Towards an Axiomatization of Dialogue Acts

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Abstract

Conversations involve all sorts of verbal activities beyond those strictly related to the performance of the task at hand. Among other things, the participants in a conversation have to make sure they both understand what's going on, to manage turn taking, and to keep each other informed about their progress in achieving their task. The participants share information about the status of all of these processes; this suggests that the view of the conversational score they share is rather more complex than assumed in previous accounts. We proposed a preliminary formalization of this more complex view of the conversational score in previous work; in this paper we revise that earlier model, and use our theory of the conversational score to give a partial specification of the effect of the dialogue acts included in the DRI classification.

1 Introduction

Conversations, even task-oriented ones, are a complex business involving all sorts of activities beyond those strictly related to the performance of the task at hand. Among other things, the participants in a conversation have to make sure they both understand what's going on, manage turn taking, and keep each other informed about their progress in achieving their task (Clark, 1996). The information about the status of all of these processes is shared among the participants; this suggests that the view of the CONVERSATIONAL SCORE they share is rather more complex than assumed in previous accounts (Stalnaker, 1979; Lewis, 1979).

We proposed a preliminary formalization of the complex view of the conversational score that emerges from this research in (Poesio and Traum, 1997). In this paper, we revise that model, and use our theory of the conversational score to partially specify the effect of the dialogue acts included in the DRI classification Discourse Resource Initiative (1997); Allen and Core (1997)–especially those aspects of dialogue act meaning that have not been covered in AI work on speech acts such as Cohen and Levesque (1990b), including how dialogue acts determine which information gets grounded, and how they affect the participants' obligations.

2 Dialogue Acts

Most classic theories of speech acts concentrate on the actions performed by the conversational participants as a way of 'getting the job done'—e.g., instructions to the other conversant, requests for information necessary to accomplish the task, etc. But these actions are only a part of what happens in conversations; the participants in a conversation spend a lot of their time making sure they do not talk over each other and ensuring that 'informational' coordination is achieved. Recent theories of speech acts (e.g., Novick (1988); Kowtko et al. (1992); Traum (1994); Bunt (1995)) are built on the assumption that a good theory of the actions involved in these aspects of a conversation is as important to a dialogue system as a good theory of task-oriented acts.

The multi-level CONVERSATION ACTS theory, presented in Traum and Hinkelman (1992), maintains the classical illocutionary acts of speech act theory (e.g., **inform**, **request**), now called CORE SPEECH ACTS. These actions are, however, reinterpreted as multi-agent collaborative achievements, taking on their full effect only after they have been *grounded*, i.e., acknowledged. Rather than being actions performed by a speaker to a hearer, the core speech acts are joint actions; the initial speaker and the hearer (called hereafter INITIATOR and RESPONDER, respectively) each contribute actions of a more basic type, the result being the common ground assumed to be the effects of core speech acts.

In addition, Conversation Acts (CA) theory also assumes that three other kinds of speech acts are performed in conversations: acts for TURN-TAKING, GROUNDING, and more complex acts called ARGUMENTATION ACTS; we include in this class both the macro structures of conversation often called GAMES (Carlson, 1983; Levin and Moore, 1978) and the organization of acts according to the rhetorical structure of discourse, as in elaborations. In (Poesio and Traum, 1997) the additional level of LOCUTIONARY ACTS was made explicit in addition to the four levels of the initial proposal. We will not be concerned with turn-taking and argumentation acts here.

The dialogue acts whose interpretation we will discuss are those proposed in the Discourse Resource Initiative (Discourse Resource Initiative, 1997; Allen and Core, 1997), currently the most widely examined proposal for a task-independent set of dialogue acts.[1] The DRI scheme has a somewhat different conceptual organization from CA theory, but it is relatively easy to establish a connection.

We assume throughout that speech acts are just ordinary events, for which we adopt a Davidsonian treatment (Davidson, 1967) as usual in Discourse Representation Theory Kamp and Reyle (1993)–more specifically, the version of Davidson's theory proposed by Muskens (1995), in which eventualities are objects of type ϵ and each predicate has an extra argument for the eventuality. We adopt however the standard DRT notation, and write $e : \mathbf{p}(\overline{x})$ for $\mathbf{p}(\overline{x},e)$. Each eventuality e is associated in Muskens (1995) with a unique time interval $\vartheta(e)$; we will mostly omit the time intervals below except where necessary to specify the udpates.

[1] It is being developed by an international team of dialogue researchers from previous coding schemes and speech act taxonomies, and the reliability of this classification scheme has been studied in (Core and Allen, 1997; Di Eugenio et al., 1997).

Locutionary Acts

We use the ternary predicate e : **Utter**(A,P) to characterize locutionary acts, where A is an individual, P is a string, and, as mentioned above, e is an eventuality. A locutionary act may consist of an utterance of a single word, a sentence constituent such as an NP, or a complete sentence.[2]

Core Speech Acts

Core speech acts are dialogue acts which have to do with managing the topic of the conversation, in a general sense. Some of them play a FORWARD-LOOKING FUNCTION: they introduce new social attitudes in the conversation that have to be addressed. The forward-looking acts from the DRI dialogue act coding scheme are shown in (1).

