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Dialogue Control Functions
and
Interaction Design

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Dialogue control functions and interaction design

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Abstract

This paper is concerned with the design of interactive teaching systems from the point of view of dialogue theory.

It is argued that *transparency* and *naturalness* are important qualities of a dialogue for the student, helping him to concentrate on the learning task (thanks to naturalness) and to understand his own performance (thanks to transparency). It is argued that these qualities are also important for system design, since they result in student communicative behaviour that is easier to understand.

A concise, non-technical description is provided of the framework of *Dynamic Interpretation Theory*, an approach to dialogue developed especially for information dialogues. On this approach, a dialogue is viewed as a sequence of complex elements of communicative behaviour, intended to change the dialogue context. The elements of communicative behaviour are analysed as simultaneously expressing a variety of 'dialogue acts'; dialogue acts being defined as the functional units used by the speaker to change the context. Based on a fairly detailed analysis of the notion of context which is relevant here, a system of communicative functions of dialogue acts is developed with a focus on 'dialogue control' functions, i.e., functions specific to the management of the interaction.

It is argued, and illustrated with some examples, that the understanding and application of the notions of transparency and naturalness can benefit from using the concepts of Dynamic Interpretation Theory, and that these concepts are also of importance for the construction and maintenance of adequate student models by the system.

Keywords: dialogue theory, dialogue act, dialogue control, context analysis, transparency, naturalness

1 Introduction

As interactive teaching systems are concerned with a particular form of systematic, goal-driven interaction, their design could benefit from what we know about the general principles and mechanisms governing natural goal-driven dialogue. We deliberately use the phrase 'natural dialogue' here, rather than 'natural *language* dialogue', since communication in natural settings is not purely linguistic in nature but multimodal; when speaking, people use paralinguistic devices such as laughs, coughs, and sighs, as well as intonation, and nonlinguistic means such as gestures, mimics, and direction of gaze in order to effectively perform the desired communicative functions. The use of these devices depends on properties of the communication situation, properties that range from technical conditions, such as the available media, to social characteristics. For example, in a telephone conversation the technical conditions rule out the effective use of gestures, mimics, and other visual cues; more socially determined is the phenomenon that in an information-seeking dialogue at an information desk one finds little use of laughs and shoulder clapping, compared to the situation of running into an old friend.

The interaction between a computerized teaching system and a student commonly bears some resemblance to telephone conversation in that the system has no visual channel for communication. It also has features in common with the natural information dialogue, in being matter-of-fact and lacking some of the 'social' and emotional aspects of other, less formal forms of interaction, and also in being driven by a well-defined goal which is intended to be reached effectively and economically.

In this contribution we discuss some of the central concepts of dialogue analysis according to a theoretical framework called *Dynamic Interpretation Theory*, developed especially to deal with information dialogues, with an eye to their potential importance in the design of interactive teaching systems.

2 Dialogue theory and teaching systems

One of the most important aspects of designing an interactive teaching system is designing the interaction, i.e., the *user interface*. A user interface is a gateway for two-way information traffic between user and system. We argue in this paper that it can be advantageous for both system and user to develop the user interface on the basis of well-founded general principles

for systematic, goal-driven communication.:

1. For the user, it can facilitate the development of a communication form that is transparent and natural to him;
2. For the system, it can support the construction and maintenance of adequate student models by the system.

We consider these advantages for each side of the user interface in turn.

2.1 The user side

Transparency

Concerning the advantages for the user, *transparency* of the user interface means that the user is offered a clear view of the system activities concerned with the teaching task. The student can thus understand the system's communicative behaviour in relation to aspects of the teaching and learning. Understanding the system's behaviour may be advantageous for two reasons:

1. It permits the student a view of how the system views the progression of the teaching/learning task; this may help the student to understand his learning performance.
2. It provides the student optimal information as to what kind of actions the system expects him to perform.

The first of these advantages concerns the educational task, which can be facilitated by not only the teacher (system) but also the student (user) having a model of the current state of the task, a model that may be more explicit and more accurate by seeing the system's model than it would otherwise be (notably, on the basis of mere introspection).

