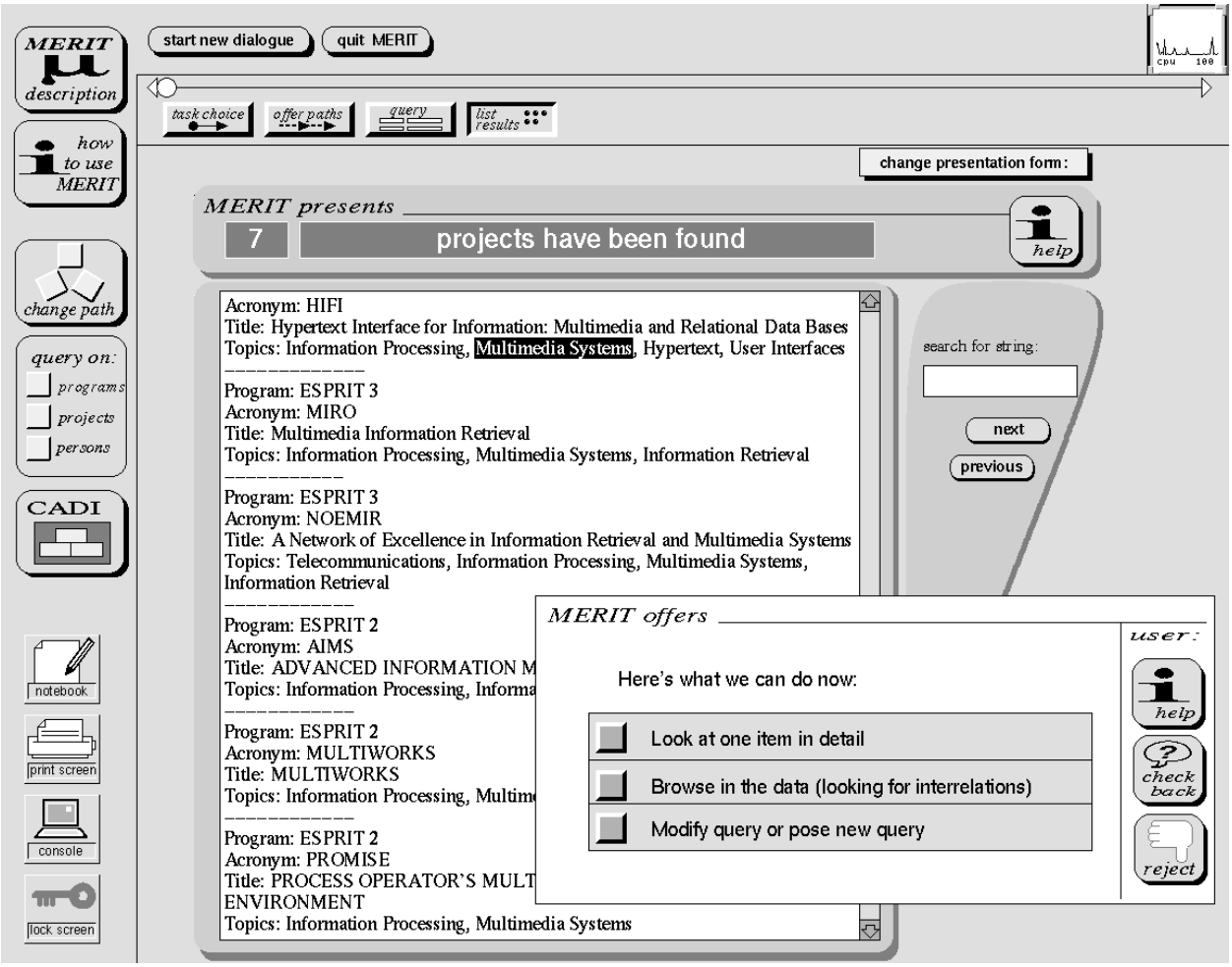

Figure 4: Sample Screen

options such as "history" and "info on next step" offer the possibility for inserting meta-dialogues (for a more detailed analysis with sample screendumps from MERIT see Stein & Thiel 1993 and Stein, Thiel & Tißen 1992).

Some preliminary user-tests with this MERIT version indicated, however, that the users had sometimes difficulties in understanding the 'logic' of the order of steps in a case. Therefore, an alternative MERIT version is currently being implemented, where more abstract dialogue 'scripts' are used to structure the dialogue, and cases can be seen as instantiations of such scripts. They model not only the sequence of query- and result steps like in the former version, but also model feedback sequences explicitly, e.g. the insertion of a sub- or meta-dialogue for negotiating the strategies or tactics of subsequent dialogue steps. Figure 4 displays a sample screenshot that may occur in such a situation. Here, an inform act of the system was shown first ("MERIT presents ..."), then the user clicked on the continue icon (not visible) and finally got an offer of how she might proceed in the dialogue ("MERIT offers ..."). In contrast to the previous MERIT version, the user does not – after having pressed "continue" – get the next query or presentation form defined by the current case, but first gets the opportunity for choosing a strategy to pursue, possibly activating a new script.

In addition, we are currently integrating in MERIT a text generation component based on the Penman system (cf. Bateman et al. 1991) in order to enable the system to generate context information in natural language, e.g. for assisting the user in her query formulation. Our experiences with the first MERIT version indicate that graphical information often does not provide sufficient support to users – particularly when problematic situations arise, or system responses do not conform to the user's expectations. Based on previous work on the coordination of text and graphics in explanation generation (e.g. Feiner & McKeown 1990), we assume that text is the appropriate medium for inform acts in meta-dialogues and many clarification dialogues, since they require a discussion of abstract entities or qualities, e.g. misconceptions. In particular, the flexible generation of natural language is needed to enable the system to engage in meta-dialogues with the user about her possible problems in understanding the consequences of dialogue actions, e.g. a specific query or the selection of a new dialogue script.

4 Conclusions and Future Work

In this paper we have presented a comprehensive conversational model that combines interrelated levels of the user's and the system's actions, i.e. illocutionary, rhetorical, and topical aspects. It captures local dialogue tactics describing the possible patterns of exchange and connects these local patterns to global information-seeking strategies. The integrated model provided the basis for the dialogue manager of the information system MERIT, which allows graphical actions as well as linguistic responses to be interpreted in a consistent way as 'communicative acts'. Different variants of the MERIT user interface featuring different interaction styles (e.g. highly structured vs. poorly structured interaction) are currently under development. Comparative evaluations will be carried out to get more empirical evidence about the use of these different approaches. The leading hypothesis is then that interaction in variants with more options for interactive feedback and clarifying exchanges will be more effective and better accepted by the users – particularly in poorly defined problem situations and complex information-seeking tasks.

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