(1)
- **Statement**
  - **Assert**
  - **Reassert**
  - **Other-statement**
- **Influencing-addressee-future-action**
  - **Open-option**
  - **Directive**
    - **Action-directive**
    - **Info-request**
- **Committing-speaker-future-action**
  - **Offer**
  - **Commit**
- **Conventional**
  - **Opening**
  - **Closing**
- **Explicit-performative**
- **Exclamation**

In this scheme acts are hierarchically organized in classes and subclasses; sub-acts maintain all of the properties of the parent act, while also adding additional information about the act.[3] The current scheme specifies six main act types with subtypes. An initiator is committed to the veracity of her **Statement**. If the statement is used to try to achieve the belief of the addressee (regardless of its success, or the prior belief of the addressee), then it is an **Assert**. If

[2]We assume that the participants in a conversation also share additional information about a locutionary act such as its syntactic classification if any or its meaning. See (Poesio and Traum, 1997; Poesio, 1997) for details.

[3]The scheme as developed in Discourse Resource Initiative (1997) included **Info-request** as a sub-class of **Action-directive** — it is a directive in which the directed act is one of making a statement. The authors of Allen and Core (1997), subsequently decided to make **Info-request** its own main type, since it was often easy to identify using a different syntactic form than other directives (i.e., interrogative vs. imperative mood). While this change is sensible for a coding manual, for reasons of semantic simplicity, we stick with the prior formulation in this paper.

the initiator was already previously so committed, then it is a **Reassert.** An **Other-statement** is a statement that is not an assert or reassert, such as taking a stand on a particular position, without concern to the beliefs of other convesants on this matter. The decision as to whether to classify an utterance for the **Statement** dimension, and if so which class to use, is guided by the decision tree for statements as shown in Fig. 1.

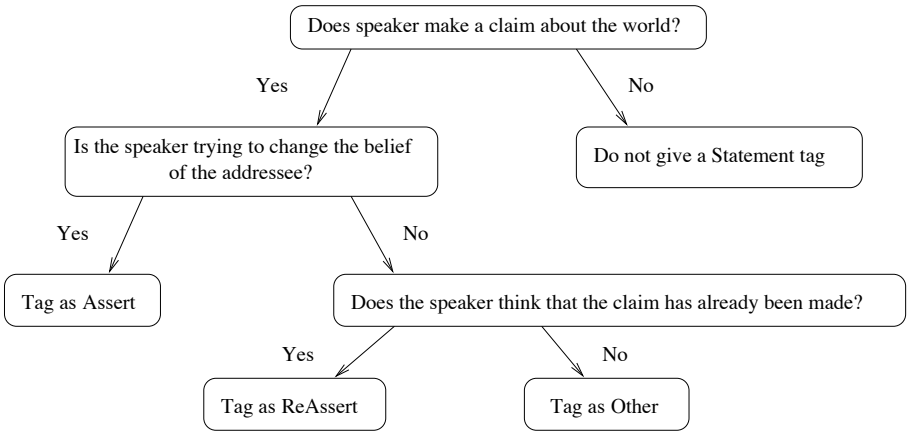


Figure 1: The DRI decision tree for statements

Influencing-addressee-future-action acts constrain the discourse situation to contain an option for the addressee. **Open-option** does only this; more precisely, it does not count as an attempt to get the addressee to actually do the mentioned act, merely allows it as a possibility for consideration. A **directive**, on the other hand, *does* count as such an attempt. The DRI scheme includes two types of directives to the other agent, depending on what kind of action is directed. **Info-requests** are directives to perform a statement.**Action-directives** are directives to perform another kind of action. Both types of directives also impose an obligation to address the directive itself (though not necessarily to perform the requested action) Traum and Allen (1994b). A **Committing-speaker-future-action** act mentions an option of the initiator. A **Commit** act means that the initiator has an obligation to perform the action. An **Offer** is a conditional commitment: if the addressee accepts, then the initiator is committed. **Explicit-performatives** are the traditional speech acts from (Austin, 1962). The DRI scheme also includes the acts **Opening** and **Closing**, which have to do with the conventional organization of conversations. We will not discuss explicit performatives, conventional acts, and exclamations here. We refer the reader to (Allen and Core, 1997) for more discussion and examples of these classes, as well as their decision trees.

Other core speech acts are instead classified in the DRI scheme as responses to previous acts: for example, the initiator may accept or reject a previous proposal, or answer a request for information. These acts are called BACKWARD-LOOKING in the DRI classification. The backward-looking acts from the DRI scheme playing a function related to the task are listed below; as we will see, other backward-looking acts play functions related to grounding. The specification of such acts always involves mention of the dialogue act(s) that they are

a response to; i.e., all of these acts are implicitly anaphoric on previous speech acts. The decision tree for backward-looking acts is shown in Fig. 2; again we refer the reader to (Discourse Resource Initiative, 1997; Allen and Core, 1997) for discussion and examples.