To appreciate the second advantage, we should bear in mind that the system's (and the student's) communicative behaviour is the result not only of the teaching/learning task to be accomplished, that is of the application of a *didactic strategy*, but also as the result of applying a *communicative strategy*. Didactic goals have to be turned into communicative goals and communicative effects have to be interpreted in terms of didactic effects, with the result that didactic and communicative planning and interpretation are intertwined; moreover, communicative events by themselves can trigger other communicative events, not directly relating to didactic goals.

Transparency of the user interface allows the student to see what motivates the system's communicative actions, and thus to have an optimal understanding of what he is expected to do and why.

Naturalness

The notion of *naturalness* concerns a quality aspect of human-computer dialogue, particularly from the user's point of view. There are two sides to naturalness, relating to the system's and the user's communicative options. We will say that a dialogue has a high degree of naturalness if it has the following two properties.

1. The user's communicative options are natural to him in the sense that he is not put under obligations to perform communicative actions he would find unnecessary or irrelevant, nor does he have to observe restrictions forcing him to wriggle in order to achieve his goals.
2. The system's communicative behaviour is natural to the user: he is not required to explicitly devote effort to interpreting the system's behaviour; it comes to him as obvious.

Naturalness and transparency in a well-designed dialogue go hand in hand and enhance each other; nonetheless, they correspond to different aspects of the quality of a dialogue interface.

Transparency relates to the possibility to 'look through' the communicative behaviour; it deals with the quality of the coupling between communicative activities and the underlying teaching activities (activities such as assessing the correctness of a student response, selecting a test, diagnosing a student error, etc.). Naturalness, on the other hand, is a quality aspect of the dialogue design ensuring that the student is not required to devote specific effort to interpretation and generation of communicative actions; in a natural dialogue, the student can concentrate all his efforts on the learning task. In particular, he can communicate about his learning activities in what is for him the easiest, most natural way.

2.2 The system side

Student Modelling

For an interactive teaching system to act sensibly and flexibly, taking the student's behaviour adequately into account, it must base its actions on a model of what the student knows (including any mistaken beliefs), what

actions he performs well, etc. In relatively simple teaching systems, system actions are related *directly* to student behaviour rather than via an explicitly constructed student model ('If student does X, then do Y'); this relation incorporates implicit assumptions on what the student's behaviour signals about his current state of beliefs and competence, as well as about appropriate actions to perform, given that state.¹ The implicitness of these two kinds of assumption imposes two important limitations on such systems:

1. the system is unable to separately investigate or reason about the student's current state;
2. the system is not in position to derive its teaching actions from the application of a reasoned didactic strategy to the current state of the learning task.

More sophisticated teaching systems build up and maintain an explicit student model, often using the dynamics of this model and its comparison with an ideal student model to determine appropriate continuations of the interaction (see e.g. Sleeman, 1984; Sleeman & Brown, 1982; Kearsley, 1987). The quality of such systems clearly depends on their success in understanding student behaviour as a basis for constructing a student model. Since good understanding of student interactive behaviour is hardly possible without an analysis process based on knowledge of the general principles for rational and purposeful communicative action, it follows that the system may benefit from principle-based dialogue design in important ways:

- A principle-based dialogue, as opposed to one that is 'engineered' in an *ad hoc* fashion, is more natural to the student as he is allowed to act according to the general principles for communicative action - which is precisely the natural thing to do.

Increased naturalness of the student's behaviour is advantageous for the system, as it can rely in its analysis of student interactive behaviour on the application of well-tested generally valid principles. The communicative behaviour of the student in a dialogue with an *ad hoc* design is more difficult to interpret, since the student in this case will often have to act in unusual ways, not corresponding to well-established ways of signalling aspects of one's cognitive state. In sum,

¹On this approach, often no clear distinction is made between teaching actions and communicative actions, although this distinction is crucial from the point of view of transparent user interface design.

natural dialogue behaviour is easier to understand and allows for a more generic system design.

- The principles for rational, purposeful cooperative dialogue involve relations between communicative activity and the underlying noncommunicative goals and activities, in this case of the teaching/learning task. More specifically, the use of particular communicative acts in order to signal the speaker's state of beliefs, disbeliefs, and other attitudes, is governed by general principles allowing the interpreter to reconstruct the relevant aspects of the speaker's cognitive state. These principles and their application to the specific kinds of communicative act, relevant in the interaction between student and interactive teaching system, form an essential part of the basis for constructing and maintaining articulate student models.