- **Agreement**
  - **Accept**
  - **Accept-part**
  - **Maybe**
  - **Reject**
  - **Reject-part**
  - **Hold**
- **Answer**

Hold is the label used for any actions that do not explicitly accept or reject the act they are a response to, but merely postpone the decision.

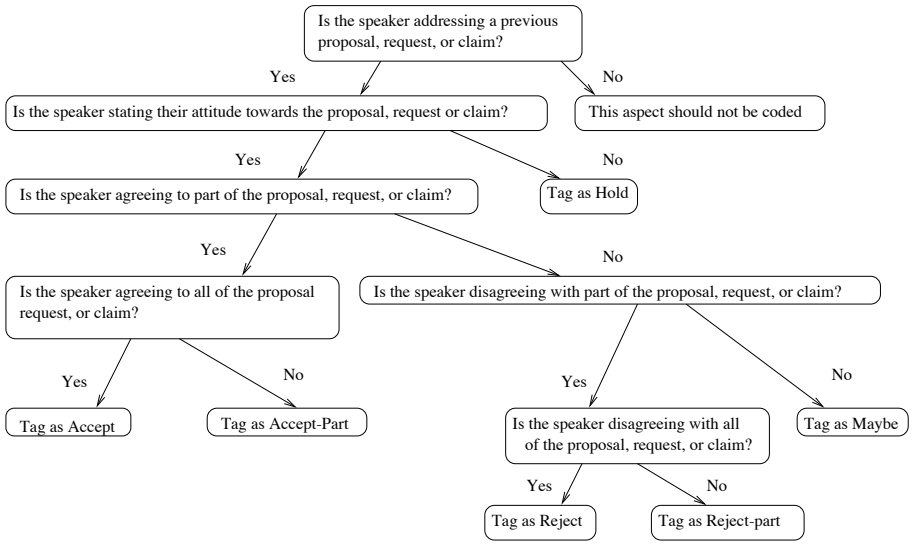


Figure 2: Backward-looking acts in the DRI scheme

Grounding Acts

Our model inherits a fundamental assumption of theories such as (Clark and Schaefer, 1989; Traum, 1994): that information has to be GROUNDED before it becomes part of the common ground. As in (Traum, 1994), we assume that grounding is achieved by means of dialogue acts. Acts such as assertions or instructions specify CONTRIBUTIONS that have to be ACKNOWLEDGED before they become a proper part of the common ground. Acknowledgments can either be performed implicitly or explicitly, by means of linguistics expressions such

as *okay* or *gotcha* but also by nodding or by means of expressions such as *uhu*. Here is an example of acknowledgment from the TRAINS-93 corpus:

(2) `utt1: s: take the Avon train to Dansville`
`utt2: u: Okay`

The participants in a conversation do not always acknowledge contributions right away: they may also signal that they did not understand, e.g., by saying *Sorry, I didn't hear that.*

Some of the backward-looking acts in the DRI classification are concerned with grounding; they are listed below.[4]

- **Understanding-act**
  - **Signal-non-understanding**
  - **Signal-understanding**
    - **Acknowledge**
    - **Repeat-rephrase**
    - **Completion**
  - **Correct-misspeaking**

Turn-taking Acts

The classification in (Traum and Hinkelman, 1992) also includes a class of acts having to do with the management of the turn–i.e., who is speaking at any given point. Actions in this class include **take-turn**, **keep-turn**, **release-turn**, **assign-turn**. The DRI scheme does not include actions of this type at the moment.

Multiple Dialogue Acts

One hypothesis shared both by CA theory and by the DRI proposal is that a locutionary act may generate more than one dialogue act. For example, a locutionary act such as *okay* is typically used to perform actions at both the grounding level and at the core speech act level at the same time; but it is also possible to perform multiple actions at the core speech act level–e.g., an utterance such as *There is an engine at Avon* in the TRAINS domain can be both an **Assert** and an **Open-option**. Following (Goldman, 1970), we assume that in these cases multiple events are GENERATED by a single locutionary event.

3 The Conversational Score

Grounded and Ungrounded Information

The view of the grounding process proposed by Clark and Schaefer (1989) implies that the conversational score does not simply consist of a record of the information about the conversation that is shared by its participants; instead, it includes both a record of the material that has already been grounded, which

[4]We should note that some of the grounding acts in (Traum and Hinkelman, 1992) are not included in the DRI scheme - for example, requests for acknowledgments.

we will indicate as G, and of the material that hasn't yet been grounded. Following (Clark and Schaefer, 1989; Traum and Hinkelman, 1992), we assume that the ungrounded part consists of a specification of the current 'contributions,' or DISCOURSE UNITS, as they are called in (Traum and Hinkelman, 1992).