Having looked at both the user side and the system side of the advantages of designing the dialogue between the two according to general principles of rational, purposeful cooperative dialogue, we now turn to these principles and the conceptual framework of *Dynamic Interpretation Theory*, in which they are developed.

3 Dynamic Interpretation Theory

In Dynamic Interpretation Theory we view dialogues in an action perspective and communication as a way to bring about changes. Communication leads, first of all, to changes in what each participant knows about the other; we might call this changes in *cognitive context*. However, communication may also affect other aspects of the context besides the cognitive dimension. In the next subsection we briefly look at the various aspects of dialogue context in relation to potentially being affected by communicative activity.²

3.1 Dimensions of dialogue context

The term 'context' is used in many different ways in the literature about (linguistic) communicative behaviour, ranging from referring to the preceding text to referring to the goals of the underlying task. What is common to the various uses of the term 'context' is that they all refer to *factors, relevant*

²Much of the remainder of this section is material from Bunt (1994), and Bunt (1993), in a condensed and simplified form.

to the understanding of communicative behaviour. We believe that these factors can be grouped into five categories: the *linguistic*, *semantic*, *physical*, *social*, and *cognitive context*. Moreover, for each of these 'dimensions' of context we may fruitfully distinguish between *global* aspects, determined at the beginning of the dialogue and remaining constant throughout, and *local* aspects, whose values develop and change as the dialogue proceeds, and which have a momentary significance in determining the continuation of the dialogue. Some of the most important global and local aspects of these context dimensions are the following.

Linguistic context.

With the term 'linguistic context' we refer to properties of the surrounding linguistic material (textual or spoken). 'Linguistic' should be taken in a very broad sense here, including prosodic properties and use of nonlinguistic sounds in the case of spoken interaction, and interpunction, use of italics, graphics, and other visual elements in the case of textual interaction.

- *Global aspects*: what, if anything, the participants have said (or written) to each other on previous occasions; the language they speak;
- *Local aspects*: the surrounding linguistic (textual or spoken) material; raw material as well as relevant properties, detected by its analysis.

Semantic context.

The semantic context is formed by the underlying task and the task domain (the objects, properties and relations relevant to the task).

- *Global aspects*: the underlying task as a whole, in particular its overall goal; global characteristics of the task domain;
- *Local aspects*: specific facts in the domain of discourse; the current state of the underlying task.

Physical context.

The physical dimension of dialogue context comprises the physical circumstances in which the interaction takes place.

- *Global aspects*: place and time; the question of whether there is eye contact between the participants; the communicative channels that may be used; the presence or absence of third parties;

- *Local aspects*: current availability of communicative channels and, in the case of communication at a distance or through electronic devices, the presence of the partner at the communicative device.

Social context.

By 'social context' we mean the type of interactive situation and the roles of the participants in that situation, with their specific communicative rights and obligations.

- *Global aspects*: the 'dialogue genre': the type of institutional setting in which the dialogue occurs, or the type of communicative event that the dialogue represents; the roles of each participant in the event or setting; the relative social status of the participants (employer and employee; teacher and pupil; shopkeeper and customer);
- *Local aspects*: the communicative rights and obligations that each participant has at a given point in the dialogue, including the right or obligation to say something at a given moment, and the right or obligation to perform a communicative act with a specific form and function.

Cognitive context.

The 'cognitive context' comprises the participants' beliefs, intentions, plans and other attitudes; their states of processing relating to perception, production, interpretation, evaluation, dispatch (such as carrying out an instruction or fulfilling a request), and their attentional states.

- *Global aspects*: overall communicative goals of each participant; the question which participant, if any, has expert knowledge about the task;
 - *Global aspects*: overall communicative goals; the question which participant, if any, has expert knowledge about the underlying task;
 - *Local aspects*: current participants' beliefs, intentions, and other attitudes; plans for performing the underlying task and for continuing the communicative task; participants' states of processing; current attentional states; active discourse topics and their relative salience.