We propose that the view of the conversational score entertained by each CP at any given time (her CONVERSATIONAL INFORMATION STATE) has the structure in (3). We view the conversational information state as a DRS which specifies information about G and the discourse units; this DRS gets updated over time as a result of dialogue acts. G and the discourse units are also DRSs; we are shortly going to see what kind of information they contain. There are two reasons for these decisions: first of all, the grounding acts refer back to the DUs, as we will see shortly; and second, the modifications to G and to the discourse units can be easily modeled as modifications to discourse markers in an extended version of Compositional DRT (Muskens, 1995) with markers denoting DRSs. The CIS also contains information about the currently pending discourse units, which are put together in a list UDUS. The top of UDUs is the Current Discourse Unit CDU– the Discourse Unit to which new material gets added. We write below CDU for **first**(*UDUS*).

(3)

G UDU CDU DU1 DU2 DU3
G = ...
DU1 = ...
DU2 = ...
DU3 = ...
UDUS = $\langle DU3, DU1 \rangle$
(CDU = **first**(*UDUS*) = DU3)

The picture of dialogue we are going to assume below is one in which each act leads to an update of the CIS. All new information gets first added to a DU; this results in obligations of various types and possibly in the responder coming to some conclusions about the intentions of the initiator. Information moves from UDUS into G as the result of acknowledgments.

The Conversational Score as a Record of the Discourse Situation

Our second main hypothesis is that the conversational score is, first and foremost, a record of the dialogue acts that take place during a conversation, as well as of the public beliefs, intentions and social commitments of the participants. As such, it can be characterized in terms of the language introduced in DRT to characterize other types of situations. For example, the utterances in (4), if interpreted as an **Assert**, and **Accept**, and an **Assert**, respectively, result in the conversational participants sharing the information in (5), that includes a record of the occurrence of three locutionary acts and three core speech acts generated by them (we have omitted from (5) all information about smaller locutionary acts such as the uttering of *there*):

(4) a. A: There is an engine at Avon.

b. B: Okay.

c. A: *It* is hooked to a boxcar.

(5) G=

u1-6 u7 u8-13 ce1 ce3 s s′ s″ K1 K2

---

u1-6 : **Utter**(*A*, *"There is an engine at Avon"*)
ce1 : **Assert**(*A*,*B*,*K1*)

K1 =
x w e
engine(*x*)
Avon(*w*)
e : **at**(*x*,*w*)

K1(*s*)(*s′*)
generate(*u1-6*,*ce1*)
u7 : **Utter**(*B*, *"Okay"*)
ce3 : **Accept**(*B*,*ce1*)
generate(*u7*,*ce3*)
u8-13 : **Utter**(*A*, *"It is hooked to a boxcar"*)
ce4 : **Assert**(*A*,*B*,*K2*)

K2 =
y u e′
boxcar(*y*)
e′ : **hook**(*y*,*u*)
u **is** *x*

K2(*s′*)(*s″*)
generate(*u8-13*,*ce4*)
satisfaction-precedes(*ce*,*ce4*)

This hypothesis about the conversational score plays two important roles in what follows. First of all, we can assume that agents can reason about the occurrence of dialogue acts and draw some conclusions; most of the updates we will see below are originated by observations of this type. Secondly, we can assume that agents can refer back to dialogue acts just like they do with other events; in this way we can handle the implicit anaphoric reference to events in backward-looking acts.

Compositional DRT

Our formalization is based on DRT–most specifically, on Muskens' formulation of DRT in terms of the theory of types, Compositional DRT (Muskens, 1995). The crucial properties of CDRT to understand what follows are that assignments are treated as first-class objects– of type *s*–and that discourse entities are viewed as functions from assignments to entities in the domain. DRSs can then be defined as relations between assignments, i.e., objects of type $\langle s,\langle s,t\rangle\rangle$: the DRS $[u_1, \ldots, u_n|\varphi_1, \ldots \varphi_m]$ is defined as follows:

$$[\mathrm{u}_1, \ldots, \mathrm{u}_n \mid \varphi_1, \ldots, \varphi_m] = \lambda\, i.\ \ \lambda\, j.\ \ i[\mathrm{u}_1, \ldots, \mathrm{u}_n]j \wedge\ \varphi_1(j), \ldots, \varphi_m(j)$$

where $i[u]j$, the UPDATE OPERATOR, is short for (simplifying somewhat):

- $\forall v\ (u \neq v) \rightarrow (v(i) = v(j))$

For example, the DRS which is the value of the marker K1 in (5) has the following value:

(6) $[\![[x\ w\ e|\mathbf{engine}(x),\mathbf{Avon}(w),\ e:\mathbf{at}(x,w)]\ ]\!] = \{\langle$i,j$\rangle$ | i and j are states, j differs from i at most over x, w and e, and the values assigned by j to x , w and e satisfy $[\![\mathbf{engine}(x)]\!]$,$[\![\ \mathbf{Avon}(w)]\!]$, and $[\![e:\mathbf{at}(x,w)]\!]\}$