Communicative activity in itself cannot accomplish a change in physical circumstances, nor can it directly change the state of the underlying task and its domain of discourse. Directly, communicative actions can only change the linguistic context, the knowledge of an interpreter, i.e. the cognitive context, and local communicative rights and obligations, i.e. local social context. Indirectly, in principle every aspect of the context can be changed through the dialogue. However, some aspects are more readily changed than others. In general, the local aspects of each context dimension change much more readily than the global aspects.

3.2 Local context change

The first and most obvious contextual changes that communicative actions may bring about concern new information becoming available to the hearer, i.e., they change the local cognitive context. We will often speak of hearer *beliefs* rather than *information*, to avoid the connotation with factual truth. The beliefs that a hearer builds up on the basis of his interpretation of the speaker's communicative actions are, initially, always beliefs about the speaker; indirectly, they can relate to any of the context factors listed above. For factual questions and answers, the beliefs generated indirectly in the interpreter concern the underlying task and its domain of discourse, and are thus part of the *local semantic context*. For feedback utterances, the beliefs generated concern *only* the local cognitive context: beliefs about the speaker's processing of the other's previous utterances.

Secondly, a communicative act may create 'social obligations' for the hearer. For instance, when the speaker greets the hearer, he thereby puts a certain pressure on the hearer to respond with a return greeting. Similarly for introducing oneself, for apologizing, and for thanking, where utterances like "*Thank you*" create a pressure to say something like "*You're welcome*"; we refer to such pressures as '*reactive pressures*' (Bunt, 1991).³ Resolving

³We think this term is more appropriate than other terms found in the literature, such as communicative 'obligations' (Allwood, 1994); 'adjacency pairs' (Schegloff & Sachs, 1973), and 'preferred organization' (Levinson, 1983). 'Obligation' is slightly too strong, as the 'obligating' utterance does not really *oblige* the addressee to respond in the 'obligated' way. 'Adjacency pair' is also too strong, since the two elements of the pair do not really have to be adjacent, and in fact the second element does not necessarily have to appear at all. 'Preference organization' would seem to have the right kind of strength, but this term belongs to a structural framework of dialogue analysis, where the term 'preference' is not meant to have a cognitive interpretation (Levinson, 1983, p. 332-333). Our approach, by contrast, does have a strong cognitive orientation and considers reactive pressures to be

reactive pressures is one of the basic mechanisms in dialogue, besides acting on the basis of intentions. Creating and resolving reactive pressures are ways of changing the *local social context* of the dialogue. Taking turns in a dialogue is also a case of creating and resolving a kind of reactive pressure; when a speaker indicates that he considers his turn to be finished, for example, he puts pressure on his partner to take over.

Finally, and trivially, a communicative action changes the local linguistic context. This aspect of utterances is only rarely addressed explicitly in dialogue; it comes to the fore most clearly when there is uncertainty or disagreement about what one of the partners has contributed to the dialogue (“*Did you say ‘Thursday’?*”; “*But you said...*”).

3.3 Dialogue acts

Communicative behaviour, according to Dynamic Interpretation Theory, consists of expressions of communicative actions, aimed at changing the context in specific ways. We introduce the concept termed ‘*dialogue act*’ as the *functional units used by the speaker to change the context*. These functional units do not correspond to natural language utterances or other instances of communicative behaviour in a simple way, because utterances in general are *multifunctional*, as we will see below. The important point of the stipulation ... *used by speakers* is that we are not considering elementary update functions in a mathematical or computational sense, but update functions *that speakers try to perform* with their utterances. We therefore require every communicative function to correspond to features of communicative behaviour.

The most important aspects of a dialogue act are its *communicative function*, and its *semantic content*. In addition, a dialogue act is expressed through its *utterance form*, which determines the changes to the linguistic context that a dialogue act causes. The idea of the communicative function and semantic content is that the semantic content will have a particular significance in the new context, resulting from the performance of the dialogue act; the communicative function defines precisely what this significance is. The communicative function tells us how to update the context, given the semantic content. In other words, a communicative function is a particular context update function.

For instance, a dialogue act with the utterance form “*Does it rain?*”,

an aspect of the local cognitive context.

the communicative function YES/NO QUESTION and the proposition it is raining as semantic content, has the effect of adding the utterance *Does it rain?* to the linguistic context, and creating in the addressee (among other things) the belief that the speaker wants to know whether the proposition it is raining is true.

Using the term 'utterance' to refer to everything contributed (said, keyed,...) by a speaker in one turn, an utterance may correspond to more than one dialogue act, and thus be multifunctional, for several reasons. First of all, an utterance may consist of several sentences or phrases that each express dialogue acts. So dialogue acts often relate to parts of utterances. Moreover, the expressions that carry functional meaning in terms of dialogue acts, typically carry more than one functional meaning simultaneously, due to the following factors.

1. Indirectness. A question like "*Do you know where John's office is?*" may function indirectly as a request to tell where John's office is.
2. Functional subsumption. Some dialogue act types are more specific than others. The promise "*I will come tonight*" is, besides a promise, also an informative statement.
3. Functional multidimensionality. Aspects of performing the underlying task are very often combined in one utterance with aspects of dialogue control.

As an example of functional multidimensionality, consider the utterance "*Thank you*". Used in reaction to an answer, the utterance not only expresses gratitude but also offers feedback information, since it implicitly indicates that the answer was understood and, by default, accepted; depending on intonation, it may in addition have a turn management function.⁴

Goal-driven dialogues, like instruction dialogues and information-seeking dialogues, by their very nature find their motivation in an underlying task that the participants want to carry out and for which the dialogue is instrumental. Since cooperative communication is an activity with its own rules, rights and obligations, two kinds of elements are commonly found in cooperative goal-driven dialogues: communicative actions motivated by the underlying task, such as instructions, questions, and answers, and actions motivated by the communicative task, such as acknowledgements, attention signals, self-corrections, and turn taking signals. We call these actions

⁴On multifunctionality see also Allwood et al. (1990).

task-oriented dialogue acts and *dialogue control acts*, respectively. Dialogue control acts, which include feedback acts as an important subclass, have a variety of functions in making communication smooth and successful, and are largely responsible for the naturalness of a dialogue.

The action view on communication obviously owes much to speech act theory (Austin, 1962; Searle, 1969). We use the term ‘dialogue acts’ rather than ‘speech acts’, firstly in order to avoid the association with pure linguistic, in particular spoken forms of communicative behaviour; secondly in order to restrict ourselves to those types of communicative act relevant in *dialogue*; thirdly to avoid the frequent confusion between the use of the term as referring to a linguistic token (‘locutionary act’, in Austin’s original terminology), or as referring to an abstract action denoted by the linguistic token (‘illocutionary acts’), or as referring to both together. The dialogue act concept is not situated at the linguistic level of words and phrases, but at the level of formal operations changing local aspects of the context. The idea to view communicative acts as context-changing operations has occasionally been suggested in the speech act literature (e.g., Gazdar, 1979; Isard, 1975), but has not been worked out to the point of formalization. In Bunt (1989; 1990) a proposal has been formulated for formalizing task-oriented dialogue acts in information dialogues in terms of context changes, context construed as the pair of the cognitive states (consisting of intentions and strong and weak beliefs) of the two participants. In what follows we will focus on dialogue control acts (‘DC acts’, for short), which have received much less attention in the speech act literature and in earlier work in Dynamic Interpretation Theory.

3.4 Dialogue control acts and task-oriented dialogue acts

In terms of context change, we can make the distinction between task-oriented and dialogue control acts precise as follows. Every dialogue act, when interpreted by the addressee, changes the cognitive context; the difference between a task-oriented (‘TO-’) dialogue act and a DC act is that the former only causes further changes in the *semantic context*, whereas a dialogue control act may cause changes in the social or physical context, but does *not* affect the semantic context.

Note that the TO/DC-distinction is primarily one between classes of dialogue acts, not between communicative functions. Although there are indeed communicative functions specific for dialogue control purposes, a dialogue control act can also be formed by combining a communicative function,

seemingly typical for a task-oriented dialogue act, such as INFORM, with a semantic content relating to some aspect of context other than the semantic dimension, as in “*I didn’t hear you*”.

We will refer to all those dialogue acts, formed with a communicative function concerned with information-seeking and information-providing, as ‘informative dialogue acts’, and we call their communicative functions ‘informative functions’. Depending on their semantic content, these acts are TO-acts or DC-acts.