Poesio and Muskens (1997) proposed to extend the standard version of CDRT in order to allow for discourse markers of two new types: ranging over assignments, and ranging over relations between assignments (DRSs). We use that formalism here even though some technical issues concerning how to allow the second modification still have to be addressed.[5]

4 The Update Effects of Dialogue Acts

Cohen and Levesque (1990b) argued that illocutionary acts are not an essential ingredient of a theory of communication; they can be 'defined away' by capturing their effect in terms of intentions and beliefs. Our goals here are more modest. The axiomatisation of dialogue acts that we propose below specifies for each dialogue act the update to the conversational score that results when an occurrence of that act is recorded; e.g., what gets grounded as the result of an acknowledgment, or the attitudes that become public (i.e., the corresponding states are recorded in G) as a result of a core speech act. However, we feel it is too early to claim that the update properties we specify completely define the DRI dialogue acts, and that therefore these can be dispensed with.

The update effects are specified using the format:

Name:	**Act**
Condition on update:	Φ
Update:	Ψ

In the simplest cases, the update simply depends on the occurrence of the dialogue act being recorded in one of the DRS that constitute the CIS; in more complex cases, additional conditions on the CIS are involved. The update condition may also depend on the condition holding in a specific DRS among those that constitute the CIS: e.g., the update resulting from a core speech act being added to a discourse unit are typically different from that that results from that speech act being added to G. We use the shorthand K::$\varphi$to specify that condition φ must hold in DRS K, meaning:

$$\text{K::}\varphi =_{def} \forall ijK(i)(j)\rightarrow\varphi(j)$$

We use the notation X += K to indicate the operation of DRS update in which the value of X is updated by concatenating K to it by means of the CDRT ; operator:

$$\text{X +=K} =_{def} \lambda i\lambda jX(j) = (X(i);K)$$

Finally, we use two operators for doing list manipulation, **push** and **remove**, defined in turn in terms of a concatenation operator | and a deletion operator on lists:

[5]We also assume that discourse markers become accessible in a conversation because each (core) speech act in a discourse segment extends the current FOCUS SPACE, as proposed in (Grosz and Sidner, 1986); we assume here that focus spaces are situations, which conceptually can be thought of as ⟨world,assignment⟩ pairs, and are implemented as assignments with a distinguished variable w.

$$\mathbf{push}(X,Y) =_{def} \lambda i \lambda j X(j) = \langle Y | X(i) \rangle$$
$$\mathbf{remove}(X,Y) =_{def} \lambda i \lambda j X(j) = X(i) Y$$

Primitives

First of all, a brief introduction to the terminology we use to talk about events and types. We use the term EVENTUALITY TYPE to refer to abstracts over conditions describing events or states of type $\langle \epsilon, \langle s,t \rangle \rangle$, such as $\lambda e.\lambda i.e(i)$: **Accept**(*x(i), e'(i)*) where **Accept** is an event type, x, e and e' are discourse markers[6] and e' is the event being accepted; or $\lambda e.\lambda i.e(i)$: **Bel**(*x(i), K(i)*), where **Bel** is a state type and K a discourse marker taking values over DRSs. We also refer to event types as ACTION TYPES. We use the symbol α to refer to action types, and the symbol σ to refer to state types.

Our characterization of the effects of DAs on the CIS makes use, first of all, of the event types **Try**, **Achieve** and **Address**, informally described as follows:

- e : **Try**(A,α) means that e is an event of A trying to perform an act of type α .[7]
- e : **Achieve**(A,σ) means that e is an event of A bringing about the satisfaction of state type σ.
- e : **Address**(A,e') means that e is an event of A considering and responding to e$'$.

Secondly, we assume that the conversational score can include information about agents being in the state having one of the following mental attitudes:

- s : **Bel**(A,K): s is a state of agent A believing the proposition expressed by DRS K.
- s : **Int**(A,τ), where τ is either an action type that agent A intends to perform or a state type that A intends to achieve.
- s : **Option**(A,α): action type α is one that A is aware that she can perform.

In addition to 'private' attitudes such as **Bel** and **Int**, which are traditional ingredients of formalizations of speech acts (Allen, 1983; Cohen and Levesque, 1990b), our formalization also relies on some *social* attitudes, which relate an agent not only to a course of events or action, but also to a social group. These include:

- s : **SCCOE**(A,B,K): this stands for Socially Committed to a Course of Events. It is the public counterpart to individual belief. It means that A is committed to B to K being the case (whether or not she actually privately believes it).[8]

[6] We recall that in CDRT discourse markers are functions from assignments to objects in the domain.

[7] **Try** expresses the notion of present-directed intention (Cohen and Levesque, 1990a, pg. 35) and is related to Cohen and Levesque's **ATTEMPT**.

[8] A default inference can generally be drawn in the case of an honest agent between SCCOE and actual belief, as follows:

$$\forall \text{a,b,K,s,i} \quad \boxed{s : \mathbf{SCCOE}(a,b,K)}(\text{i}) \Rightarrow \exists\, \text{s}' \, \boxed{s' : \mathbf{Bel}(a,K)}(\text{i})$$

- s : **Obliged**(A,B,α) state s is one of A having the obligation to B to perform an act of type α(whether or not she actually intends to) Traum and Allen (1994b).