Among the dialogue control acts, of particular interest are those that have communicative functions specific for dialogue control purposes. We call such functions ‘*dialogue control functions*’ or *DC functions*.

3.5 Dialogue control functions

To identify a communicative function, we have two criteria that follow immediately from the definition of dialogue act:

- the function defines a specific way of changing the context, which is elementary in the sense that this context change cannot be obtained through a combination of dialogue acts with other communicative functions;⁵
- specific features of communicative behaviour (notably linguistic or paralinguistic features of utterance forms) are used to refer to the context change defined by this communicative function;

This leads to the following clusters of DC functions in information dialogues, clusters being defined on the basis of similarity w.r.t. their associated utterance features or update operations, or both. Three major clusters of dialogue control functions are those concerned with *feedback*, *discourse structuring*, and *interaction management*. Each of these is subdivided into smaller clusters. For each cluster we provide a general description of the function and some characteristic utterance forms.

- **Feedback functions:**

Feedback is the phenomenon that a dialogue participant provides information about his processing of the partner’s previous utterances.

⁵This aspect of the definition of a communicative function can be expressed in terms of the preconditions for appropriate use of a dialogue act with that function; see further Bunt (1989) and Beun (1989).

This includes information about perceptual processing (hearing, reading), about interpretation (direct or indirect), evaluation (agreement, disbelief, surprise,...), and dispatch (fulfillment of a request, carrying out a command,...), and possibly other aspects of local cognitive context.

Feedback is either 'positive' or 'negative' in the sense that negative feedback messages report difficulties in processing, whereas positive messages report successful processing.⁶

Feedback is realized through a large variety of specific linguistic, paralinguistic and nonlinguistic means. Positive feedback is for instance expressed linguistically by "OK" or "Yes", paralinguistically by "Mmm", "Ah" and the like, and nonlinguistically by nodding.

- **Discourse structuring functions:**

Dialogue acts with a discourse structuring function serve to indicate the speaker's view of the state of the dialogue (local linguistic context) and his plan for how to continue.

Utterance forms: expressions for (sub-)dialogue delimitation include "OK then", "Now then", "Something else"; devices for topic introduction like "Now concerning John,..", "As for John,..".

- **Interaction management functions:**

- **Turn management functions:**

Dialogue acts with a turn management function put a pressure on the addressee to continue the dialogue, in the case of a TURN-GIVING act; to allow the speaker to continue in the case of a TURN-KEEPING act, and so on.

Turn-giving and turn-keeping functions are seldom expressed linguistically; paralinguistic means such as intonation are more commonly used for this purpose. In the case of human-computer interaction, common nonlinguistic devices are the use of the RETURN key and of cursor prompts or auditory prompts.

- **Time management functions:**

Direct communication, be it in spoken form or through a keyboard, is subject to conventions for how quickly one is supposed

⁶See also Bego (1992) on this subject.

to continue the dialogue when one has the turn. This is especially important when there is no visual feedback, as in a telephone conversation. Here, a prolonged silence creates uncertainty as to whether there is contact.

When a speaker needs more time before continuing the interaction than is conventionally allowed, for instance because something has to be looked up, he should therefore issue a warning or a request for patience (*"Just a moment"*), or use 'fillers'.

– **Contact management functions:**

These functions are meant to establish and to check contact; if they reach the partner and elicit a response, they thereby establish contact and thus change the local physical context.

A prototypical expression is here *"Hello??"*, for checking contact. *"Yes"* and other expressions of positive feedback can be used to confirm contact.

– **Own communication management functions** (term borrowed from Allwood et al., 1992):

These functions update the addressee's information about the speaker's ongoing speech production processes. Hesitations, self-corrections and apologies for (speech) errors are the main functions in this class. These acts typically do not call for any reaction from the partner. A persistent hesitation can, however, have the additional function of inviting the partner to take the turn.

Typical expressions of these functions are *"eh"*; *".. I mean.."*.

– **Social obligations management functions:**

Subclasses within this class are functions concerned with introducing oneself; with greeting (welcome or farewell); with apologizing; and with thanking.

All functions in this class have two variants, an 'initiative' one and a 'reactive' one, borrowing terminology from the 'Geneva school' of discourse studies (e.g. Moeschler (1989)). The initiative variant creates a reactive pressure which can be resolved by the corresponding reactive act. The same expressions can often be used for either purpose (like *"Dag"* in Dutch, or *"God Dag"* in Danish).

The diagram below represents this system of communicative functions.

viour, or with cooperation (e.g. Grice, 1975; Searle, 1969; Allwood, 1976; 1994; Bunt, 1993). These principles apply partly at the level of observable communicative behaviour, such as Grice's principle of manner. For the most part, however, these principles address a more abstract ('illocutionary') level, such as the Gricean principles of relevance, quality, and quantity. In the framework of Dynamic Interpretation Theory, this more abstract level is the level of context change, and the various principles translate to context-based rules for the use of dialogue acts.

In Bunt (1993) we have discussed some of these principles. The 'Dialogue Act Licensing Principle' formulated there says, in essence:

- Every dialogue act should either:
 - contribute to achieving a current goal of the local semantic context (the underlying task);
 - contribute to achieving a dialogue control purpose;
 - relieve the speaker from an existing reactive pressure.

This principle can be seen as summarizing the reasons for performing a dialogue act. Note that the principle may allow various dialogue acts to be licensed: there may be more than one, equally current goal of the underlying task, giving rise to equally many task-oriented acts. Indeed, participants in information dialogues occasionally ask more than one question in a single utterance. Also, various control purposes may be equally relevant in a given local context, giving rise to alternative dialogue control acts. Finally, while the above conditions for performing TO-acts and DC-acts may obtain, at the same time a reactive pressure from the preceding dialogue may give rise to a reactive dialogue act. The Dialogue Act Licensing Principle is thus fully compatible with the observed frequent multifunctionality of dialogue utterances.

4 Using dialogue theory in interactive teaching system design

Concepts and insights from dialogue theory which are of general relevance to designing the interaction with a teaching system, include the following:⁷

⁷See also Bouwhuis & Bunt (1994) for the use of concepts from language technology and dialogue theory in the domain of computer-assisted teaching of reading skills.

- Dialogues can be decomposed into sequences of complex, multifunctional communicative activity;
- Such communicative activity can be analysed in terms of functional units, called 'dialogue acts', defined as intentional units of context change;
- The various kinds of dialogue acts can be divided into task-oriented (TO-) acts, motivated by the underlying task, and dialogue control (DC-) acts;
- Dialogue control acts can be further subdivided a number of categories, such that the functional units of communicative behaviour can have (at most) one communicative function in each category.
- In a multimodal setting, various DC-functions are often naturally realized with paralinguistic or nonlinguistic means, and in this way combined with a linguistically expressed TO-function;
- Dialogue control acts, including feedback acts, are indispensable for securing successful communication and, more generally, for making a dialogue natural.

Specific contributions from dialogue theory to the design of interactive teaching systems we believe to be in the following two areas:

1. The design of the system-student interaction in a way which is natural and transparent to the student;
2. The design of student models taking into account not only the student's position with respect to the learning task, but also his 'interactive state', i.e. his interactive goals and his assumptions about the ongoing interaction.

Transparency and naturalness

In the introduction, we have argued the importance of both the transparency and naturalness of the dialogue. Transparency enables the student to understand how he is doing with respect to the learning task, and to understand how the system's communicative behaviour relates to that. To achieve transparency, it is essential to clearly distinguish TO-acts from DC-acts and to express TO-acts in such a way that it is clear to the student how the

communicative goal of the dialogue act relates to a goal of the underlying teaching/learning task. A simple, effective instrument can be to *describe* this relation explicitly (see below).

Naturalness has two functional sources, corresponding to the two possible motivations of a dialogue act: a task-oriented goal or a dialogue control goal. The naturalness of a TO-act is determined by the rationality of the underlying task structure. An instruction dialogue, for example, where the user is instructed how to assemble a bicycle, would be most unnatural if after dealing with the attachment of one of the pedals, the dialogue would switch to the attachment of the front light and subsequently turn to the second pedal.

The naturalness of dialogue control acts, by contrast, is determined by conventions of cooperative communication. These conventions can be expressed as preconditions for the appropriate use of DC acts, these preconditions being primarily conditions on the local cognitive and social context, also taking global social and physical context properties into account (differences in global social context often corresponding with differences in style of communication.) Appropriate use of DC-acts often determines the feel of naturalness of a dialogue.