Typically these states cease to hold after a while, either because e.g., the obligation has been addressed, or because an intention has been dropped. Current states are those whose associated time interval $\varphi(s)$ properly contains the indexical time point **now** (**now** $\subseteq \varphi(s)$, in Muskens' notation); some of the acts below update the temporal duration of some of these states making them not current anymore.

Locutionary Acts

As a new utterance is perceived, the current discourse unit is updated with the corresponding locutionary act. This update rule specifies a sort of default co-presence assumption - everything that gets uttered is by default recorded as part of the conversational score. This case differs from the others in that there are no update conditions–the act is not recorded anywhere in the CIS prior to this update. u is a new discourse marker.

Name:	**Utter**
Condition on update:	
Update:	CDU += [u|u : **Utter**(A,*"..."*)]

For example, as soon as the first word in (4a), *There*, is perceived, the update to the CDU in (7a) takes place; assuming that the initial constituents of the CIS are empty, and the initial CDU is DU1, the result is the CIS in (7b), where *u1* is a new discourse marker. The same update takes place after each locutionary act.[9]

(7) a. CDU += [*u1*|*u1* : **Utter**(A,*"There"*)]

b.

G UDUS CDU DU1
G = [|]
DU1 = [*u1*|*u1* : **Utter**(A,*"There"*)]
UDUS = $\langle DU1 \rangle$ (CDU = DU1)

Core Speech Acts

A fundamental property of core speech acts is that they impose an obligation on the responder to perform an **Understanding-act** (e.g., acknowledge them) when she recognizes their occurrence. Let F be any core speech act, with arguments $A, B, \overline{x}$; then the occurrence of an action of that type in K (G or a DU) results in the following update :

Name:	**F**
Condition on update:	K::[e : **F**(A,B,$\overline{x}$)]
Update:	K += [s|s : **Obliged**(B,$\lambda s'.s'$: **Understanding-act**(B,e))]

[9] This is actually a simplification, in reality one often can't tell to which DUs various parts of an input utterance will belong. In an extended version of this paper, we will give more details on how to handle this kind of update using **continue** grounding acts to merge new input with existing DUs. For now, the assumption that all new material from a current utterance gets put into the CDU will suffice.

Some forward-looking actions also impose an obligation on the responder to address them. This is certainly the case for **directives** – arguably, it holds for **Statement**s and **Offer**s, as well. Let D be a forward-looking action of this class, with arguments $A, B, \overline{x}$; then its occurrence in K (DU or G) results in the following update:

Name:	**D**
Condition on update:	K::[e : **D**(A,B,$\overline{x}$)]
Update:	K += [s|s : **Obliged**(B,$\lambda s'.s'$: **Address**(B, e))]

The specific update effects for some of the forward-looking acts are shown in Table 1. These formalizations are fairly direct implementations of the specifications in (Allen and Core, 1997). As mentioned above, we assume that the occurrence of an act such as **Assert** that specializes another act (**Statement**) results in the updates associated both with the more general and with the more specific act.

Name:	**Statement**
Condition on update:	G::[e : **Statement**(A,B,K)]
Update:	G += [s|s : **SCCOE**(A,B,K)]
Name:	**Assert**
Condition on update:	G::[e : **Assert**(A,B,K)]
Update:	G += [e'|e' : **Try**(A,$\lambda s'.s'$: **Bel**(B, K)), [e"|e" : **Accept**(B,e)] ⇒ [s|s : **SCCOE**(B,A,K)]]
Name:	**Influencing-addressee-future-act**
Condition on update:	G::e : **IAFutA**(A,B,$\lambda e'.e'$: φ)
Update:	G+=[s|s : **Option**(B,$\lambda e'.e'$: φ)]
Name:	**Open-option**
Condition on update:	G::[e : **OpOp**(A,B,$\lambda e'.e'$: φ)]
Update:	G+=[|¬[e"|e" : **Try**(A,$\lambda s'.s'$: **Achieve**(A,$\lambda e'.e'$:φ))]]
Name:	**Directive**
Condition on update:	G::[e : **Dir**(A,B,$\lambda e'.e'$: φ)]
Update:	G += [| [e"|e" : **Accept**(B,e)] ⇒ [s|s : **Obliged**(B,A,$\lambda e'.e'$: φ)]]
Name:	**Committing-speaker-future-action**
Condition on update:	G::[e : **CSFA**(A,B,$\lambda e'.e'$: φ)]
Update:	G+=[s|s : **Option**(A,$\lambda e'.e'$: φ)]
Name:	**Commit**
Condition on update:	G::[e : **Commit**(A,B,$\lambda e'.e'$: φ)]
Update:	G += [s|s : **Obliged**(A,B,$\lambda e'.e'$: φ)]
Name:	**Offer**
Condition on update:	G::[e : **Offer**(A,B,$\lambda e'.e'$: φ)]
Update:	G += [| [e"|e" : **Accept**(B,e)] ⇒ [s|s : **Obliged**(A,B,$\lambda e'.e'$: φ)]]