Finally, a third aspect of naturalness concerns the form, rather than the function of communicative behaviour. Every global social context has certain standard ways of expressing dialogue acts, and the behaviour is 'natural' only if it conforms to those standards. We will return to this issue below.

Student modelling

Using the concepts of Dynamic Interpretation Theory, student modelling has two sides: a task-oriented side and a dialogue control side. Interpretation of the student's communicative behaviour will, in all cases, provide information to the system about the student's communicative goals. This is 'simply' a matter of recognizing the preconditions of the dialogue acts expressed in the behaviour.

For TO-acts, having an underlying task-related motivation, the system should in addition derive the task-related aspects of the student's cognitive state. For instance, if the student gives an incorrect answer to a question, the system may infer that the student doesn't know how to perform the operations needed for finding the answer to the question. Further diagnosis may then be needed to determine the precise nature of the student's problem,

possibly leading to new communicative goals.

For DC-acts, the situation is often different in the sense that a DC act by the student once being dealt with by the system is no longer of interest, and does not lead to persistent changes in the student model. This is for example the case with perception- or interpretation feedback (*Did you say/mean Thursday? Yes.*). In other cases, however, the situation is very similar to that of TO-acts, for instance, if the student responds being unable to answer a certain question, the system may infer that the student doesn't know how to perform the operations needed for finding the answer to the question. Fine distinctions between types of DC-act, as made above in Figure 1, are essential here.

New forms of interaction

When new forms of human-computer interaction are designed, innovative features in user interfaces are almost invariably *innovative expressions of 'old' communicative functions*. Entirely new functions are hardly ever invented, and that's perhaps just as well, since these would not be easy to understand for untrained users. What does happen, of course, is that frequent users of a program label certain combinations of functions, for instance by programming a function key. Some examples of innovative 'computer forms' of dialogue control functions from the schema in Figure 1 are the following, where we indicate the location in Figure 1 by means of a dotted path.

- Prompts on the screen, like '>' or '\$':
dialogue-control.interaction-management.turn-management.
- Rectangle, gradually filling up:
dialogue-control.interaction-management.time-management.
- Messages like 'MS-DOS>' or 'This is the interactive YP System':
dialogue-control.interaction-management.social-oblig-management.
- Graphics in email communication, like ':-)':
dialogue-control.feedback.positive.evaluation.

The use of dialogue control communicative functions to enhance the transparency and naturalness of the dialogue is illustrated in the following fragment of an instructional dialogue:

System: Now what is the result of substituting this value?

Student: (*gives correct answer*)

System: OK. Next problem. Mr Jones has bought ...

In the first two sentences of its second turn, the system performs the following communicative functions:

1. Positive evaluative feedback on the preceding student response.
(Implicitly also positive feedback concerning the system's processing of that response.)
2. Dialogue structuring. The second sentence makes clear that what follows is a new problem, not a continuation of the previous problem. As usual in dialogues that have a tight coupling with an underlying task, the dialogue structure often reflects the structure of the task (see Grosz & Sidner, 1986). This utterance therefore adds to the transparency of the dialogue.
3. Turn management. The first two sentences in this turn in no way elicit a response from the student; rather, it is understood that the system is going to continue the dialogue (turn keeping').

It is quite clear that the interaction in this example would be much less transparent and natural to the student if the system, in its second turn, would omit the first two sentences. If the system would immediately present the next problem, without any feedback or dialogue structuring, the student could at most guess that his previous answer is correct, and that the system present a new exercise, rather than elaborate on the previous one. The student would, however, face a great deal more uncertainty and potential confusion.

Concluding remarks

We hope to have shown that the use of concepts and insights from dialogue theory may be useful for designing the interaction with a teaching system. In particular, use of the 'dialogue act' concept as a local context-changing operation, combined with an articulate notion of local context and with an understanding of what drives a dialogue forward as expressed in the 'Dialogue Act Licensing Principle', may be helpful in

- designing a user interface which is natural and transparent to the student. This is not only in the interest of the student, but also in the

interest of the system, as it supports student communicative behaviour that is easier to understand.

- supporting the construction and maintenance of a student model by the system.

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