Table 1: Forward-Looking Act Definitions

What distinguishes an assertion from a garden variety statement is the intention to get the responder to believe the claim (one could make a statement in the case where one knows the responder won't believe it, or already believes it). But the achievement of that belief (a successful assertion) is too strong a condition, that defines the perlocutionary act of **convince**: that only results if the responder explicitly **Accepts** the act, which results in a further inference because of the conditional originated from the update. For an example of the consequences of an **Assert**, consider again (4a). The situation after all of the locutionary acts have been processed is as in (8) (we omit here all information about the locutionary acts derived from incremental syntactic and semantic interpretation):

(8)

G UDUS CDU DU1

G = []

DU1 = *u1 ... u6*

u1 : **Utter**(A, *"There"*)
.....
u6 : **Utter**(A, *"Avon"*)

UDUS = $\langle DU1 \rangle$ (CDU = DU1)

In the meantime, intention recognition takes place. Assuming that the utterance unit consisting of *u1 ... u6* is interpreted as an **Assert**, the following update of the CDU takes place (the occurrence of other acts such as a **Release-turn** and perhaps other core speech acts are also possibly inferred):

CDU += *ce1 K1 s s'*

ce1 : **Assert**(A,B,*K1*)

K1 = *x w e*

engine(x)
Avon(w)
e : **at**(x,w)

K1(s)(s')
generate(*u1-6*,*ce1*)

(we have glossed over how precisely the semantic interpretation of the utterance unit is computed - see Poesio and Traum (1997) for some details). This update results in an obligation to signal understanding or misunderstanding with respect to *ce1* and (possibly) in an obligation to address it, which result in the following update of the conversational score:

(9) CDU+=

s1 s2

s1 : **Obliged**(B,$\lambda s'.s'$: **Understanding-Act**(B, *ce1*))
s2 : **Obliged**(B,$\lambda s'.s'$: **Address**(B, *ce1*))

As we mentioned earlier and we will see in more detail shortly, acknowledging a DU has the effect of updating G with the information in that DU. The utterance in (4b), *Okay*, has a dual purpose: it serves as an acknowledgment of *ce1*, as well as an acceptance. The acknowledgment leads to the occurrence of *ce1* being grounded, which in turn leads to the updates associated with an **Assert** act according to Table 1, namely:

G += *s3 e1*

s3 : **SCCOE**(A,B,*K1*)
e1 : **Try**(A,$\lambda s'.s'$: **Bel**(B, *K1*))
[*e"*]*e"* : **Accept**(B,*ce1*)] ⇒
[*s*]*s* : **SCCOE**(B,A,*K1*)]

The crucial property of backward-looking acts is that they remove the obligation to address an act. If **F** is a forward-looking act and **B** an 'appropriate'

backward-looking act,[10] then performing an act e of type **B** with respect to the occurrence of act e' of type **F** removes the obligation:

Name:	**B**
Condition on update:	K::[s : **Obliged**(B,$\lambda s'.s'$: **Address**(B,e')) $\varphi(s) = t$ e : **B**(B,e')]
Update:	K += [t|$t <$ **now**]

The specific updates resulting from backward-looking acts are described in Table 2.

Name:	**Agreement**
Condition on update:	G::[e : **Agreement**(A,ce)]
Update:	-
Name:	**Accept** (Assert)
Condition on update:	G::[e : **Accept**(A,ce)]
Update:	[effect specified by conditional in update for **Assert**]
Name:	**Accept** (Request)
Condition on update:	G::[e : **Accept**(A,ce), ce : **Directive**(B,A,α)]
Update:	[work done by conditional]
Name:	**Reject**
Condition on update:	G::[e : **Reject**(A,ce)]
Update:	G+= [|¬[s|s : **SCCOE**(A,B,*K1*)]]

Table 2: Backward-Looking Act Definitions

The DRI scheme includes a single **Accept** act that may be used to address acts of different types; we hypothesize that the act-specific consequences of acceptance are part of the definition of the forward acts themselves, in the conditionals introduced as the result of the performance of the forward acts. Thus, for example, B's acceptance of *ce1* by the *Okay* in (4a) leads to G being updated with the information [s\|s : **SCCOE**(B,A,*K1*)].

Grounding Acts

Of the grounding acts, we only consider here **Acknowledge**, that we treat as a predicate ce : **Acknowledge**(A,*DU1*) relating a CP A to a DU DU1. The occurrence of an acknowledgment of DU1 results in G being updated with that discourse unit, which is then removed from UDUS. Grounding acts do not seem to ever get added to G; we hypothesize that they are included in their own DUs that also get removed after they update the conversational score.[11]

Name:	**Acknowledge**
Condition on update:	CDU::[u : **Acknowledge**(A,*DU1*)]
Update:	G += DU1;**remove**(*UDUS*,*DU1*);**remove**(*UDUS*,*CDU*)

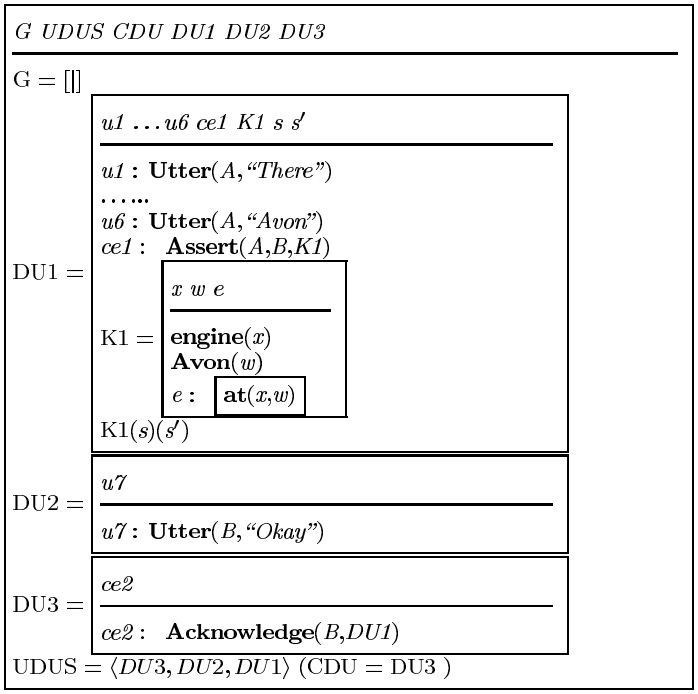
For example, we hypothesize that the *Okay* in (4b) works as follows. At the end of the first turn in (4) the CIS is as after the update in (9). As the turn is taken by B a new DU is initiated, DU2. (This is an effect of the implicit **Release-turn**

[10] We will leave the notion of what counts as 'appropriate' unspecified–see (Ginzburg, 1995) for the case of questions.

[11] The importance of grounding acts is not that they occur and are objects of discussion, but their effect on restructuring parts of CIS.

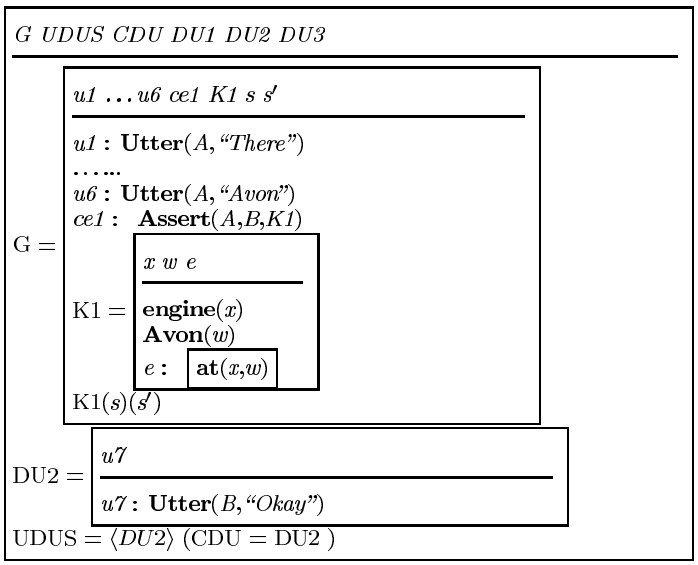
performed at the end of (4)a.) The locutionary act *u7* of uttering *Okay* is added to DU2, as is the **Acknowledge** act *ce2* as soon as it is recognized. The result is the situation in (10).

(10)



At this point, as a result of the acknowledgment, G is updated with DU1, DU1 and DU3 are removed from UDUs, and DU2 becomes CDU:

(11)



5 Conclusions and Future Work

To summarize, we have proposed a preliminary characterization of the DRI acts in terms of a notion of conversational score that takes into account the fact that the construction of the common ground is not an immediate process, and in which the functions of both forward-looking and backward-looking acts can be characterized, if in a preliminary fashion. The inclusion of accounts of these processes, as well as of the process of introduction and removal of social obligations, is the main differences between our proposal and previous formalizations of speech acts such as Cohen and Levesque. More detailed comparisons will only be possible with a more detailed analysis of the basic building blocks.[12]

The current formalization doesn't cover yet some of the DRI acts; of these, 'partial' acts such as **Accept-part** may be particularly tricky to handle since this may involve some notion of structured propositions. And anyway we have concentrated until on clarifying the mechanism by which the conversational score is put together, rather than the attitudes expressed by the acts. We also plan to look at task-dependent actions - i.e., those actions that explicitly manipulate objects related to the task (such as the plan in the TRAINS conversations). Such actions are currently not included in the DRI scheme.

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[12] CDRT actually incorporates many ideas from dynamic logics–see Muskens (1995) for discussion.

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